WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
5000 SERIES RAPID TRANSIT CARS
TECHNICAL SPECIFICATIONS
TABLE OF CONTENTS

Section **Page**

Section **Page**

Section **Page**

Section **Page**

LIST OF EXHIBITS

Exhibit Page

SECTION 1
SCOPE, DEFINITIONS, CONTRACT DATA REQUIREMENTS, SYSTEMS ASSURANCE, TRAINING, AND OTHER REQUIREMENTS

TABLE OF CONTENTS

Section **Page**

Section **Page**

Section **Page**

Section **Page**

SECTION 1

SCOPE, DEFINITIONS, CONTRACT DATA REQUIREMENTS, SYSTEMS ASSURANCE, TRAINING, AND OTHER REQUIREMENTS

1.1 SCOPE

1.1.1 General

This Specification is for the complete design, manufacture, delivery and testing of rapid transit cars for the use on the Washington Metropolitan Area Transit Authority (hereinafter WMATA or "the Authority") system. The cars shall be powered from the Authority's 700 VDC third rail system and be configured as married pairs capable of operation in either direction. The cars shall be fully compatible with the Authority's existing infrastructure, system interfaces, and operational and maintenance practices. This Specification also addresses requirements for furnishing spare parts, executing a user education program, delivering special tools and test equipment, providing software and other deliverables referred to throughout this Specification, and executing warranty and reliability test programs.

1.1.2 Compatibility with Existing Cars

The cars shall be designed, manufactured, and adjusted to be able to operate in-train and to be in all respects compatible with the Authority's existing cars.

1.2 DEFINITIONS OF TERMS AND ABBREVIATIONS

Most terms and abbreviations are defined in the Special Provisions, and in the General Provisions. Other definitions are as follow:

A. "Married Pair" or "Two-car unit" means the combination of an "A" car and a "B" car, semi-permanently coupled and sharing certain essential apparatus, and the smallest unit capable of independent operation.

B. "A" car is the even-numbered car of a married pair that houses the Automatic Train Control Apparatus.

C. "B" car is the odd-numbered car of a married pair.

D. "ATC" refers to Automatic Train Control, which includes Automatic Train Operation (ATO), Automatic Train Protection (ATP), and Automatic Train Supervision (ATS).

E. "Vital Function" is a function critical to safety.

F. "Vital Component" or "Vital Circuit" is any device, circuit, or software module used to implement a vital function.

G. "Vital Relay" is a relay as described in Section 15.31.2.2.

H. "JEDEC" means Joint Electronic Device Engineering Council.

I. The term "Existing Cars" as used throughout this Specification serves to identify all of the cars now in use on the Authority's property.

J. “Service-Proven” means that the equipment shall offer a demonstrated history of satisfactory performance in rapid transit rail service with a high level of availability under a duty cycle and environmental conditions similar to those encountered in the Authority’s operations.

K. “Day” means calendar day unless otherwise specified.

L. “Fail-safe” means that any malfunction or failure of a system, component, or device will cause the system to revert to a state that is known to be safe and self-annunciating. See Section 1.11.4 for fail-safe design requirements.

Whenever reference is made to a specification or standard, it shall be understood that the reference is to the latest issue on the date of solicitation for offers, unless otherwise stated herein. The Contractor may propose the use of later revisions with approval from the Authority.

1.3 DESIGN DOCUMENTATION AND OTHER DELIVERABLES

1.3.1 Contract Overview

The Contract Specification and Drawings describe the overall dimensions, shape, appearance, and functions of the car, and the environment in which it will operate. In certain areas, design details are given where it is necessary to ensure compatibility with existing cars, or where experience has dictated the need to limit the Contractor’s choice of materials or methods. In other areas, additional details and clarifications have been inserted for the benefit of prospective Contractors who may not be familiar with North American car building practices. To ensure compatibility between existing cars and cars furnished under this contract, the Contractor will be provided with additional information, if necessary, regarding the design of the existing cars. Where temperatures are expressed in both Fahrenheit and Celsius, the value in parentheses is for reference only; compliance with the Specification shall be measured in terms of the first value stated, whether Fahrenheit or Celsius. The detailed design of the car is solely the responsibility of the Contractor, and it shall be the Contractor’s responsibility to provide a car which will, in all respects, be suitable for the purpose intended. If any part, device, or assembly is required to make the car function as specified, it shall be the Contractor’s responsibility to provide that part, device, or assembly.

The design life of the car and its components shall be consistent with a useful life of 35 years.

1.3.2 Contract Data Requirements

1.3.2.1 General

The Contractor shall comply with the Specification requirements for the submission of schedules, reports, plans, certificates, drawings, and other data. The Contract Data Requirements List (CDRL), shown in Exhibit 1-1, delineates the due dates, number of copies required, frequency required, and whether the Authority’s approval is required. Specific requirements for each deliverable are contained in the referenced specification section and are noted by the use of “*(CDRL)*” in italics after the requirement.

Each item of data submitted to the Authority shall be identified to the applicable CDRL number, either on the first page of the document or in the transmittal letter.

Exhibit 1-1 – Contract Data Requirements List (CDRL)

SERIAL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****
100	**SCOPE, DEFINITIONS, CONTRACT DATA REQUIREMENTS, SYSTEMS ASSURANCE, TRAINING, AND OTHER REQUIREMENTS**					
101	Drawing List	1.3.3.1	PDR-60	3	1/Periodically	Yes
102	Detail Drawings	1.3.3.1	Note 1	3	1	Note 1
103	Car Arrangement Drawings	1.3.3.2	CDR-30	4	1	Yes
104	Dynamic Outline Calculations	1.3.3.3	CDR-30	3	1	Yes
105	As-Built Drawings	1.3.3.4	Note 2	2	1	Yes
106	Operator’s Cab Mock-up	1.3.4.1	PDR	1	1	Yes
107	Underfloor Equipment Mock-up	1.3.4.2	FDR	1	1	Yes
108	Decorative Material Samples	1.3.4.4	FDR-30	2	2	Yes
109	Car History Books	1.3.6	Note 3	1 per married pair	A/R	Yes
110	Program Management Plan	1.4.1.1	45	3	1/Every 6 months A/R	Yes
111	Master Program Schedule	1.4.1.2.1	60	3	1/Monthly	Yes
112	Production/Delivery and Acceptance Schedule	1.4.1.2.2	120	3	1/Periodically	Yes
113	Monthly Progress Reports	1.4.1.3.2	30	3	Monthly	
114	CDR Packages	1.4.2.1	CDR-30	6	1	Yes
115	PDR Packages	1.4.2.2	PDR-30	6	1	Yes
116	FDR Packages	1.4.2.3	FDR-30	6	1	Yes
117	Systems Engineering Plan	1.4.3.2	90	3	1	Yes
118	Configuration Management Plan	1.4.4.2	CDR-30	3	1	Yes
119	Serial Numbers Description	1.4.4.3.1	FDR-30	3	1	Yes
120	Engineering Change Proposal	1.4.4.6	A/R	8	A/R	Yes
121	EMC and EMI Control and Test Plans	1.4.5.2	PDR-30	3	1	Yes
122	Manuals and Catalogs Outlines and Samples	1.5	PDR-30	3	1	Yes
123	Draft Manuals and Catalogs	1.5	Note 4	50	1	Yes
124	Final Manuals and Catalogs	1.5	Note 5	Note 14	1/Periodically	Yes
125	Training Manuals	1.6.1	Note 6	Note 15	1/Periodically	Yes
126	Educational Program Outline and Schedule	1.6.3	FDR-30	3	1/Periodically	Yes
127	Instructor Qualification and Resumes	1.6.6.1	FDR-30	3	1	Yes
128	Quality Assurance Program Plan	1.7.2	60	3	1/Periodically	Yes
129	Inspection and Test Plan	1.7.2	PDR-30	3	1/Periodically	Yes
130	Sample Quality Assurance Reports	1.7.3.5	PDR-30	3	1	Yes
131	Statistical Quality Control Inspection List	1.7.3.7.5	PDR-30	3	1	Yes
132	FAI Packages	1.7.3.7.8	Note 10			Yes
133	Audit Reports	1.7.4.1	Note 7	3	A/R	Yes
134	Master Test Plan	1.8.2.1	150	3	1/Periodically	Yes
135	Test Procedures	1.8.2.2	Note 8	3	1	Yes
136	Test Reports	1.8.2.3	Note 9	3	1	Yes
137	Test Status Log	1.8.2.4	FDR-30	3	1/Monthly	
138	Car Weighing Procedure	1.8.4.1	Note 11	3	1	Yes
139	Reliability Assessment Response Report	1.9.6	Note 13	3	Ref. 1.9.4	
140	Reliability Test Report	1.9.7.1	Note 12	3	Monthly	
141	Maintainability Analysis	1.10	PDR-30	3	1/Every 90 days A/R	Yes
142	System Safety Program Plan	1.11.1	PDR-30	3	1/Periodically	Yes
143	Preliminary Hazard Analysis	1.11.2.1	PDR-30	3	1/Periodically	
144	Failure Mode and Effect Analysis	1.11.2.2	PDR-30	3	1/Every 60 days A/R	Yes

Exhibit 1-1 – Contract Data Requirements List (CDRL) Continued

SERIAL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****
300	**CARBODY**					
301	Stress analysis for carbody, truck and equipment supports	3.3.2.3	PDR-30	3	1	Yes
302	Repair procedure for lining material	3.6.12	FDR-30	3	1	Yes
900	**POWER SUPPLY AND MISCELLANEOUS ELECTRICAL APPARATUS**					
901	Battery system electrical compatibility plan	9.1.4	60	4	1	
902	Converter/ATC system compatibility certification	9.4.2	PDR-30	4	1	Yes
1000	**PROPULSION AND BRAKING SYSTEM**					
1001	Performance data adjustment calculations	10.1.3	Note 9	2	1	Yes
MOD 1 1002	Slip Slide Test Report and Analysis	10.5.3	Note 9	3	1	Yes
1200	**TEST AND DIAGNOSTIC APPARATUS**					
1201	List of bench testers, with details	12.3	90	3	1/Every 90 days	Yes
1202	VMS interface design	12.6.1	PDR-30	3	1	Yes
1203	VMS Signal List	12.6.2.1	PDR-30	3	1	Yes
1204	VMS Shutdown Method	12.6.2.4	PDR-30	3	1	Yes
1205	VMS Fault Messages	12.6.9	PDR-30	3	1	Yes
1206	List of Special Tools	12.7	120	3	1/Every 60 days	
1207	List of signals to be recorded	12.6.3	PDR	3	1	Yes
1500	**MATERIALS AND WORKMANSHIP**					
1501	Test and inspection plan for stainless steel in weld applications	15.3.4	PDR-30	3	1	Yes
1502	Test and inspection plan for structural steel applications	15.4.2	PDR-30	3	1	Yes
1503	Radiographic Inspection	15.5.3.2	PDR-30	3	1	Yes
1504	Grounding scheme	15.19.8.1	PDR-30	3	1	Yes
1505	Full penetration weld inspections sampling plan	15.23.4	FDR-30	3	1	Yes
1506	Contractor's Welding procedures	15.23.6	FDR-30	3	1	Yes
1507	Special welding procedures for SS	15.23.7	FDR-30	3	1	Yes
1508	Welding settings, shear strength and diameter records	15.23.8	FDR-30	3	1	Yes
1509	Torch soldering test samples	15.23.12	FDR-30	3	1	Yes
1510	Flammability and smoke emisisons test results	15.25.1	PDR-30	3	1	Yes
1511	Software assurance plan	15.30.5	CDR-30	3	1/As-Required	Yes

A/R = As required
* Calendar days after contract award unless otherwise noted. "Event-30" means 30 days prior to event. "Event +30 means 30 days after the event.
** Entries in the "Quantity" column are the number of copies/sets to be submitted to the Authority. A single additional copy of each data deliverable, including transmittal letter, will be forwarded to the Authority's engineering consultant at the time of transmittal to the Authority. Forwarding address for the engineering consultant will be provided by the Contracting Officer.
*** "Frequency" indicates the number of times a submittal is required. Initial, or one-time submittals are shown as "1." Where the general term "periodically" or "as required" (A/R) appears, refer to the referenced paragraph where the data requirement is established.
**** Approval requirement indicated by "Yes" in this column. Where blank, item is to be submitted at required times for information/review.
Note 1: Due dates to be compatible with project schedule for design development and construction. Approvals as determined under CDRL 101 submission.
Note 2: Acceptance of last car -30 days
Note 3: Acceptance of each married pair of cars
Note 4: Acceptance of first pair of cars -30 days
Note 5: Acceptance of first pair of cars +120 days
Note 6: 60 days prior to training
Note 7: 14 days after completion of QA audit
Note 8: Test date -60 days
Note 9: Test date +30 days
Note 10: Inspection date -45 days
Note 11: Weighing date -60 days
Note 12: Commencement of reliability test +30 days
Note 13: 60 days after receipt of Authority's reliability assessment report
Note 14: Ops Manuals = 650; RM Manuals = 360; HRM Manuals = 120; Parts Catalogs = 120
Radio Maintenance Manual = 20; PTD O&M Manuals = 20 per device; BTD O&M Manual = 20 per device
Note 15: Quantities of training materials to be developed on basis of final approved training program plan.

1.3.2.2 Alternate Schedule

The Authority may permit changes to the specified submittal due dates of CDRL items if the Contractor can demonstrate that these dates are not consistent with its normal sequence of work. The Contractor shall propose an alternate CDRL schedule for the Authority's review, with submission of the Master Program Schedule (see Section 1.4.1.2.1). All changes from the CDRL included herein shall be uniquely identified and highlighted in the Contractor's proposed revision.

1.3.3 Drawings

1.3.3.1 General Requirements

The Contractor shall submit a drawing list *(CDRL 101)* that shall identify all drawings used in the assembly of the vehicle, from the completed vehicle down to the lowest level replaceable unit, in a logical manner by subsystem and level of assembly. The drawing list shall indicate those drawings to be submitted for approval and those to be submitted for information and/or reference only. The number of sheets per drawing shall be indicated and the most current revision level submitted. The list shall also identify the Contractor's letter of transmittal and the current approval status for each drawing. As part of the initial drawing list submittal, the Contractor shall describe the primary drawing numbering system, including the significance of characters.

The Contractor shall submit, for the Authority's review and approval, detail drawings of all assemblies, subassemblies, wiring schematics and diagrams, equipment, and apparatus. *(CDRL 102)* Sufficient drawings shall be submitted to convey concept, design, dimensions, maintenance, operating, overall assembly aspects, and interfaces. Detail parts drawings need not be furnished unless required by the Authority to permit its review of another drawing. Arrangements and details of all apparatus, including apparatus within equipment boxes, shall be submitted for review; outline drawings will not be sufficient. This applies particularly to subcontractor-furnished items.

All dimensions on drawings shall be expressed in the English system; all wording on drawings shall be in the English language. English translations shall appear adjacent to, and dominate, the original wording/units. A drawing key shall be provided to permit rapid identification of elements portrayed. Electrical drawings shall include the state of the circuitry. All terminology used in drawings and correspondence shall be conventional to the North American transit and railroad industries. Drawings shall be made to either the first-angle or third-angle projection system. MOD 2

Unless otherwise approved by the Authority, every drawing shall include a complete bill of materials and parts list on the field of the drawing, or on a separate sheet of the same drawing, describing all parts or subassemblies, including subcontractor-furnished items, which form a part of the assembly, subassembly, or piece depicted. Every assembly drawing shall include the weight of the assembly. All drawings shall reference the number of the drawing showing the next higher subassembly or assembly on which it is used. This requirement does not apply to standard hardware, electrical, or electronic components. Drawings shall be comprised of not more than five sizes with 36-inches by 72-inches being the largest drawing size permissible.

Whenever reference is made on the drawing to a material or process by the Contractor's own specification number, the drawing shall also give the commercial equivalent. If there is no commercial equivalent, the Contractor shall provide the Authority with copies of its specification. Except as otherwise allowed in Section 15.28, all semiconductors shall be identified by JEDEC numbers.

Revisions to drawings, and drawing change orders affecting submitted drawings, shall be submitted for approval as they are issued. No more than five drawing change orders shall remain unincorporated on any drawing at any time.

Drawings on which any changes have been made, even though less than five, shall be revised to incorporate those changes no less frequently than at 2-month intervals. The revision block shall give details of the changes made by that revision, or the numbers of drawing change orders may be used instead of detailed descriptions. In the latter case, the drawing change orders shall have been submitted no later than at the time of submittal of the revision.

Approval of a drawing does not relieve the Contractor of the obligation to meet all the requirements of the Contract. Approval of a drawing that contains a deviation from, or violation of, the specification does not constitute authority for that deviation or violation. Such deviations must be specifically requested and granted.

1.3.3.2 Arrangement Drawings

Prior to beginning the detailed design of the cars the Contractor shall submit to the Authority for approval complete and comprehensive arrangement drawings of the car. *(CDRL 103)* These drawings shall show the floor plan, reflected ceiling plan, underfloor equipment arrangement, inside longitudinal sections of both sides of the car, exterior side elevations of both sides of the car, elevation views of both ends of the car, and sufficient transverse half-sections or full-sections through the car to show all variations in cross section such as at windows, doors, and door pockets. The cross-sections shall also show underfloor equipment. The drawings shall be dimensioned, and all key points shall be located by dimensions from the longitudinal center line, the pulling face of the "F" end coupler, and the top of rail. Subsequent to approval of these drawings, they shall be kept up-to-date no less than monthly so as to continually represent the as-built description of the cars. These drawings shall be to a scale of 1:25 or larger for all drawings except cross sections, which shall be to a scale of 1:10 or larger.

1.3.3.3 Dynamic Outline Drawing

The Contractor shall submit, prior to beginning the detailed design of the cars, a complete dynamic outline of the proposed car including all projecting appurtenances, and including all possible motions, which fall
MOD 1 within the limiting dynamic outline given on the Contract Drawing 97936-017.*(CDRL 104)* Supporting calculations shall also be provided.

1.3.3.4 "As-Built" Drawings

The Contractor shall furnish, prior to acceptance of the last car, two sets of legible aperture cards and one set on a single, uniform electronic medium. *(CDRL 105)* The electronic media shall conform to the following requirements:

A. Drawings that have been created originally on a computer using drafting/engineering (CAD/CAE) software shall be provided to the Authority in either Initial Graphics Exchange System (IGES/Version 3.0), vector format data files, or an approved alternative.

B. In those instances where drawings were not created using CAD/CAE software, scanned images (at 300 dpi) of full-size original mylar, or clean original paper sheets shall be provided as image data files in TIFF, PCX, or an approved alternative format.

C. If an alternative image data file format is approved by the Authority, and that format can be delivered in CCITT Group 4 format, the Contractor shall also provide the complete image files in CCITT Group 4 format, together with the software required for file decompression.

D. Vector data files and image data files shall not be mixed on the same reel of tape. Each tape shall be accompanied by a complete list of drawings recorded thereon by drawing number and title, cross-referenced to file number or other designator, and labeled according to file format, type, and name.

Every Engineering Change, Deviation, Material Rejection Board (MRB) repair, and similar variance affecting form, fit, or function shall be incorporated on the affected drawing whenever it applies to five or more cars; and the drawing shall be clearly labeled with the car numbers (Authority's) applying to each configuration. Those applying to fewer than five cars may also be incorporated; but may alternatively, be supplied separately, with a list of those applying included in the Car History Book for that car, cross-referenced to the affected drawings.

If the Contractor's drawing system is such that drawings of details are not included in the assembly, subassembly, and arrangement drawings referred to above, it shall furnish eight complete sets of prints and two sets of aperture cards of all drawings that are, in the opinion of the Authority, necessary for the operation and maintenance of the car. The Contractor shall retain all drawings of the car for a period of 35 years. It shall make available, without charge, for a minimum of 5 years from the date of acceptance of the last car, prints of any details required for extraordinary repairs arising from accidents. During the remaining 30 years, the Authority shall be provided with any prints required, at cost.

1.3.3.5 Use of Terminology of Existing Cars

In order to facilitate understanding and maintenance of the cars, each component or device that corresponds closely in function to a counterpart on the Authority's existing cars shall be designated by the same name and symbol as used for the counterpart in the drawings, schematics, and manuals describing the Authority's existing cars. Vehicle logic and trainline interface circuit schematic arrangements shall be the same as those of the Authority's existing cars except in cases where the specification requires otherwise or where those arrangements would not be satisfactory in the context of the new car. Upon Contractor request, the Authority will provide sample documentation; e.g., manuals, schematics, and other drawings, demonstrating names and symbols used for the existing cars.

1.3.4 <u>Engineering Mock-ups and Materials</u>

1.3.4.1 Cab

The Contractor shall construct a full-scale mock-up of the Operator's cab showing the locations and arrangements of all controls, switch and circuit breaker panels, seats, front and side windows, door, heater, fire extinguisher, handbrake unit, curtain arrangement, partitions, and any other apparatus specified.*(<u>CDRL 106</u>)* This mock-up shall be used to convey the layout of the cab in the detail illustrated in drawings, and as such, shall show the current status of the design. It shall be reviewed and approved by the Authority before the design of this area is finalized. It shall remain intact as approved, or if changes are made, kept up-to-date until the Pilot Car is completed.

1.3.4.2 Underfloor Equipment

A full-scale mock-up of the underfloor equipment shall be constructed showing all boxes, enclosures, piping, and conduit on all equipment; and showing thereon, space necessary for removal of equipment, opening of doors, and access for maintenance.*(<u>CDRL 107</u>)* The mock-up can be submitted separately or as part of the Pilot Car. It shall be reviewed and approved by the Authority before further production.

1.3.4.3 Seat

Seats shall be provided in accordance with Section 3.11 and the Contract Drawings; but, because of the difficulty of depicting the shape and comfort of the seat in drawings, the Contractor shall provide for inspection (prior to production), a production prototype of each seat type to supplement the seat drawings and convey all aspects of the seat design. Drawings and prototype seat assemblies shall be submitted to the Authority for approval prior to production of the seats. Prototype seats shall be delivered to the attention of the General Superintendent, Rail Car Maintenance at Washington Metropolitan Area Transit Authority Brentwood Major Repair Transit Yard, 601 T Street, N.E., Washington, D.C. 20018-1009. Upon Authority approval and if in good condition, the prototype assemblies may be used by the carbuilder for installation on a car.

1.3.4.4 Decorative Material Samples

Two samples of each material (i.e., plastics, upholstery, paint chips, floor coverings, and other decorative materials) shall be provided to the Authority for approval during the design development process. <u>(CDRL 108)</u> In addition, two complete sets of all such materials shall be delivered to the Authority with the delivery of the first car. These sets shall include source information for follow-on purchase of replacement materials by the Authority. The information shall include stock numbers, paint manufacturer's color mixture identification numbers, and the like for all decorative material items.

1.3.5 <u>Pilot Cars</u>

The "Pilot" cars are the "A" and "B" cars that are the most advanced in the production line. The Authority reserves the right to examine and approve each assembled and completed part of the work before similar work is undertaken on the remaining cars of that type. Major inspections of each Pilot Car will be made at the following stages of completion, which are not necessarily in order:

A. All underfloor equipment, piping, and wiring in place and connected
B. Car structure complete (no liners installed)
C. Side doors installed and operating (no side liners installed)
D. Overhead air conditioning apparatus in place and connected (no liners installed)
E. Cab complete
F. All liners installed (no seats installed)
G. Car complete in all respects, ready to run in revenue service operation.

Additional inspections of the Pilot Cars may be performed by the Authority as it elects during Pilot Car construction. At least 7 days notice shall be given by the Contractor for each of the seven stages of completion. The Authority will advise the Contractor of approval or corrections required at the time of the inspection. The remaining cars shall be constructed and assembled in accordance with the Pilot Cars and no changes shall be made unless authorized in writing by the Authority. The intent of this paragraph is that all cars shall be the same. All engineering changes shall be made on all cars unless permission to incorporate them at an effective point later than the first car is given by the Authority. This is not intended to discourage the incorporation of design improvements during the construction of the cars, as "effective point" changes, with the Authority's concurrence.

1.3.6 <u>Car History Books</u>

A loose-leaf history book shall be provided by the Contractor for each married pair of cars. *(<u>CDRL 109</u>)* The binder shall contain the following information for each car of the pair:

A. Car Numbers (Builder's Number and Authority's Number), Type, and Class

B. Serial numbers of all serially-numbered apparatus listed in Section 1.4.4.3.1

C. A summary of each test performed on the car, or any part thereof

D. Car Weight

E. Wheel, Journal Bearing, and Gearbox Quill Mounting Records, including heat numbers, manufacturer and manufacturing dates for wheels, axles and journal bearings and results of inspections and tests specified in Section 14.11

F. Copies of the manufacturer's test reports that the materials used in the manufacture of all wheels and axles have been sampled, tested and inspected in accordance with AAR Standards M-101 and M-107

G. Mill reports applying to materials used on the car

H. List of all changes applied to the car that have not been applied to all cars

I. Configuration records, including the revision number and revision date of all assemblies/ subassemblies and major components and a list of accepted deviations and unincorporated changes

J. List of workmanship defects noted and the disposition of each, including MRB repairs.

The Authority will advise the Contractor regarding the format of the book. The Car History Books shall be kept up-to-date by the Contractor and shall record all changes, retrofits, and additions made to each car until cars are accepted by the Authority. Documentation on changes made to the car by the Contractor during the warranty period shall be furnished to the Authority for inclusion in the Car History Book.

1.4 MANAGEMENT SYSTEMS

This section specifies the requirements for management systems. The management systems shall be sufficiently comprehensive to clearly demonstrate the Contractor's ability to meet the requirements of these specifications, and to enable the Authority to monitor the contractual effort.

1.4.1 Program Management

The Contractor shall establish an organization to properly manage this transit vehicle procurement program. The organization shall be highly responsive to the needs of the Authority as required in these specifications.

1.4.1.1 Program Management Plan

The Contractor shall develop and submit to the Authority for approval, a Program Management Plan. The Management Plan shall be updated every 6 months or as-needed due to significant changes.*(CDRL 110)* The Management Plan shall include, but shall not necessarily be limited to:

A. An organizational chart including a definition of the responsibilities and qualifications of all personnel therein.

B. The internal methods and communications to be used to control the program schedule, technical performance, program changes, subcontracts or purchase orders, material procurement, and field service support.

C. A master program schedule (Ghantt chart) showing key milestones and events.

D. A flow chart/critical path method (CPM) schedule of all project tasks indicating interaction of vehicle components and subsystems from subsuppliers.

E. Design reviews conducted on a periodic basis to assess the degree of completion of technical efforts related to major milestones.

The Contractor shall establish methods and procedures to ensure formal accountable channels of communication for the exchange of technical information establishing and defining interfaces. This methodology shall include both initial definition and formal change information when a change on one side of the interface will require a corollary change to the other. MOD 1

1.4.1.2 Schedules and Project Control

The Contractor shall prepare and maintain a detailed master program schedule. This schedule shall be the Contractor's intended working schedule and shall be used to plan, organize, and execute the work; record and report actual performance and progress; and forecast remaining work.

1.4.1.2.1 *Master Program Schedule*

The Contractor shall supply a master program schedule.*<u>(CDRL 111)</u>* The program schedule shall identify all contractual milestones, the earliest possible and latest possible dates for accomplishing each milestone, the shortest and longest permissible time span between each dependent milestone, and critical and minor paths that are essential for accomplishment of program objectives. A structured format shall be used.

The master program schedule shall include all significant subsystem development milestones and shall address subsystem development including conceptual and detail design reviews, appropriate qualification testing through First Article Inspection (FAI), delivery of units for assembly of the pilot cars, final assembly, factory test, delivery, and final acceptance of pilot cars.

1.4.1.2.2 *Production Delivery and Acceptance Schedule*

The Contractor shall submit a detailed baseline production schedule.*<u>(CDRL 112)</u>* This detailed schedule shall identify for each subsystem, as a minimum, receipt of the necessary materials, production, factory acceptance test, pre-delivery inspection, and delivery of the cars. In addition, each production and on-site acceptance testing stage shall be shown. The production, delivery and acceptance schedule may be incorporated into the master program schedule or maintained separately.

1.4.1.3 Progress Reviews and Reports

1.4.1.3.1 *Monthly Progress Review Meetings*

Progress reviews shall be held on a monthly basis. The reviews shall be held at either the Contractor's or the Authority's facilities, as directed by the Authority. The Authority will be responsible for providing minutes of monthly progress review meetings.

1.4.1.3.2 *Monthly Progress Update Reports*

During the performance of this contract, the Contractor shall submit monthly progress reports *<u>(CDRL 113)</u>* which shall provide detailed information in narrative form on the following:

A. Work completed to the reporting date
B. Work in progress to the reporting date
C. Major problems (i.e., delays incurred) and action items
D. Progress against the approved master program schedule
E. Technical performance variations from the specification requirements
F. Organizational changes
G. Subcontractor program progress.

The monthly progress reports shall include a current assessment of progress against the approved master program and production delivery and acceptance schedules. The assessment shall clearly show the state of the program relative to approved schedules and identify the critical path(s) to project completion. A printout of the schedules shall show progress to date (in Ghantt chart format) showing all activities, activity durations, remaining durations, early start, early finish, late start, late finish, predecessors and successors. (See Exhibit 1-2 for an example.

Exhibit 1-2 - Sample Schedule Report for Monthly Progress Report

Activity ID	Activity Description	Org. Dur-ation	Rem. Dur-ation	%	Target Early Start	Target Early Finish	Early Start	Early Finish	Float	Year 1	Year 2	Year 3
DESIGN PHASE												
D01	Define Scope	90	0	100	05/01/97	08/01/97	05/01/97	08/01/97				
PROCUREMENT PHASE												
P01	Approval	90	0	100	05/01/97	08/01/97	05/01/97	08/01[illegible]				
P02	Pre-Bid											
P03	BAFO											
P04	NTP											
MANUFACURING/PRODUCTION												
M01	Design Review	120	0	100	05/01/[illegible]	[illegible]	[illegible]	08/01/97				
M02	Preproduction											
M03	First Article											
M04	Testing											
M05	Production											
DELIVERY												

SAMPLE ONLY

Whenever the work progress falls behind the approved master or production delivery schedules, the Contractor shall submit a detailed explanation of the work-around or recovery plan to be followed to regain acceptable progress. The work-around or recovery plan shall be included in the monthly report.

Beginning 30 days after completion of the first car, the monthly progress reports shall include the following minimum data regarding engineering changes, modifications, MRB repairs, and any variances affecting form, fit, function, safety, or reliability:

A. Exclusive number
B. Title
C. Car numbers affected
D. Systems affected
E. Implementation date
F. Authority approval date.

1.4.1.4 Communications Protocol

All oral communications shall be in English. All meeting reports, correspondence, and written communications shall be presented in English on 8-1/2- x 11-inch standard size paper.

1.4.2 <u>Design Reviews</u>

Periodic in-progress reviews shall be conducted to evaluate the progress and technical adequacy of the design and compatibility with the performance requirements of the Contract. Prior to each review, a review package shall be submitted that includes the drawings, technical data, analyses, CDRL and other items required for the review. The Contractor shall distribute minutes of review meetings. Additionally, three formal design review meetings shall be held to assess and summarize progress of design.

1.4.2.1 Conceptual Design Review (CDR)

The purpose of the CDR is to provide early agreement on the Contractor's approach in the design of the car and its systems. The CDR should be based on, and consistent with, the Contractor's best and final offer providing such additional details as necessary to fully present the design approach and to eliminate ambiguities and narrow alternatives as system vendors are selected. The CDR may be accomplished progressively on a system-by-system basis; and separate CDR sessions may be scheduled. Vendor representation shall be as selected by the Contractor as deemed necessary to support his presentation of the design concepts. The CDR process shall be completed no later than 120 days after contract award.

Prior to the CDR (or CDR sessions) the Contractor shall submit a CDR package or packages. *(<u>CDRL 114</u>)* The CDR package(s) shall include:

A. Narrative descriptions of the major subsystems proposed by the Contractor and the subsupplier(s). This may be an elaboration, conformation, or clarification of information submitted during pre-award discussions and/or as part of the best and final offer.

B. A dynamic outline and calculations for the vehicles including worst-case conditions of wear and failures.

C. Updated car arrangement drawings.

D. Identification of all interfaces between the major systems and subsystems.

1.4.2.2 Preliminary Design Review (PDR)

A formal PDR shall be conducted to summarize the progress made and adequacy of the selected design approach and to evaluate specification compliance. The PDR shall represent approximately 60% completion of the total engineering effort required for the vehicles to be supplied and shall be held at a place to be determined by the Authority. The Contractor shall submit a PDR package that addresses the following topics as a minimum *(<u>CDRL 115</u>)*:

A. Interior layout

B. Underfloor layout

C. Detailed functional descriptions of the car subsystems and major components

D. Detailed interface descriptions and drawings, including mounting arrangements, installation methods, and definitions of all electrical connections with voltage, current, waveform, and impedance levels

E. Software design descriptions for microprocessor-based or other programmable equipment

F. List of trainlines and proposed coupler pin arrangement

G. Heat load calculations for HVAC subsystem, including psychometric charts for each control condition

H. Data verifying that the propulsion and friction brake equipment meet the specified performance and thermal duty cycle

I. Propulsion motor characteristics showing speed, voltage, and tractive effort versus motor current

J. List of special tools required for each subsystem

K. List of all person/machine interfaces in the Operator's cab area

L. Roll center location and list of carbody motion limits in relation to the truck as follows: vertical, lateral, longitudinal, roll (degrees)

M. Suspension characteristics including damping constant of each shock absorber, natural frequency and spring rate of primary and secondary suspension

N. Details of passenger door system

O. Specifications for seating

P. Side window and windshield specifications

Q. Preliminary brake failure mode analysis.

1.4.2.3 Final Design Review (FDR)

The FDR shall be conducted incrementally as the detailed design of each subsystem is complete and the production drawings are ready for release. The FDR shall confirm that the design of the system/ subsystem under review satisfies the contract requirements including compatibility of vehicle interfaces with other systems on the vehicle, other railcars in the Authority's fleet, and the Authority's wayside systems.

The Contractor shall submit an FDR Package that addresses the following topics as a minimum *(<u>CDRL 116</u>)*:

A. Latest revisions of the drawings and documentation submitted for the PDR

B. Assembly drawings down to the lowest level replaceable unit

C. Software documentation consisting of structured data flow diagrams to the lowest level of decomposition, with software module descriptions in structured narrative format.

D. Electrical schematic drawings, down to the individual signal or wire level, for each electrical circuit

E. Pneumatic schematics or flow schematics for each fluid circuit, showing control and check valves, test point orifices, and other circuit details

F. Final brake failure mode analysis.

1.4.3 Systems Engineering

1.4.3.1 General

The Contractor shall treat the car, in its design and manufacture, as a single system; rather than as an assembly of independently engineered and manufactured elements.

1.4.3.2 Systems Engineering Plan

The Contractor shall prepare, and submit for the Authority's approval, a Systems Engineering Plan *(CDRL 117)*, which may be part of the Management Plan. The Systems Engineering Plan shall describe the organization and process by which the Contractor proposes to:

A. Transform specification requirements into a description of system and subsystem performance parameters and a system and subsystem configuration through the use of an iterative process of definition analysis, design, test, and evaluation.

B. Integrate related technical parameters and ensure compatibility of physical, functional, and program interfaces in a manner that optimizes the vehicle design.

C. Integrate reliability, maintainability, safety, quality assurance testing and human factors into the total engineering effort.

1.4.4 Configuration Management

1.4.4.1 General

The Contractor shall prepare to acceptable commercial standards, and maintain, accurate and current configuration records. The configuration records shall be contained in a controlled release document, which shall be available to the Authority throughout the period of performance of the Contract and for a 3-year period after final Contract payment. The Contractor shall ensure that its subsuppliers' equipment incorporated in the vehicle design complies with all requirements specified in this section.

1.4.4.2 Configuration Management Plan

The Contractor shall prepare and submit a Configuration Management Plan. *(CDRL 118)* This plan shall illustrate how the Contractor intends to meet the configuration management requirements.

1.4.4.3 Configuration Records

The Contractor's configuration records shall be prepared to acceptable commercial standards and shall define the approved configuration of equipment under development, test, or production, or in operational use, and supporting engineering data (e.g., test procedures, wiring diagrams, etc.). All such items shall be identified to the lowest level required to ensure repeatable performance, quality, and reliability. The configuration records shall portray the relationship between all items. Hardware configurations not used on this contract, and manufacturing status, shall not be included in the configuration records.

A. The Contractor’s configuration records and documentation shall indicate the following:

1. The composition of any part number at any level in terms of subordinate part numbers

2. All next higher assembly part numbers for any part

3. The specification document, specification control drawings, or source control drawing numbers associated with any subsupplier, vendor, or Contractor part numbers.

B. The Contractor’s configuration 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 that shall ensure that differing parts, assemblies, and installations are uniquely identifiable. The part number used by the Contractor and its subcontractors shall identify a specific item having a specific configuration. All items beginning with the lowest level of repair or replacement, 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. Old and new configuration items that require segregation shall be identified either by a new drawing number or a dash number added to the original drawing.

C. The Contractor shall, where physically possible, permanently mark all hardware components to the lowest level of repair and replacement with part number identification. The hardware identification marking shall at all times coincide with the officially released engineering data. Nameplates on major equipment items shall provide space for Authority numbers to be added by the Contractor, at its expense, at the direction of the Authority. Serialization is required on each item of equipment delivered unless otherwise directed by the Authority. Individual serial numbers shall be assigned in a numerical sequence established for the type or model series of the equipment being supplied.

D. The Contractor shall maintain a serialization and configuration record for each vehicle, and two copies submitted to the Authority at the time of vehicle delivery.

1.4.4.3.1 *Serial Numbers*

Serial numbers are not to exceed 10 digits. Duplicate serial numbers shall not be used within a type or model series. Serial numbers are required for:

A. Wheels
B. Axles
C. Truck Frames and Truck Bolsters
D. Journal Bearings
E. Air Conditioning Apparatus
F. Temperature Control Apparatus
G. Couplers
H. Destination Signs
I. Door Operators and Controls
J. Traction Motors, including rotors
K. Gear Units
L. Batteries
M. Converters
N. Inverters
O. Principal Units of Traction and Braking Apparatus

P. Brake Calipers and Actuators
Q. Air Compressors
R. Principal Units of Radio and Public Address Equipment (not including speakers)
S. Principal Units of Automatic Train Control Apparatus
T. Motors in any of the above listed Apparatus and equipment
U. Any other items of equipment which are customarily serially-numbered.

Serial numbers shall be provided in the Car History Book, referred to in Section 1.3.6. A description of each serial number (a block of numbers from which they will be drawn or, as a minimum, the number of characters in the serial number and whether numerals, letters, or a combination thereof) shall be provided at least 3 months prior to acceptance of the first pair of cars. *(CDRL 119)* Existing serialization programs of the Contractor or any Subcontractors will be considered acceptable, subject to review and approval by the Authority. Serial numbers used by the Contractor and Subcontractors shall not duplicate serial numbers assigned to like products, equipment, or parts delivered to the Authority under separate ongoing or previously completed contracts or subcontracts.

1.4.4.3.2 *Bar Codes*

Standard Code 39 bar codes to identify each part number and serial number shall be permanently affixed to each serially-numbered component below the stamped or engraved serial number. The location shall be chosen for ease of reading without removing the component from the car, wherever possible. The medium used for the bar code shall be approved by the Authority.

As a minimum, the bar code itself shall contain the manufacturer’s part number, serial number and a 9-digit allocation for the Authority’s stock number.

All equipment assemblies shall be bar-coded to facilitate electronic scan recording of maintenance actions.

1.4.4.4 Change Control

This Specification identifies the procurement baseline for the transit vehicle. Changes to the procurement baseline shall be controlled by the processing of Engineering Change Proposals (ECPs).

All ECPs shall be reviewed by the Contractor’s organization responsible for configuration control for total impact evaluation prior to recommendation and submittal to the Authority for review and approval.

1.4.4.5 Classification of Changes

A proposed engineering change to any part, assembly, subassembly, or equipment item of the supplier’s product shall be designated a Class I change when one or more of the following is affected:

A. Form, fit, function or interchangeability
B. Reliability or maintainability
C. Weight or balance (where it is a factor)
D. Safety
E. Electromagnetic interference characteristics
F. Delivered product (retrofit)
G. Delivered training, operation, or maintenance manuals
H. Sources of repairable items (source control drawing)
I. Schedules or deliveries
J. Spares provisioning.

Any engineering change not affecting form, fit, function, or interchangeability, and not falling within the preceding definition of a Class I change shall be designated as a Class II change. Some examples of Class II changes are correction and clarification of documents and drawings.

1.4.4.6 Engineering Change Proposal (ECP)

Each Class I change shall be processed as an Engineering Change Proposal and shall be submitted to the Authority for approval prior to initiating any implementation action. *(CDRL 120)* Eight copies of the ECP, accompanied by the technical documentation and the cost information necessary to fully evaluate the change shall be provided to the Authority. 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 its subcontractors.

All Class I changes that affect safety shall be immediately reported by the Contractor by telefax, telephone, in person, or by other expeditious means. The Contractor shall identify the change by ECP number, and if reported verbally, shall confirm the change in writing to the Authority within 24 hours. Class II ECPs shall be submitted to the Authority for information.

1.4.5 Electromagnetic Interference and Compatibility

1.4.5.1 General

All equipment shall operate in the cars on the Authority's existing system and with the Authority's other cars without being affected by, or causing interferences that may adversely affect, the Authority's system operation or safety because of conducted, induced, and/or radiated emissions.

1.4.5.2 Control and Test Plans

The Contractor shall submit electromagnetic compatibility (EMC) and electromagnetic interference (EMI) control and test plans to the Authority. Control of EMC and EMI shall be part of the earliest stage of apparatus design. *(CDRL 121)* The EMC and EMI control and test plans shall describe the methods to be used by the Contractor to meet the specified EMC and EMI requirements. The approved versions of these plans shall be incorporated in all Contractor apparatus purchase specifications. Authority approval of these plans does not relieve the Contractor from providing apparatus which functions properly on the cars and in the Authority's transit system environment.

In addition to the requirements contained in this section, the Contractor shall perform the car level Electromagnetic Compatibility qualification tests described in Section 1.8.4.7.

1.4.5.3 Methods and Apparatus

The Contractor shall employ design techniques, construction methods, and whatever apparatus is required to prevent interference—caused by installed equipment—from affecting the proper operation of any car, including existing Authority cars, and wayside systems; and to prevent interference caused by existing car and wayside systems from affecting the proper operation of the installed equipment. In addition to coordinating frequencies, the Contractor shall provide necessary on-board balancing, filtering, shielding, modulating techniques, grounding, and isolation to provide adequate signal-to-noise (S/N) ratios and to reduce undesirable effects of interference. Electrostatic and magnetic shielding methods shall be employed to minimize the effect of stray signals and transient voltages on interconnecting cables. Interconnecting power and signal cables shall be physically separated. Induction into trainline circuits due to propulsion system and converter current transients shall be reduced as required to prevent interference.

To contain EMI emissions, the suppression of EMI shall, wherever possible, be at the source of the EMI. The following design requirements shall be included in the EMC and EMI control plan:

A. All magnet valves, relay and contactor coils, and other inductive devices shall have free-wheeling diode or metal-oxide varistor transient suppression. Other means of suppression or the omission of suppression, for performance reasons, shall have the approval of the Authority prior to use.

B. The number of suppression device types shall be kept to a minimum.

C. Apparatus design and enclosures shall shield the apparatus from any effects resulting from the operation of an Authority handheld transceiver when the transceiver is within 18 inches of the enclosure.

D. Apparatus design and enclosures shall shield the apparatus from any effects resulting from the operation of cellular telephones, including when the telephones are operated within the car and on the passenger platforms.

1.4.5.4 Emission Limits

The electromagnetic emission limits specified herein shall not be exceeded, in order to avoid undesirable effects upon external environment along the right of way by onboard vehicle subsystems. Additionally, a review of each vehicle's ("A" and "B" car) impedance shall be performed by the Contractor so as to determine the following desirable characteristics: at 60 Hz the input impedance shall not be capacitive in nature, the input impedance resonant frequency must be below 55 Hz.

Meeting the following requirements is the first level of defining the interface between installed equipment systems and subsystems and other electromagnetically-sensitive systems in the Authority's environment. The Contractor shall be responsible for reducing the above limits, if necessary, to prevent interference.

1.4.5.4.1 *Radiated Emissions*

Between the frequencies of 0.15 MHz and 30 MHz, the maximum permissible interference limit shall not exceed 20 dB above the limit of Figure 22 (REO5) of MIL-STD-461A. From 30 MHz to 88 MHz, the maximum limit shall be 58 dB above one microvolt/meter/MHz bandwidth. From 88 MHz to 1,000 MHz, the maximum limit shall be 68 dB above one microvolt/meter/MHz bandwidth. These limits shall not be exceeded when measured at a distance of 100 feet from the track centerline. A graphical representation of these limits is given in Exhibit 1-3.

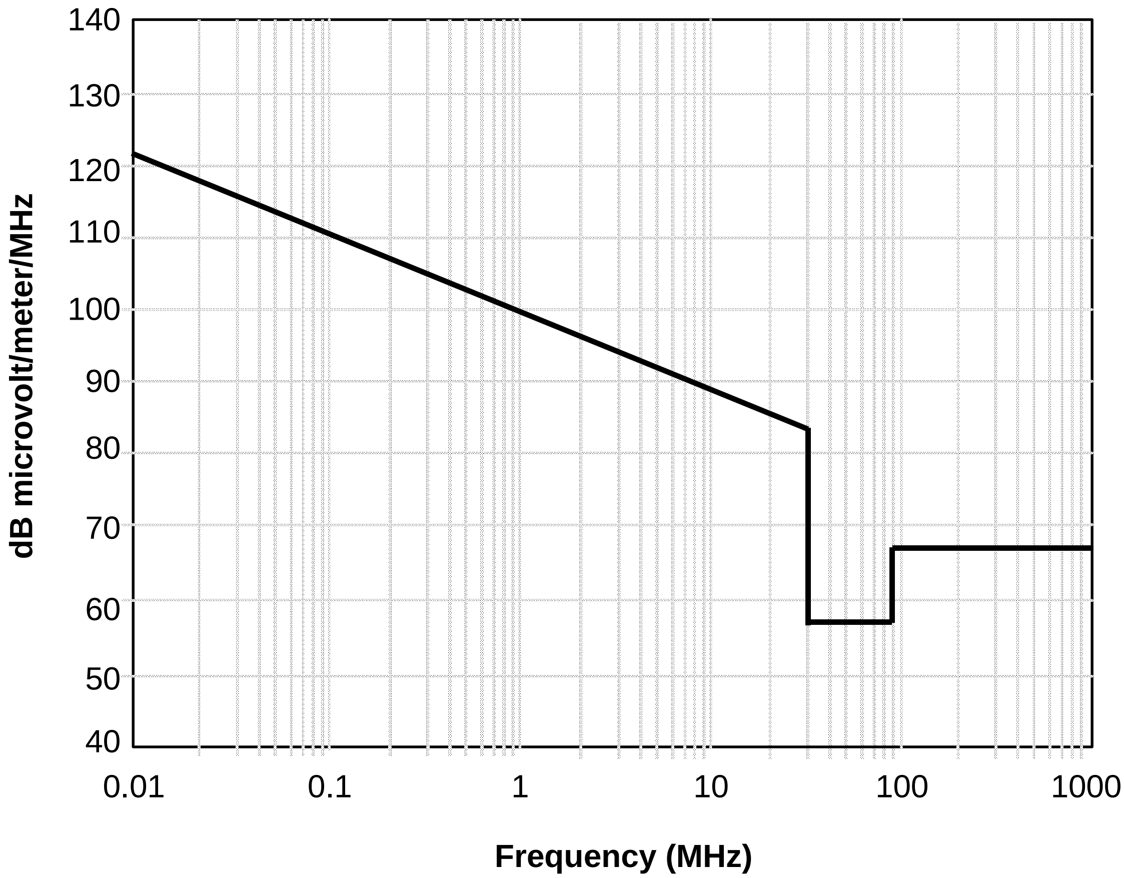
1.4.5.4.2 *Conductive Emissions*

The conductive emissions, as measured by the procedures of "Conductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures," UMTA-MA-06-0153-85-6, shall have a maximum current limit (amperes RMS) of 1.1A between the frequencies of 55 Hz and 65 Hz, and 0.030 ampere from 2 kHz to 20 kHz. This condition shall be met by each individual power component as well as the simultaneous operation of all car apparatus.

1.4.5.4.3 *Inductive Emissions*

The inductive emissions, as measured by the procedures of "Inductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures," UMTA-MA-06-0153-85-8, shall be limited to a maximum of 100 millivolts RMS between 55 Hz and 65 Hz, and 10 millivolts RMS, rail-to-rail, at all frequencies between 2 kHz and 20 kHz. This condition shall be met by each individual power component as well as the simultaneous operation of all car apparatus.

Exhibit 1-3 – Radiated Emission Limits



1.4.5.5 Conducted Interference

The Contractor shall formulate a set of criteria governing both generation and tolerance of electrical interference on conductors between assemblies. The criteria shall distinguish the basic types of circuits present on the car and shall define a suitable, comprehensive classification of disturbances which could be present in each type of circuit. The criteria shall insure that each connected assembly will be able to tolerate the disturbances introduced simultaneously by all of the other assemblies to which it could be connected. The criteria shall include any required reduction of the limits described above on conducted interference into the third rail and running rails, with levels selected to prevent interference with signal and communications system which use those circuits for their means of operation and communication. These criteria shall be a part of the EMC and EMI control plans.

1.4.5.6 Inductive Interference

The Contractor shall formulate a set of criteria governing generation and tolerance of magnetically coupled interference on or between assemblies. The criteria shall identify the basic types of circuits present on the car and shall define a suitably comprehensive classification of disturbances which could be present in each type of circuit. The criteria shall insure that each connected assembly will be able to tolerate the disturbances introduced simultaneously by all other assemblies to which it is inductively coupled. The criteria shall include any required reduction of the limits described above on the inductive interference into the third rail and running rails, with levels selected to prevent interference with signal and communications systems which use these circuits for their means of operation and communication. These criteria shall be a part of the EMC and EMI control plans.

1.4.5.7 Cab Signal Interference

The Contractor shall minimize the amount of EMI that couples into the cab signal receiver coils over the range of 4 to 6 kHz. To this end, the level of in-band interference at the two cab signal receiver carrier frequencies (4,550 Hz and 5,525 Hz) shall not exceed 50 mA (RMS).

1.5 MANUALS AND CATALOGS

The Contractor shall submit to the Authority Tables of Contents and sample formats for all the manuals and Parts Catalogs as listed herein. *(CDRL 122)*

Manuals and catalogs shall be produced in the same format as the existing vehicle manuals. A complete correspondence between literature is desired; e.g., Propulsion and Control System shall be in Chapter 3 of both the old and the new manuals. The same size and style of type shall be used throughout, except for emphasis.

They shall be complete, modern, thoroughly organized, and authentic with no extraneous material such as advertisements or irrelevant information. The publications shall be designed for continuous, long-term service.

Delivery of 50 sets of final drafts of manuals and catalogs shall be provided *(CDRL 123)*

The final editions of all manuals, incorporating all changes deemed necessary, shall be completed and delivered to the Authority. *(CDRL 124)*

All publications shall be in loose leaf form, on good grade paper. They shall be in six general categories as follows:

A. Train Operator's Instruction Manual (pocket size)
B. Running Maintenance and Servicing Manual (8-1/2 x 11-inch pages)
C. Heavy Repair Maintenance Manual (8-1/2 x 11-inch pages)

D. Parts Catalog (8-1/2 x 11 inch pages)
E. Carborne ATC Maintenance Manual (8-1/2 x 11-inch pages)
F. Carborne ATC Parts Catalog (8-1/2 x 11-inch pages).

Pocket size manuals shall be 4-1/4 inches wide, 7 inches high, and not more than 1-1/4 inches thick. They shall be bound along the 4-1/4 inch dimension and the pages therein shall be as large as can be accommodated without damage. Punch holes shall be on 9/16-inch centers.

Manuals for 8-1/2 x 11-inch pages shall be 10 inches to 10-1/2 inches wide (depending on ring size) and 11 inches to 12 inches high. They shall be bound along the 11-inch dimension. The 8-1/2 x 11-inch binders shall not exceed 3 inches overall thickness. Punched holes shall be on 3/4-inch centers. Folding pages will be permitted (11 x 17 inches, "Z"-folded) where the information to be conveyed cannot be presented clearly on single pages. Manuals for 8-1/2 x 11-inch pages may be divided into Book 1, Book 2, etc., if the required material cannot be accommodated within the maximum binder thickness. Adequate cross reference and Table of Contents shall be provided in each book.

All covers shall be approximately 1/16-inch thick, resistant to oil, moisture, and wear, to a high degree commensurate with their intended uses. Final sets of manuals shall be serialized with numbers to be supplied by the Authority. The numbers shall be permanently marked on the spine of the cover. Loose-leaf binder rings shall have locking triggers for opening and positive engagement closing. Diagrams and illustrations shall not be loose or in pockets. All printed material shall be clearly reproducible by dry copying machines and this precludes the use of halftone illustrations. Line drawings are required.

The car shall be treated as a whole and not as a grouping of disassociated parts. The material in the Maintenance Manuals and the Parts Catalog shall be similarly organized and indexed, with a standard numbering system in accordance with an approved Contractor's outline. Indexing of the pocket size manuals may be abbreviated as required to achieve compactness.

All sections shall be subdivided, to the extent required by the subject matter, into the following topics:

1. General subsystems description and operation
2. Block diagram
3. Signal flow diagrams
4. Functional schematics
5. Functional wiring and piping diagrams
6. Troubleshooting techniques
7. Microcomputer software
8. Lubrication and cleaning, including frequency, methods and trade identifications of recommended materials; component location and description
9. Inspection and maintenance standards including wear limits, settings and tolerances
10. Installation and removal
11. Test and evaluation procedures.

If microcomputers are used, 5 sets of software documentation conforming to the requirements of Section 15.30 shall be provided in separate binders, but shall be subject to the same revision requirements imposed on manuals in this section.

The format of all data contained in each section of the maintenance and parts manual shall be consistent from section to section. Note: The detailed contents of sealed assemblies need not be displayed, but their functions shall be explained and the appropriate voltage and current values shown for each external terminal. Procedures appropriate to their replacement, including methods and tests, shall be stated.

Following the issue of each publication, the Contractor shall provide revised pages covering any changes, whether required by change of design or procedures or due to error, and these revisions shall be kept current during the warranty period. Manual and catalog revisions shall be supplied to the Authority before or coincidental with the arrival of the altered parts or components.

After the warranty period, revisions shall be supplied to the Authority, as applicable, every 6 months until the end of the reliability test program. A new revision sheet with the dates of the period of validity and a list effective pages shall be included for each manual. When no changes are required for the 6-month period, the revision shall consist of only a new revision sheet showing the new period of validity.

1.5.1 Train Operator's Instruction Manual

The Train Operator's Instruction Manual shall contain all information needed for the optimum operation of the vehicle. It shall include general vehicle familiarization material: location, function and operation of controls, gages, indicators and switches; a discussion of the trucks, couplers, lights, environmental control, air springs, height control valves, ATC, and other features of the car which the Operator may not be in a position to control or adjust but of which he should have some basic knowledge; emergency procedures; and trouble symptom and diagnosis methods.

The manual shall be logically organized with systems and elements considered in descending order of importance. Care shall be taken that all statements are clear, positive and accurate, with no possibility of incorrect implications or inferences.

1.5.2 Heavy Repair Maintenance Manual

The Heavy Repair Maintenance Manual shall contain a detailed analysis of each component of the car excluding the ATC System so that maintainers can effectively service, inspect, maintain, adjust, troubleshoot, repair, replace, and overhaul it. It shall also include, in a separate section, all information needed for periodic inspection and servicing requirements, including lubrication, inspection and adjustment of all apparatus. ATC System hardware and software shall be contained in a separate Carborne ATC Maintenance Manual with the same requirements as above.

1.5.3 Running Maintenance and Servicing Manual

The Running Maintenance and Servicing Manual shall provide the maintainer all information needed for on-car running maintenance and adjustment, and on-line trouble diagnosis of each system including such data as troubleshooting guides and schematics for the car and each of its systems.

1.5.4 Parts Catalog

The Parts Catalog shall enumerate and describe every component (excluding the ATC system) with its related parts, including the supplier's number and the commercial equivalents. A separate column shall be provided for including the Authority's stock number in future revisions. Cutaway and exploded drawings shall be used to permit identification of all parts. Parts common to different components (for example, bolts and nuts) shall bear the same Contractor's number. Each part or other component shall be identified as being part of the next larger assembly. ATC system components shall be contained in a separate "Carborne ATC Parts Catalog," with the same requirements as above.

1.5.5 Operation and Maintenance Manuals - Test Devices

Operation and Maintenance manuals for the test devices shall include the requirements of Section 12.1 and shall be presented in the format requirements of Section 1.5.

After the warranty period, revisions shall be supplied to the Authority, as applicable, every 6 months until the end of the reliability test program. A new revision sheet with the dates of the period validity and a list of effective pages shall be included for each manual. When no changes are required for the 6-month period, the revision shall consist of only a new revision sheet showing the new period of validity.

1.6 USER EDUCATION

1.6.1 General

The Contractor shall provide an educational program for the Authority's Training Instructors and Supervisory staff of a quality and depth sufficient to permit satisfactory use, servicing, and maintenance of the equipment. This program shall include classroom and hands-on instruction, mock-ups, models, manuals, diagrams, and parts catalogs. The Contractor shall assume no knowledge of the features of the cars on the part of the Authority's personnel and shall design the program to bring the level of knowledge to one fully adequate for the objective. The Contractor may assume that the Authority's personnel have the basic skills pertinent to their crafts. The Contractor's approach to this effort shall be based on the assumption that the Contractor's own interests, immediate and ultimate, are best served by a satisfactory program. All courses of instruction shall be presented in the English language.

Prior to the initiation of classroom instruction, all instructors to be utilized by the Contractor shall attend a one-day orientation at the Authority to become familiar with Authority safety regulations and facilities and the layout of the car, and to be advised of student qualifications and expectations.

Manuals to be used during training shall be delivered to the Authority; the manuals shall be accurate, complete, and of professional quality. *(CDRL 125)* Instructor and student manuals shall be provided for each course.

The program shall be conducted at the Authority's facilities in Washington, D.C. and include classroom and hands-on instruction for a selected group of Instructors, Supervisors, Mechanics/Technicians and Train Operators. The Contractor shall provide an adequate supply of high quality, professionally prepared material on paper, and such other training aids as may be necessary to impart the essential knowledge to the people involved and leave them with authoritative and up-to-date reference material. The program shall include steps to determine the proficiency of the students.

The Contractor shall provide full-time on-site management and coordination of the training program to insure continuity of classes and proper distribution of training materials, and to be responsible for interfacing with instructors.

1.6.2 Objectives

The primary objective of the Maintenance Training program shall be to train the Instructors and Supervisors so that they are proficient in the operation and maintenance of the transit car to the extent that they may provide the instruction and training of the Authority's maintenance personnel.

The primary objective of the operations training program is to provide train operators and operations supervisors with proficiency in the operation of the transit car.

1.6.3 Educational Program

The program will provide for a combination of classroom and hands-on instruction in the shop and on the rail car to perform operations and maintenance functions. Maintenance and operations courses shall have a length commensurate with material required for in-depth presentation.

The Contractor shall submit an educational program outline and schedule, which identifies milestones for submitting the course outlines, lesson plans, instructor/student guides, audiovisual aids, mock-ups/simulators, written and practical tests, and for conducting classes. *(CDRL 126)* The training outline shall identify each module of instruction and the general topics to be taught and indicate the order in which modules will be conducted. The Authority will provide samples of how training materials should be organized, and how instructor guides, student guides, lesson plans and audiovisual aids shall be designed.

As training materials are being developed, the Contractor shall work closely with Authority staff to ensure that the Authority's standards—with respect to the course organization, content, and overall quality of written documents—are being met. The Authority will provide samples of current training materials.

1.6.3.1 Operations Training

Topics to be covered in the operations training program shall include, but not be limited to the following: car specifications, controls and indicators; car systems (i.e., propulsion, friction brake, electrical, truck and coupler assemblies, door control, environmental, lighting and communications); car operations (that is, actual operation of the car in maintenance yards and on the revenue railroad); troubleshooting procedures and recovery operations.

The Contractor's instructor will be accompanied at all times by a qualified Authority instructor or supervisor to ensure that all Authority rules and procedures are respected.

1.6.3.2 Maintenance Training

Topics to be covered in the maintenance training program shall include, but not be limited to: carbody; car logic control; destination signs; propulsion; friction brake; pneumatics; primary power; auxiliary power; trucks and suspension; coupler and draft gear; door control; heating, ventilation and cooling; lighting; automatic train control and communications.

Authority employees shall be exposed to the depth of detail that is necessary for the performance of preventive (scheduled) and corrective (unscheduled) maintenance operations. Students shall be afforded the opportunity to perform the more complex maintenance functions on the car and in the shop, in addition to troubleshooting "bugged" systems using the appropriate subsystem test devices.

The program shall emphasize the details of performing heavy maintenance repair and rebuilding of selected components. Examples include replacement of compressor seals and traction motor bearings.
Courses shall be divided into two classifications: electrical or electronic and mechanical. To allow student participation during the demonstration and performance of maintenance functions, each course shall be separated into these two classifications.

1.6.4 <u>Training Courses</u>

The Contractor shall provide detailed schedule data for proposed courses. This information shall be grouped by course and separately indicated for each individual course proposed.

A qualified instructor shall be assigned to each group of students during training. This training shall provide in-depth understanding of vehicle assembly, subsystem installation and operation, and vehicle verification testing. Additionally, the student shall observe proper maintenance practices and shall become aware of the requirements to use the proper tool for the job (e.g., special tools), the importance of proper torquing and sealing procedures, and the most expeditious way to perform maintenance. Classes shall be scheduled on a 40-hour work week basis, 8 hours per day, 5 work days per week. No classes shall be scheduled on the Authority's holidays. Class instruction periods shall normally be 50 minutes in duration with a 10-minute break between periods of instruction. Length of practical application periods is not fixed.

The Maintenance courses shall be initiated within 5 days after acceptance of the first pair of cars.

Operator Training shall be initiated within 5 days following acceptance of the second pair of cars.

There shall be a 10-day break following the first class to permit Authority personnel to evaluate the quality of instruction and to request changes to enhance training effectiveness.

1.6.5 Training Aids

Training aids for both the Operator and the maintenance classes shall consist of:

A. Operation and Maintenance Manuals.

B. Transparencies, 8-1/2 x 11 inches in size, to be utilized with an overhead projector. These transparencies shall illustrate component locations, component cutaways, schematics, and wiring diagrams. Viewgraphs depicting hydraulic, pneumatic, and air conditioning systems shall include direction of flow for the particular medium.

C. The Contractor shall furnish a computer-driven video display for use during the propulsion electrical maintenance course. The video display shall include, but not be limited to, an animated schematic of the propulsion primary motor circuit and a display of propulsion system operating parameters. The animated schematic shall:

    1. Use the same page layout, graphic symbols, circuit notation, and terminology as the propulsion system schematic diagrams found in the maintenance manuals.

    2. Accurately display on screen all motoring and electric braking configurations and have the capability to change configurations without any noticeable delay for screen re-drawing or refreshing.

    3. Accurately display, on screen, current flow in all parts of the propulsion primary circuit for all modes and all configurations.

    The propulsion system operating parameters display shall:

    1. Accurately display, on screen, propulsion system operating parameter values for all modes and configurations. The parameters displayed on screen shall include, but not be limited to—line currents, motor currents, motor voltages, motor RPMs, train speed and acceleration, relay and contactor status, and any internal logic flags or variables that would ordinarily be monitored by maintenance personnel during maintenance or troubleshooting. There shall be no noticeable delay in updating the parameters display. Any other parameters, which in the opinion of the Contractor or the Authority would aid in a student's understanding of the operation of the propulsion system, shall be included in the display.

    2. Allow the user to simulate changes to various propulsion operating parameters including, but not limited to: trainline inputs, line voltage, car weight, and tractive effort request. The display shall then immediately show the effect of those changes on the propulsion system.

    The display shall allow the user to simulate common propulsion system faults including, but not limited to: low or high line voltage, semiconductor faults, relay and contactor failures, tachometer failures, and over-temperatures. The display shall then immediately show the actual effect that those faults would have on the propulsion system.

    The Contractor shall furnish all documentation, materials, and tools necessary to modify and re-compile the software should any future changes to the propulsion system require that the display be updated.

D. A minimum of ten training tapes, including all major subsystems plus subsystem interfaces, in 1/2-inch color VHS audio-video cassettes shall be supplied. The tapes should be 10-20 minutes in length and shall include unusual or difficult-to-explain operations such as disassembly, assembly, repair and test regarding the subject.

E. Wiring diagrams, when used as training aids and reference material, shall be divided to facilitate comprehension. There shall be single-line functional diagrams of systems. Schematic diagrams shall include details of each component in the systems. Where parts are identified by initials or reference numbers, there shall be a key to permit precise identification.

F. All Operators' Manuals, Running Maintenance and Servicing Manuals, Heavy Repair Maintenance Manuals, Parts Catalogs, Radio Maintenance Manuals, Portable Test Device Operation and Maintenance Manuals, and Bench Test Device Operation and Maintenance Manuals shall be provided to the Authority on diskette in WordPerfect 6.1 or other specifically approved format.

Training aids may include actual samples of manually operable devices or working samples of devices, the functions of which can be displayed without dismantling the device. The workings of other significant components shall be illustrated with diagrams or cut-away views, etc., displayed with sufficient scale and clarity to permit all to see clearly.

Notebook-size copies of all visual displays used by an instructor shall be included in the student handouts.

The Contractor shall make corrections and improvements to the audio-visual aids during the conduct of the course when examinations, tests, or instructor observations indicate that a majority of students fail to attain the learning objectives.

Suitable protective covers shall be provided for each audio-visual aid master reproducible.

Test points shall be included on any models or mock-ups together with the hardware necessary for maintenance operations.

Proper nomenclature for all components shall be applied, and shall be in accordance with the terminology used on schematics and wiring diagrams incorporated in operating and maintenance manuals.

All training materials, such as training aids and lesson plans, shall become the property of the Authority at the completion of the training program. The Contractor shall be responsible for the condition of these materials for the duration of the training program, and shall replace all damaged materials unless the damage resulted from neglect by the Authority. Lesson plans shall be updated as required during the course of instruction.

The following are the numbers of personnel to be instructed and of manuals and other software to be provided:

A.	Number of operating personnel, including supervisors	65 maximum
B.	Number of mechanical maintenance supervisors, including training instructors	24 maximum
C.	Number of electrical or electronic maintenance supervisors, including training instructors	24 maximum
D.	Operator's Manuals	650
E.	Running Maintenance and Servicing Manuals	360
F.	Heavy Repair Maintenance Manuals	120
G.	Parts Catalogs	120
H.	Radio Maintenance Manuals (for FCC licensed personnel)	20
I.	Portable Test Device Operation and Maintenance Manuals	20, with each type of test device
J.	Bench Test Device Operation and Maintenance Manuals	20, with each type of test device

1.6.6 <u>Classroom Instruction</u>

1.6.6.1 Instructor Qualifications

All of the instructors provided by the contractor shall be fully capable of transmitting in-depth technical information that can be understood by participants. A detailed resume for each instructor shall be provided to the Authority for approval. *(<u>CDRL 127</u>)*

The Authority will recognize the instructor as qualified when:

A. He or she has been trained in adult teaching principles and methods and has had experience in conducting technical training courses

B. Has an in-depth knowledge of the system under discussion, how it interfaces with other systems or subsystems, and the procedures for isolating faults and troubleshooting and is able to communicate that information to students in an effective manner

C. Is able to design practical and written tests to determine the extent to which students understand and can apply the information that has been taught.

1.6.6.2 Class Size and Timeframes

Class size will generally be from 5-10 employees, depending on the nature of the course being taught. The Contractor shall supervise all classes.

The Authority will provide a reasonable amount of classroom space and assistance in the movement of equipment within its own property, and will furnish suitable classroom furniture such as desks and chairs. The Authority will also provide for the availability of trainees to accommodate training class schedules to the maximum extent possible within the constraints of individual work schedules and operational demands. Classroom schedules will be adjusted within reason to accommodate operational exigencies.

1.6.6.3 Instructional Format/Materials

All maintenance and operations courses shall include a combination of classroom and hands-on instruction. Written or practical tests will be designed and given at suitable points in each course to determine the extent to which students have learned and can apply the information.

Manuals and other materials used by the contractor shall be complete, accurate and available 60 days prior to the beginning of training.

Classroom instruction for maintenance courses shall include not only the anatomy and functioning of parts under discussion, but the essentials of their routine care including lubrication schedules, materials, Contractor's recommendations for test frequency, tolerance limits and methods for testing, including instruments required, when applicable. When methods of access, removal, dismantling or application are not self-evident, the instruction shall cover these matters. Overhaul procedures need not be included.

1.6.7 <u>Hands-on Instruction</u>

The extent of instruction in the Contractor's and Subcontractors' shops shall be at the discretion of the Authority. The Authority may request access to these shops for limited number of supervisory and technical personnel to familiarize them with assembly methods; the Contractor shall make a reasonable effort to comply with such a request, but not to the detriment of production. Similarly, the Authority's operating supervision shall be granted access to all equipment for the purpose of familiarization.

Hands-on instruction involving use of a car, including both maintenance and operation, shall be presented by instructors having thorough experience in maintenance services or operation as the case may require. They shall have their subjects properly organized prior to commencement of the class.

Instruction in operation shall follow a logical progression involving the anatomy of the car, the manipulation of all controls, and actual operation. Operating instruction shall include trouble indications, their proper reporting, and corrective measures available to operators.

The Authority will make available, upon proper notice, pairs of cars and trains at accessible shop locations for instructional purposes; and will arrange for road operation as well as furnishing power, dispatching, and operational supervision as necessary. There will be no charge for the cooperation.

1.7 QUALITY ASSURANCE PROGRAM

1.7.1 General

The Contractor shall be responsible for providing a quality product to the Authority under this Contract. To this end, the Contractor shall have planned and established a quality assurance program which shall be maintained throughout the execution of the Contract. The elements of the Contractor's quality assurance program shall be imposed on all entities within the Contractor's organization and on all manufacturers, subcontractors, and suppliers that perform contract work. This section defines the quality assurance requirements that the Contractor shall establish, implement, and execute in the performance of the Contract to assure that the design, materials, processes, and workmanship are furnished in conformance with the Contract Technical Specification, and that the approved Contractor's design and manufacturing documentation are provided in a timely manner.

Quality assurance responsibilities required by this Specification include planning, establishing, and maintaining a quality assurance program; performing all work required by the program; and conducting regular quality program audits. Required tests and adjustments are specified in Section 1.8.

1.7.2 Quality Assurance Program Plan

A Quality Assurance Program Plan *(CDRL 128)*, specific to this contract, shall be submitted to the Authority. The plan shall include a company policy statement which clearly defines the authority and role of Quality Assurance within the Contractor's organization, particularly with regard to schedules and cost. The Quality Assurance Program Plan will be evaluated by the Authority and revised by the Contractor, as required, to achieve conformance with the Specification requirements for the quality assurance program. The Authority may visit the Contractor's and subcontractor's facilities, prior to approval of the Quality Assurance Program Plan, to perform an assessment of the effectiveness of the submitted quality assurance program. The submittal shall have provided objective technical evidence of the adequacy of the quality assurance program to assure product compliance; either through the presentation of historical records, or the examination of operations in progress. If deficiencies are noted during the assessment of the program, corrective action shall be accomplished and documented as a condition of having the Quality Assurance Program Plan approved.

The Contractor shall maintain a Quality Assurance Program with established quality control functions that is in accordance with the approved Quality Assurance Program Plan. The approved plan and all implementing manuals, procedures and programs will be subject to regular audits by the Authority as specified in Section 1.7.4 to determine implementation status during the performance of the Contract.

The Quality Assurance Program shall include an inspection and test plan. *(CDRL 129)* The inspection and test plan shall include a narrative description of the manufacturing and inspection process for major equipment. Additionally, the inspection and test plan shall include major manufacturing and inspection milestones on a schedule, which may be incorporated into CDRL 112. This plan, and its attendant schedule, shall be updated as milestone dates or other significant items change. The inspection and test plan will be used by the Authority's quality representative to identify the Contractor's inspection, witness, and hold points. The plan shall include a rectifying feedback system to the Contractor's engineering and production groups.

The Contractor's Quality Assurance Manual shall describe methods to plan, implement and maintain its quality program. The Quality Assurance Manual shall contain a comprehensive collection of all forms to be used for the documentation of quality control activities that assure material, process, personnel and product compliance to applicable specifications. The Quality Assurance Manuals of the Contractor and those from the suppliers shall be submitted and revised until they receive the Authority's approval. Contract work that is performed prior to the Authority's approval of related, implementing sections of these manuals shall be at the Contractor's risk.

1.7.3 Quality Assurance Program Requirements

The responsibility for the quality assurance function shall be so placed within the Contractor's own organization that meeting schedule and cost projections will not compromise the quality of products delivered under the terms of this Contract. Any conflicts that may arise as a result of this provision shall be brought to the Authority's attention by the Contractor's Quality Assurance designee and shall be resolved to the Authority's satisfaction prior to the shipment of affected items. The management responsibility for the quality assurance function shall be set forth in the Contractor's policy statement and organization chart and shall be independent of the production function.

The quality assurance program shall provide the following activities consistent with the Contractor's Scope of Work as defined in the Contract.

1.7.3.1 Design Control

Provide written procedures for the following:

A. Control of design inputs and changes thereto, to assure that Specification design requirements are correctly translated into the drawings and specifications used for procurement, manufacturing, and testing.

B. Establishment of procurement and performance specifications. Purchased materials shall be inspected by the Contractor to verify compliance with performance criteria and this Specification. Incoming inspection records shall be available to the Authority upon request.

C. Establishment of procedures for transmission of quality requirements and standards to manufacturers, subcontractors and suppliers and assurance of their compliance.

D. Establishment and maintenance of objective evidence of compliance with all of the requirements of the Contractor's procurement specifications and design control procedures.

1.7.3.2 Materials Control

Provide written procedures for the following:

A. Control of purchased material, equipment, and services to insure that they will be integrated to produce a quality product. This shall include qualification and acceptance of suppliers of products and materials or specialized services, such as equipment vendors, specialty subcontractors and testing laboratories.

B. Control of materials during storage and handling by the Contractor to prevent damage, deterioration, or misidentification.

C. Control of materials, parts, components, services and equipment that do not conform to Specification requirements to prevent their inadvertent use or installation. This control shall include documentation, segregation, disposition, and notification of the affected organizations. All non-conforming items shall be submitted to a MRB, as described below, and shall be properly dispositioned to the satisfaction of the Authority.

D. An MRB shall be established by the Contractor for the purpose of determining the disposition of non-conforming material and to investigate and recommend corrective action. The MRB shall consist, as a minimum, of representatives of the Contractor's Quality Control and Engineering groups, and shall be convened as the need to dispose of non-conforming material arises. All

MRB recommendations for rework of nonconforming materials shall be subject to Authority approval. All reworked material shall be inspected by the Contractor and either rejected or certified as conforming. At no time shall nonconforming material be installed for rework or replacement at a later time without exceptional approval of the Authority. The Authority's approval will be required before non-conforming material is redirected into the production flow. As a minimum, the MRB shall issue a monthly report to summarize activities since its last meeting. These reports shall contain a complete listing of parts received and shipped from an area set aside for rejected parts with description of part problems and dispositions.

The Contractor shall submit an MRB plan for approval as part of the Quality Assurance Program Plan outlined in Section 1.7.2.

1.7.3.3 Manufacturing and Process Control

Provide written procedures for the following:

A. Control of manufacturing and production processes shall be accomplished through the use of a manufacturing plan. The Contractor shall submit a complete manufacturing plan as part of the Quality Assurance Program Plan.

   1. This plan shall be compatible with the approved inspection plan and shall be depicted in the format of a product work-flow block diagram showing each significant operation and the related control/hold points for inspections, examinations and tests.

   2. Hold points shall be observed by manufacturing such that in no case will work be hidden from the most convenient form of inspection or test by succeeding assembly. All corrections shall require re-inspection and appropriate testing until the Authority's approval is obtained.

B. Control of the qualification of personnel during all stages of design, procurement, manufacturing, fabrication, and testing.

C. Controls to assure that special processes, including, but not limited to, welding, heat treating, and non-destructive testing are accomplished using personnel and procedures qualified in accordance with industry codes and standards or Specification requirements.

D. Identification, control, and elimination of system conditions adversely affecting product quality through the use of program effectiveness reviews and documented procedures that require evidence of the corrective actions taken to preclude the recurrence of offending conditions.

E. Control of all work instructions, procedures, and their revisions to assure that manufacturing and processes are performed in accordance with Specification requirements.

1.7.3.4 Testing

Provide written procedures for the following:

A. Control of testing programs to assure that all testing performed to demonstrate that systems or components will perform satisfactorily in service, is performed by qualified and experienced personnel in accordance with approved, written test procedures. These procedures shall incorporate acceptance limits defined by industry codes and standards or by this Specification; the more restrictive standard shall take precedence. All test results shall be documented, and submitted to the Authority for review and approval as specified in Section 1.8.

B. Control of inspection and test equipment to assure that it is maintained in serviceable condition and within correct calibration. An effective time and usage cycle calibration or certification system, with primary standards traceable to the National Bureau of Standards, or an approved alternative, shall be maintained. The system shall assure the accuracy of equipment and tools used to support this procurement.

1.7.3.5 Record Keeping

The Contractor shall demonstrate control of records that are required to furnish evidence of activities affecting quality and shall make these records available to the Authority immediately upon request.

An IBM-compatible computer-based file system shall be prepared for the storage and status reporting of Quality Assurance and Quality Control data. These records shall include:

A. Results of examinations
B. Inspection results
C. Test results
D. Process controls
E. Certification of processes and personnel
F. Discrepant material (including disposition)
G. Other quality requirements defined in the Contract.

These records shall be maintained complete at all times during the performance of the Contract. Timed, automated back-up procedures shall be established so that information is protected from inadvertent loss due to potentially harmful electronic interference, power surges, or other disaster. Monthly summaries of file contents shall be supplied and hard copies of documents that certify product compliance to this entire Specification shall also be maintained. Prior to the start of production, the Contractor shall demonstrate the proposed record system using "dummy" data. A full complement of sample reports shall be submitted during the demonstration. *(CDRL 130)* The complete system shall be designed to sort quality records by the following categories:

A. Car system
B. Car number
C. Car type
D. Supplier
E. Open and closing dates
F. Problem identification number
G. Status "open" or "closed."

Additional categories or sorts that are required as a result of the Authority's review shall be included by the Contractor. Reports shall be generated from these various sorts as required by the Authority. A full complement of sample reports shall be submitted to the Authority for approval before the start of production.

Exceptions taken to the quality of vehicle workmanship by both the Contractor's and Authority's inspection representatives shall be posted in a manner convenient to review at or on the affected vehicle. The rejection or approval status of each exception shall be readily determined throughout the vehicle's manufacturing cycle and shall be kept current by the Contractor's inspection force on a routine, daily basis. All rejected work shall be corrected, reinspected, and approved by the Contractor's quality control representative prior to continuing to the next phase of production.

1.7.3.6 Quality Assurance Procedures

Procedures shall be developed in the following areas to assure effective implementation of the quality assurance activities discussed in Sections 1.7.3.1 through 1.7.3.5 and shall become part of the Contractor's Quality Assurance Manual for this Contract:

A. Design Control, including control of all technical documentation

B. Transmission of all design, reliability, maintainability, system safety, and quality assurance requirements to procurement sources

C. Surveillance of subcontractors and suppliers for conformance with all Specification requirements

D. Receiving inspection

E. Production and process control

F. Functional testing

G. Discrepancy control

H. Measuring and test equipment calibration and certification

I. Drawing control

J. Quality assurance records

K. Shipping inspection

L. Selection of qualified procurement sources

M. Evaluation and assessment of subcontractor's quality assurance program

N. Monitoring of subcontractor quality assurance performance

O. Evaluation of procured articles against purchase order and design requirements

P. Feedback of problems and their resolutions to the Contractor's Engineering and Production Departments.

1.7.3.7 Quality Control Functions

1.7.3.7.1 *General*

Inspection and verification of compliance shall be assured by the Contractor at all Contractor and Subcontractor facilities. Further inspection at the Contractor's and Authority's facilities to assess transportation damage to vehicles or equipment shall also be required.

All entities within the Contractor's organization shall enforce the quality assurance program. The Contractor shall employ sufficient staff within a functionally independent management structure to perform effective Quality Control.

The Authority may also make inspections of items, completed or in-progress, with, or in addition to the Contractor's inspection. This shall in no way delete, lessen or take the place of the Contractor's obligation to conduct thorough inspections.

The Contractor's quality control program shall implement written procedures for enforcement of receiving, in-process, source, hold point, first article, final, and retrofit inspections. Enforcement shall assure that products are manufactured correctly, marked with appropriate identification, successfully tested, and packed to preclude damage during shipment. Preparation for shipment of each vehicle shall be confirmed by completed quality control check lists for each shipment. All quality control activities shall be documented with Contractor check lists throughout the production process.

1.7.3.7.2 *Scheduling Inspections*

The Contractor shall give 10 calendar days notice before each shipment of major items to its plant to enable the Authority to inspect components before shipment. The Contractor shall not schedule more than two vendor inspections on the same date without prior approval by the Authority. After notice by the Contractor, the Authority will advise within 5 calendar days whether or not an inspector will inspect the shipment. Work shall follow the Contractor's work plan and not be moved from sites without notice to the Authority. Equipment shall be operational before shipment.

Inspection and testing will not be conducted by the Authority on Saturdays, Sundays, or holidays observed by the Authority, except that specific tests or inspections may be permitted, as agreed. Failure by the Contractor to recognize this restriction will be reason to reject the equipment involved. Inspections will then be rescheduled at the Authority's convenience for normal daytime shifts.

1.7.3.7.3 ***Contractor Provisions for the Authority's Inspection***

The Contractor shall extend to the Authority full cooperation and provide facilities at its plant and final assembly site in accordance with Special Provisions. This shall enable convenient inspection of materials, work, and equipment. This shall include provisions for separate office space, desks, locker facilities, and file cabinets. Copies of all drawings, diagrams, schedules, changes, deviations, and data shall also be furnished. Data shall be enough to enable the Authority to verify design, construction, assembly, installation, workmanship, clearance, tolerance, and functioning of the vehicles.

The Authority's in-plant representatives shall be provided with a heated, cooled, and adequately lighted private office, with convenient access to toilets. A telephone, telefax machine, and copy machine shall be provided within the private office and dedicated to the Authority's use. The Contractor shall provide routine office janitorial services and prompt maintenance of the office equipment whenever required.

The Authority reserves the right to reject all materials and workmanship which do not fully conform to this Specification. Repetitious rejections at either the subcontractors' or Contractor's facilities shall be cause to withdraw the Authority's inspection. In such case, the work in question shall be stopped until a satisfactory corrective action agreement is reached between the Authority and the Contractor.

1.7.3.7.4 ***Levels of Inspection***

The Contractor shall specify 100%, or sampling inspection, for discrete items of work. If sampling plans are proposed, the Contractor shall submit complete details of the plans to the Authority. Sampling procedures which determine Acceptable Quality Levels (AQL) and Average Outgoing Quality Levels (AOQL) shall be performed under ASQC Z1.4, 1993, ANSI/ASQC Z1.9, or other approved plans. | MOD 1

1.7.3.7.5 ***Statistical Quality Control***

Statistical quality control (SQC) methods may be used on a case basis, to accept parts and materials and to evaluate processes. Such methods shall be performed under MIL-STD-105D guidelines. Results shall be documented. A list of parts and material to be inspected by SQC shall be presented to the Authority for approval. *(<u>CDRL 131</u>)*

1.7.3.7.6 ***Inspection Status***

The Contractor shall maintain a system to identify acceptance, rejection, or not-inspected status of materials and components. Inspection status shall be identified by tags and stamps. Materials and components which have been inspected and accepted shall be so marked and stored that they can be readily identified.

1.7.3.7.7 ***Receiving Inspection***

Written procedures shall be implemented to assure items are inspected upon receipt to verify conformance to acceptance criteria of specifications and drawings. All inspections will be performed to Specification drawing and purchase order requirements. Material certifications and test reports shall be retained.

1.7.3.7.8 *First Article Inspections*

A First Article Inspection (FAI) will be performed jointly, by the Authority and the Contractor, on all major equipment such as, but not limited to, traction equipment, brakes, air conditioning equipment, heating and cooling controls, door operators and controls, trucks, couplers, destination signs, lighting, journal bearings, batteries, converters, air compressors, public address equipment, communication equipment, and automatic train control equipment. Equipment shall be shipped from the point of manufacture only after an FAI has been offered and either passed, or waived by the Authority. The Contractor shall provide a minimum of 15 working days notice to the Authority before any FAI.

Prior to each FAI, data that includes the latest drawings, test procedures, specifications, and quality documentation required for adequate checkout of the equipment under inspection; and an indenture list of drawings shall be submitted. *(CDRL 132)* The list of drawings shall be identified by revision and shall be complete to the lowest level replaceable unit. The Contractor shall perform pre-FAIs when it is needed to assure the subcontractor is prepared. The Contractor shall not schedule more than two FAIs on the same day without prior approval by the Authority.

The FAI will evaluate component and system maintainability where possible. The FAI shall establish the quality of workmanship for the balance of like components. The level shall be established jointly by the Authority and the Contractor.

The FAI will not be conducted until the design drawings of the article have been approved. If conditionally approved drawings are used, the Authority's conditions for approval shall be satisfied at the FAI and represented by the inspection article.

FAIs will only be performed on a component built using approved production processes, tooling, and manpower.

FAIs will also be performed on carbody components, including, but not limited to:

A. Side Frames
B. Roof
C. Ends
D. Floor
E. Complete Carbody Structure
F. Plastic Front End
G. Underfloor Equipment Installation
H. Trucks
I. Cab.

The following requirements shall also apply to each FAI:

A. A complete set of approved (or conditionally approved) drawings with the Authority's comments for the item to be inspected shall be available.

B. A copy of the vendor's purchase order with commercial items excluded.

C. Completed inspection forms which controlled and accepted in-process work shall be available.

D. Completed test documents which reflect that unit has passed shall be available.

E. A well-lit work space with the necessary inspection and handling aids.

F. The inspection article shall be displayed on a stand or table.

G. Tools and labor to take mechanical or electrical measurements shall be provided.

H. Tools and labor for disassembly and removal of covers shall be provided.

I. Functional testing shall be performed.

1.7.3.7.9 *Inspection of Work In-Process*

The Contractor's Quality Assurance Department shall maintain and direct a force of quality control inspectors to verify that the work in its shops is performed in compliance with the approved design drawings and production specifications. Discrepancies in the work shall be recorded, and departments responsible for the work shall be notified of the need for corrections. Repairs and corrections shall be inspected for conformance to drawings and engineering-approved rework instructions, before continuance. Reinspection acceptance status shall be indicated by the Contractor's inspectors by stamp or initials on the original of the discrepancy report. Responsible manufacturing supervision shall be notified of rework that is rejected.

1.7.3.7.10 *Hold Point Inspection*

The Contractor shall establish hold points in the manufacturing process, as part of the inspection and test plan (Section 1.7.2) to provide the most critical form of inspection. Hold points shall be utilized to inspect completed operations or installations. Hold points shall also be used to inspect items that are about to be covered by succeeding assembly operations. Nonconforming products shall not be released from a hold point area until all discrepancies have been corrected. The Contractor shall use inspection forms to record the list of discrepancies noted. The inspection forms shall be posted at or near the point of inspection for each vehicle and included with the Car History Book when all discrepancies have been eliminated.

1.7.3.7.11 *Source Inspection*

The Contractor shall provide for inspection of subcontractor components and materials at Subcontractor plants.

Once a component has been approved at FAI, the subcontractor may begin shipment to the Contractor's facility. Source inspections shall be scheduled prior to each shipment. The Contractor shall notify the Authority 5 working days in advance of any shipment to allow the Authority adequate time to make travel arrangements. Equipment to be source inspected includes, but is not limited to, the following:

A. Couplers
B. Door Operators and Controls
C. Journal Bearings
D. Propulsion Apparatus
E. Brake Equipment
F. Seats
G. Air Conditioning Equipment
H. Light Fixtures
I. Truck Frame and Truck Bolster
J. Wheels, Axles and Mounting
K. Heating Equipment
L. Communications Equipment
M. ATC Equipment
N. Destination Signs
O. Converters
P. Inverters
Q. Batteries.

1.7.3.7.12 *Final Inspections*

The Contractor shall schedule one day for the Authority's inspection of each car before each shipment. The Contractor shall perform final inspection to written procedures prior to the Authority's inspection. Workmanship items covered by prior inspection reports shall be corrected before final inspection begins.

The Contractor shall provide a qualified supervisor to accompany the Authority during final inspection to assure that proper corrective action is taken. The Contractor shall provide labor and appropriate tools to remove or open and reapply covers and doors. During final inspection, all systems shall be operational.

1.7.3.7.13 *Retrofit Inspection*

The Contractor shall provide written procedure to inspect retrofits or changes made to vehicles on the Authority's property. When a retrofit or change is made by the Contractor, it shall be to the entire fleet, or on an effective car basis, if approved by the Authority. Quality Control shall verify and document completion status of changes. Completed changes and retrofits shall be 100 percent inspected by the Contractor's quality control representative. Records of completed changes and retrofits and associated inspections shall be made available to the Authority.

1.7.4 <u>Quality Assurance Audits</u>

1.7.4.1 General

The Authority will audit the Contractor's quality assurance and quality control activities to determine compliance with the approved Quality Assurance Program Plan. The audit will be conducted to the schedule in Section 1.7.4.2. During the initial audit of the Contractor's quality assurance functions, the Authority will audit the quality assurance programs of subcontractors. The Contractor shall audit the same sub-contractors according to the referenced schedule. Audits shall be performed to approved checklists by personnel other than those who performed the work. *(<u>CDRL 133</u>)*

The Authority will notify the Contractor of noncompliance found during audits. The Contractor shall correct noncompliance promptly and request approval by the Authority. Noncompliance with any part of the approved Quality Assurance Program Plan shall be cause for rejection of Contract work. If the Contractor is responsible, work on the Contract shall be rejected. If a subcontractor is responsible, work by that subcontractor shall be rejected.

After corrective action of the noncompliance has been verified, the Contractor will be notified; Contract work may be resumed. Schedule delays caused by non-compliance with the approved Quality Assurance Program Plan shall not justify an extension of time under the Contract.

Audits shall report on the degree of compliance with approved quality assurance procedures listed in Section 1.7.3.6.

1.7.4.2 Audits of the Contractor

The Authority will audit the Contractor's quality assurance program at the following times:

A. Before production of the first carbody.

B. One month before the Authority's acceptance of the first married pair.

C. Any time the Authority determines an audit to be appropriate.

1.7.4.3 Contractor Audits of Manufacturers

The Contractor shall audit subcontractors according to the following schedule:

A. As a condition of the subcontract or purchase order before the start of work
B. Within one month before the Contractor's acceptance of the first article inspection, or of supplied items and services.

Audits of the manufacturers, subcontractors, and suppliers may be witnessed by the Authority. The Contractor shall provide a minimum 3-week notice to the Authority of planned subcontractor audits under "B" above.

1.7.4.4 Audit Reports

Audit reports shall be submitted as follows:

A. Following each audit, the Authority will furnish the Contractor with a report of the audit describing the scope of the audit and identifying deficiencies, corrective actions, and date when corrective action for each deficiency is required.
B. The Contractor shall prepare a similar report for submittal to the Authority for each audit of manufacturers, subcontractors, and suppliers
C. The Contractor shall submit a formal written response to the Authority within 10 working days following the receipt of each audit report. The response shall request approval for the proposed methods and timetables to achieve compliance with the recommended corrective action.

1.8 TESTS AND ADJUSTMENTS

1.8.1 General

The complete car and its apparatus shall be subjected to a comprehensive test program to substantiate the design and performance requirements, and to determine compliance with reliability and maintainability requirements. Test plans, procedures, and reports shall meet the requirements of Section 1.8.2 and are subject to review and approval by the Authority. Design qualification, factory acceptance, and on-site acceptance testing on all items is required. Exhibit 1-4 is a reference listing of tests required throughout the Specification that must be performed by the Contractor (reference each section for specific requirements). The tests specified herein are considered to be an absolute minimum by the Authority, except that in lieu of performing certain tests, the Contractor may submit certified test results for approval by the Authority on a case-by-case basis. Approval will be based on service-proven history of the equipment with similar application and test requirements. The Contractor shall be responsible for assuring that each design and performance requirement of this Specification is assigned to a specific test effort.

The Contractor and its subcontractors may, at their option, perform additional testing as they deem necessary as part of the required Quality Assurance Program (see Section 1.7). Unless indicated otherwise in the following paragraphs, all costs associated with any of the tests performed are to be borne by the Contractor. In the event of failure to meet the Specification requirements in any test, necessary correction shall be made by the Contractor, and the test re-run in its entirety at the Contractor's expense, upon the option of the Authority. 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 Specification requirements.

The Authority will, at its option, witness all tests. The Contractor shall give at least two weeks notice to the Authority prior to the start of any test.

The Authority reserves the right to make, at its own expense, additional operating tests of each pair of cars separately, or in trains of up to eight cars, to verify acceptability of the cars within 30 days after completion of Contractor on-site acceptance testing and prior to acceptance of each car. The Contractor may be required to participate in, and to furnish technical assistance for, such tests. If so, the Contractor will be compensated for this participation and assistance.

Exhibit 1-4 – Design Qualification, Factory Acceptance, and On-Site Acceptance Tests Requirements Reference List

Key: DQT = Design Qualification Test; FAT = Factory Acceptance Test; OAT = On-site Acceptance Test

System	Required Test	Reference Section(s)	Type Test
ATC	Daily Safety Test	11.2.1.2.5	OAT
	Development Tests	11.4.2.1	FAT
	Compatibility Tests	11.4.2.2	FAT
	Qualification Tests	11.4.2.3 11.4.3.3	DQT
	System Test	11.4.4.2	OAT
	Static Test	11.4.5 11.4.5.2	OAT
	Dynamic Test	11.4.5 11.4.5.3	OAT
	Qualification Demonstrations	11.4.6	OAT
Auxiliaries	Auxiliary Circuit Functional Test	9.7.1	OAT
Carbody	Watertightness Test	3.15.1	DQT
	Carbody Compression Test	3.15.2	DQT
	Vertical Load Test	3.15.2	DQT
	Floor Assembly Fire Resistance Test	15.25.4	DQT
Communications	Factory Acceptance	13.9.1	FAT
	Installation Test	13.9.2	OAT
	Qualification Test	13.9.3	OAT
Couplers	Functional	1.8.4.2	FAT
	Coupler Anchor Compression Test	3.15.2	DQT
Doors	Functional	6.8	OAT
Friction Brakes	Performance Test	10.1.2, 10.5, 10.6, 10.8	OAT
	Slip-slide Test	10.5.3	OAT
	Brake Rate Characteristics Test	10.8.29.1	DQT
	Brake System Functional Test	10.8.29.3	FAT
	Brake System Performance Test	10.8.29.2	DQT
	Hand Brake Test	10.8.29.4	DQT
	Brake Unit Fatigue Test	10.8.30	DQT
	Brake Endurance Test	10.8.31	DQT
	System Capacity Test	10.8.32	DQT
	Pressure Test	10.8.33	DQT
	Filter Dryer Test	10.10.4	DQT
	Load Weigh Test	10.11	FAT
HVAC	Air Conditioner Qualification Test	7.8.1.1	DQT
	Air Conditioner Functional Test	7.8.1.2	OAT
	Air Diffuser Test	7.8.1.3	DQT
	Heating System Qualification Test	7.8.2.1	DQT
	Heat Transfer Test	7.8.2.2	DQT
	Heating System Functional Test	7.8.2.3	OAT
	Defroster Test	7.8.2.4	OAT

Exhibit 1-4 – Design Qualification, Factory Acceptance, and On-Site Acceptance Tests Requirements Reference List (Continued)

Key: DQT = Design Qualification Test; FAT = Factory Acceptance Test; OAT = On-site Acceptance Test

System	Required Test	Reference Section(s)	Type Test
Lighting	Light Intensity	8.1.2	OAT
	Beam Characteristics	8.2.1	OAT
Miscellaneous Electrical	Functional	1.8.4.2	FAT
	Battery Capacity Test	1.8.4.2	FAT
	Battery Functional Test	1.8.4.4	OAT
	Converter Type Test	9.4.3	FAT
	Third Rail Shoe Functional Test	9.8.1	OAT
Propulsion	Performance Test	10.1.4, 10.1.6	OAT
	Traction Motor Type Test	10.3.5	FAT
	VPI Verification Test	10.3.6	FAT
	Prototype EMI Test	10.7.2	DQT
	Prototype Performance Test	10.7.2	DQT
	Propulsion System Test	10.7.3	DQT
Trucks	Static Load Test	14.11.1	DQT
	Overload Test	14.11.2	DQT
	Fatigue Test	14.11.3	DQT
	Primary Suspension Test	14.11.4	DQT
	Equalization	14.11.5	OAT
	Stability Test	14.11.6	OAT
	Ride Quality Test	14.11.7	OAT
Vehicle Monitoring System	Functional	12.6	OAT
Vehicle	Weight Test	1.8.4.1	FAT
	Ground Insulation Test	1.8.4.3	FAT
	High Potential Test	1.8.4.3	FAT
	Wiring Continuity Test	1.8.4.3	FAT
	Trainline Test	1.8.4.5	OAT
	Car Compatibility Test	1.8.4.6	OAT
	Electromagnetic Compatibility Test	1.8.4.7	OAT
	Car Performance Test	10.1.4.1	OAT
	Train Resistance Test	10.1.4.1	OAT
	Drift Test	10.1.4.2	OAT
	Return Current Measurement Test	10.1.6	DQT
	Equipment Noise Test - Pre-Installation	16.2.1	DQT
	Equipment Noise Test - Post-Installation	16.2.2	OAT
	Car Interior Noise Levels	16.2.4	OAT
	Door Operation Noise	16.2.5	OAT
	Car Body Sound Insulation	16.2.6	OAT
	Miscellaneous Equipment	16.2.7	OAT
	Car Exterior Noise Levels	16.2.8	OAT
	Auxiliary Equipment	16.2.9	OAT
	Noise Test	16.4.1	OAT
	Vibration Tests	16.4.2	OAT

1.8.2 Test Documentation

1.8.2.1 Master Test Plan

The Contractor shall submit to the Authority, for approval, a Master Test Plan covering all tests and adjustments in this Specification. *(CDRL 134)* The Test Plan shall identify all tests by reference to the appropriate Section of this Specification. The Test Plan shall contain a detailed schedule showing the time and place of each test to be performed. The Test Plan shall cover all supplier and subcontractor tests to be completed at the suppliers or subcontractors plants, all Contractor's tests to be completed at its plant prior to delivery, and all testing to be conducted by the Contractor on the Authority's property prior to acceptance.

1.8.2.2 Test Procedures

The Contractor shall prepare a test procedure for each test identified in the Master Test Plan, Section 1.8.2.1. Each test procedure shall, as a minimum, include the items shown in Exhibit 1-5, Test Procedure Requirements. The Contractor shall submit test procedures at least 60 days in advance of the test commencement date. Test procedures shall be approved by the Authority prior to conducting any test. *(CDRL 135)*

A. Format. The Contractor shall use Exhibit 1-5 as a guide to develop a standardized format for all test procedures and data sheets. The Contractor's standard test procedures shall provide for all information and data required in Exhibit 1-5.

B. Data Sheets. The test procedure shall contain data sheets to record test results, which shall be included in the test report after successful completion of the test. The minimum requirements for the data sheets are as follows:

   1. The data sheet shall have checklist items such as YES/NO or √/X to indicate PASS/FAIL, in accordance with the criteria specified by the Contractor, to demonstrate compliance with the Specification requirements for each item tested or verified.

   2. Each step number in the test procedure sequence shall have one-to-one correspondence with the step numbers in the data sheet.

   3. The data sheet shall include a step-by-step format for data reduction, formulae used for calculations, acceptance criteria, and justification for the criteria set forth.

C. Test Certification Sheet. A Test Certification Sheet shall be provided, as illustrated in Exhibit 1-5, to certify that the test conducted has been witnessed by the Contractor/Subcontractor's quality control representative and the data reviewed by the appropriate test department representative before submittal to the Authority for approval. The Authority may also elect to have its quality assurance representative witness the test, which shall not constitute the Authority's approval.

Exhibit 1-5 – Test Procedure Requirements

"COVER PAGE"

Test Procedure *No. ST-PS-001* (1)	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 1 of X**	*Rev. B* / *Approved 5/1/99*

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
5000 SERIES RAPID TRANSIT CARS

CONTRACT XXX.XXX

TEST PROCEDURE

PROPULSION SYSTEM TEST

Specification Section Reference
Technical Provisions xx.xx

Prepared by ________________________(2)__________________________

(signature)

____
(printed name and title)

____
(date)

Reviewed/Approved by ________(3)_________________________________
(signature)

____
(printed name and title)

____
(date)

Note (1): Procedure numbers shall uniquely identify test type (e.g., factory acceptance, qualification, field acceptance), system, and sequence number.

Note (2): First line for signature, second line for printed or typed name and title, third line for date.

Note (3): Contractor approval; line entries same as in Note (2).

Exhibit 1-5 – Test Procedure Requirements (Continued)

"REVISION PAGE"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 2 of X**	*Rev. B* / *Approved 5/1/99*

Rev. Level	**Description of Modification**	**Date Approved**
	Provide a description of the modifications (additions, corrections, etc.) made. For example:	
A	*Basic/initial version.*	*4/3/99*
B	*Microprocessor software modification, Sections 1, 3, 5 affected in this procedure.*	*5/1/99*

"TABLE OF CONTENTS"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 3 of X**	*Rev. B* / *Approved 5/1/99*

Each section of the test procedure shall be listed by section number, description, and page number in the table of contents.

Exhibit 1-5 – Test Procedure Requirements (Continued)

"INSTRUCTIONS"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 4 of X**	*Rev. B*
			Approved 5/1/99

1. OBJECTIVE:

Provide a concise statement of the reason for conducting the test.

2. PREREQUISITE TESTS:

Clearly state the title(s) and procedure numbers of prerequisite test(s) needed to be performed and provide a means to identify that they were successfully completed as prerequisites. This shall include requirements for periodic calibration checks/recalibration.

3. TEST DOCUMENTATION REQUIRED:

List all documentation required to perform the test by name, document number and revision level. For example: schematics, wiring diagrams, configuration control lists, etc.

4. TEST EQUIPMENT REQUIRED:

All required test equipment including model numbers, if applicable, shall be clearly specified in this section. All test equipment including sensors and transducers shall be calibrated before testing commences and certificates for the same shall be enclosed with the test data sheets. Provide space for witness certification of valid current calibration.

5. TEST EQUIPMENT SETUP:

Clearly describe, with the aid of drawings or sketches, all necessary arrangements and the setup necessary for conducting the test, including physical location of instrumentation, the connections for wires, harnesses, sensors and firmware. Any requirements for periodic recalibration or calibration checks during the test shall be highlighted in this section.

6. PERSONNEL:

Clearly identify any special assistance or support needed from the Authority, including engineering, operation and maintenance personnel.

Exhibit 1-5 – Test Procedure Requirements (Continued)

"INSTRUCTIONS (Continued)"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 5 of X**	*Rev. B*
			Approved 5/1/99

7. TEST FACILITY:

Clearly identify where the testing shall be conducted (e.g., Contractor/Subcontractor's facility, Authority's facility, or any other facility). If the Contractor requires a certain part of the Authority's test track and/or facilities to conduct testing, the Contractor shall clearly indicate the requirements in this section.

8. TEST SEQUENCE:

Describe all the steps that must be taken to safely and satisfactorily conduct the test, including any precautions, specific placement of personnel to witness results, etc. The test sequence shall be written in a step-by-step format. Data sheets shall be attached to the test report described in Section 1.8.2.2.

9. TEST NOTES:

Record failures, substitutions, and other pertinent notes to document problems encountered and observations made during testing that may facilitate troubleshooting in the future.

10. ACTION TAKEN:

Use this section to record action taken on any discrepancy.

Exhibit 1-5 – Test Procedure Requirements (Continued)

"DATA SHEET"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 6 of X**	*Rev. B*
			Approved 5/1/99

The results of each test step, as required, shall be recorded in checklist form. The data sheet shall include the applicable test procedure number, test step, parameter measured and pass/fail criteria, and a column to indicate the results of each required test step.

Exhibit 1-5 – Test Procedure Requirements (Continued)

"TEST CERTIFICATION SHEET"

Test Procedure *No. ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 7 of X**	*Rev. B* / *Approved 5/1/99*

Assembly Part No.: ______________________________

Assembly/Car S/N: ______________________________

Test Data Reviewed By: ______________________________

Results: ______________________________
(Pass/Fail)

Remarks:

Signature: ______________________________

Date: ______________________________

Conducted By: ______________________________
(printed name and title of Test Department's representative)

____
(signature)

____
(date)

Witnessed By: ______________________________
(printed name and title of QC Department's representative)

____
(signature)

Witnessed By: ______________________________
(printed name and title of Authority's QA representative)

____
(signature)

1.8.2.3 Reports

The Contractor shall provide a written report of each test, including test data sheets. Upon test completion, the Contractor shall submit this written report to the Authority for review and approval. *(CDRL 136)* In the case of tests that are performed on all cars, or all components, the reports of those tests shall be included in the appropriate car history book. In every case, the report shall include a description of the test, all raw data collected during the test, and a summary of the results in a form that can be directly compared with the Specification without further calculations.

A. Test Charts and Recordings. Copies of all test recordings and charts shall be attached to the data sheets.

B. Electronic Data Storage. If an electronic copy is prepared using a laptop computer or a tape recorder, the test procedure shall clearly describe the instrumentation used for recording, including the model number. The Contractor shall also describe the process of retrieving data and tools needed. For example, any specific software, information about the product, manufacturer, and software version shall be included. In case tapes are used, the Contractor shall include information about the type of tapes used, tape running speed used for recording and retrieval, and at least two equivalent tape types.

1.8.2.4 Status Log

The Contractor shall use Exhibit 1-6, Sample Test Status Log, as a guide in preparing and maintaining a running status of all test procedures. *(CDRL 137)* The Status Log shall include as a minimum the data fields shown in Exhibit 1-6 for each test procedure.

The database/matrix shall be updated and clear copies provided to the Authority on a monthly basis after submission of the first test procedure for approval.

1.8.3 Authority Facilities for Testing

The Authority will make available to the Contractor a track of adequate length to permit the Contractor to conduct the tests required to be conducted on the Authority's tracks. The Authority will also provide, for Contractor preparation and repair of cars undergoing acceptance testing, indoor pits sufficient for one married pair of cars; jacks able to lift one married pair of cars for exchange of equipment; personnel to operate the cars and other Authority-owned equipment (e.g., jacks); storage tracks for six married pairs of cars; at least 1,000 square feet of office and storage space; and, at the pits assigned to the Contractor, 700-volt DC, 110-volt, single phase AC, and 460-volt, 3-phase AC power.

Except as may be prohibited by equipment failure or emergency situation, track to support the conduct of qualification and acceptance tests on two train simultaneously will be available to the Contractor from 01:00 AM to 04:30 AM. on weekdays and from 01:00 AM to 07:00 AM on Saturdays and Sundays, exclusive of holidays observed by the Authority.

Other facilities and personnel will be available to the Contractor for a maximum of 16 hours a day and 5 days a week, exclusive of Saturdays, Sundays, and holidays observed by the Authority; except that personnel and facilities will be made available upon request during those hours when qualification and/or acceptance tests are conducted on Saturdays or Sundays.

Exhibit 1-6 – Sample Test Status Log

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

5000 SERIES RAPID TRANSIT CARS
CONTRACT NO. XXX.XX

(1)			(2)						(3)
Test Type	**Test Name**	**Proce-dure No.**	**Rev. Level**	**Status**	**Con-tractor's Letter No.**	**Date Sub-mitted**	**WMATA Letter No.**	**Disposi-tion Date**	**Remarks**
ST	*Propul-sion System Test*	*ST-PS-001*	*B*	Approved					
ST	*Friction Brake Test*	*ST-FB-002*	*C*	Condition-ally Approved					

NOTE (1): Information rows shall be sorted by test type (e.g., system test), system name, and procedure number, in this order; Columns 1 through 3.

NOTE (2): Columns 4 through 7 respectively shall identify procedure revision level, approval status and Contractor's submittal correspondence. Columns 8 and 9 shall identify latest WMATA correspondence and date approved/disapproved.

NOTE (3): Insert remarks in Column 10 as appropriate. Include identity of latest approved version and date if revision level being reported in Column 4 has not been acted on by the Authority.

1.8.4 Miscellaneous Vehicle Tests

In addition to other tests required elsewhere in this Specification, the following vehicle tests shall be performed by the Contractor.

1.8.4.1 Weight Test

The Contractor shall weigh each car at the time of shipment. The weight of each end of the car shall be provided separately. In addition, both trucks of the first car, and of another car approximately three-fourths through the production, shall be weighed separately. A weighing device which provides a permanent record of the weight to the nearest hundred pounds shall be used, and the weight tickets therefrom shall be submitted to the Authority and copies thereof included in the car history book. The weighing device shall be maintained within a tolerance of two-tenths (2/10) of 1%. If the weighing device is electronic, it shall be calibrated at intervals of no more than 60 days. If mechanical, it shall be calibrated immediately prior to weighing the first car and annually thereafter. The car weighing procedure, including a description of the equipment to be used, shall be submitted for approval before the first car is weighed. *(CDRL 138)*

1.8.4.2 Miscellaneous Apparatus Tests

Each component that is separately assembled, housed, and wired into a package unit prior to installation in the car shall be tested at its point of manufacture and a certified test report signed by the responsible Quality Assurance representative of the manufacturer, furnished to the Authority. Tests shall be in accordance with IEEE Standards No. 11 and No. 112 for rotating machinery and No. 16 for control apparatus; batteries shall be given a capacity test at the point of manufacture in accordance with the AAR Mechanical Division Manual of Standards, Section F-304.

1.8.4.3 Car Wiring Tests

When all car wiring is complete, the Contractor shall perform the following tests on each car:

A. "Ring out" all circuits to verify continuity, proper polarity, and proper connections.

B. Make a Direct Current ground insulation test on each pair of cars by measuring, separately, current flow to ground of each side of the battery circuit and of the 700-volt circuit. This test shall be made on the Authority's property, immediately prior to car acceptance. This test shall also be made at the Contractor's plant prior to shipment, but this will not supersede the test immediately prior to acceptance. This test must demonstrate compliance with the requirements of Section 15.18.

C. Make a high-potential ground insulation test in accordance with IEEE Standards No. 11 for power circuits and No. 16 for control circuits.

The Contractor may request permission to disconnect certain components liable to be damaged or which, if not disconnected, would render the result invalid, under any of the above tests.

1.8.4.4 Acceptance Testing

Acceptance tests shall be performed in all modes, speeds, and ATC configurations. The signals to be monitored during the acceptance testing shall be identical to those required in Section 10.1.4.1. The signals specified shall be recorded simultaneously for each car.

A. The Contractor shall perform an acceptance test of each married pair of cars upon delivery to the Authority property. This testing shall include ground insulation tests as required in Section 1.8.4.3, functional testing of all apparatus and controls, field test of all Communications Systems as required in Section 13.9, and static tests of the ATC equipment to demonstrate compliance with the requirements of Section 11.

B. In addition, acceptance tests are to be performed by the Contractor on each pair of cars with the cars empty to demonstrate compliance with the requirements of Sections 10.1, 10.5 and 10.8 during operation of the cars on the Authority property on track as designated by the Authority. These tests are to be run with the cars instrumented to monitor all of the parameters measured during its performance tests in Section 10.1.4. The relationship between performance characteristics of empty and loaded cars shall be developed based on the performance tests run in Section 10.1.4 and shall be used to evaluate the performance of all two-car units tested without load.

Upon successful completion of the preceding acceptance tests, and up to 30 days of additional testing by the Authority as described in Section 1.8.1, and after correction of all known defects by the Contractor, the cars will be accepted by the Authority.

1.8.4.5 Trainline Tests

A. The Contractor shall verify the accuracy of the car's trainline connections by the use of a test panel which is connected to the coupler's electric head and indicates, by the illumination of lights or other appropriate means, that the proper trainline wires are energized when the various car control such as master controller, door controller, and P.A. systems, are operated. This test shall be made on each two-car unit, at both ends.

B. One pair of cars shall be tested with another pair of cars furnished under this contract to demonstrate that all trainline functions perform satisfactorily from control cabs at each end of each pair of cars when "F" ends of cars are coupled together in an A Car-to-A Car, B Car-to-B Car, and A Car-to-B Car configuration. This test shall be performed at the Contractor's facility prior to delivery of the first two pairs of cars. Any modifications required as a result of these tests shall be incorporated in all cars prior to delivery.

1.8.4.6 Car Compatibility Tests

The qualification test program shall also include complete functional tests of the first four pairs delivered to the Authority's property. These tests shall demonstrate the successful operation of the new cars in conjunction both with the wayside and with the Authority's existing cars. Note that the Authority's tracks will permit pairs to be turned at certain yards

1.8.4.7 Electromagnetic Compatibility Test

One pair of cars shall be tested by the methods referenced in Section 1.4.5 for compliance with the requirements and for compatibility with the Authority's power distribution and train control, signal, and communication systems. The test shall be conducted on the Authority's tracks.

1.9 RELIABILITY

1.9.1 Definitions

A. <u>Reliability</u>. The probability of performing a specified function without failure and within design parameters, for the period of operation intended, under actual operating conditions.

B. <u>Fleet</u>. All cars furnished under the terms of this contract.

C. <u>Test Fleet</u>. All cars being monitored by the Reliability Program.

D. <u>Failure</u>. Any malfunction which requires unscheduled equipment maintenance, repair, or replacement.

E. Mileage, Operating. The operating mileage of a car is the total distance traveled by the car during scheduled and non-scheduled movements over established routes as recorded by the Authority.

F. System. Any group of functionally-interrelated equipment which performs in concert to produce control of a particular function relating to the performance of the car. The components of a system are dependent on the function of the apparatus as it performs on the car, and may be furnished by one or more suppliers.

G. Components and Subsystems. Any individual assembly, plug-in module, or component which is designed to perform a particular function relating to the operation of a system such as a traction motor, gear box, door control panel, or friction brake control unit. For the purpose of reliability testing, a component or subsystem shall be considered as a component of a system which may require costly repairs or which, if inoperative, will render the car unusable.

H. Primary Failure. A failure that occurs without being related to the failure of associated items.

I. Secondary Failure. A failure of a component which is a direct result of a primary failure of an associated component or system which can be specifically identified as having been the cause of the failure. Secondary failures are not chargeable failures unless it is determined that protective elements integral to the apparatus in which the secondary failure occurred should have been provided or that such provisions were ineffective.

J. Simultaneous Failures. Multiple primary failures that independently prevent satisfactory equipment performance. Each shall be counted as a chargeable failure.

K. Chargeable Failure. A chargeable failure of an item is a failure which results in a loss of function of that item including:

1. A fault of an item while operating within its design and environmental specification limits.

2. Faults caused by improper operation, maintenance, or testing of the item as a result of contractor-supplied documentation.

3. Item degradation discovered during the recommended preventive maintenance interval which causes the loss of function or near loss of function of that item (excluding consumable items). Note: Due to the subjective nature of classifying such instances, the discrepant item(s), upon the Contractor's request, shall be retained for review on the Authority's property for a period not to exceed two weeks.

4. Consumable items requiring replacement for reasons other than normal fleet wear/aging.

L. Non-Chargeable Failure. A failure or condition of an item due to the following:

1. A failure caused by specifically identified failure in other equipment.

2. A failure caused by human error except where due to inadequate or improper Contractor documentation.

3. A failure caused by Authority personnel not complying with Contractor documentation which has been accepted and approved by the Authority.

4. A failure caused by accidents not associated with the normal operation of the item, such as collision or striking a foreign object on the right of way.

5. A failure caused by operating the item outside of design or environmental specification limits.

6. Consumable items requiring replacement during specified preventive maintenance or which should have been replaced during a previously scheduled preventive maintenance interval and were not.

7. A failure which is a recurrence of one that was thought to have been corrected. (The first failure shall be classified as chargeable, but not the recurring one, if the failure occurs within 500 miles of the initial failure.)

M. Indeterminable Failure. A failure or condition of an item not included in the definitions of chargeable and non-chargeable failures, such as:

1. Reported failures for which, upon review, insufficient or inadequate documentation is obtainable to permit classification.

2. A fault indication for which, upon review, no cause can be determined.

Failures classified as indeterminable shall be held for review and disposition by the Authority. All reported failures shall be classified as chargeable or non-chargeable by the conclusion of testing.

N. Failures per Million Miles (FPMM). The FPMM of an item is the ratio of the total number of chargeable failures to the total mileage, in millions, of the test cars. The test cars' mileage shall be determined by multiplying the average per-car mileage of the cars accepted under the Contract and released for revenue service by the average number of cars in the test fleet.

1.9.2 General Requirements

The Contractor shall make every effort to design and construct all equipment furnished under this contract to provide failure-free operation. The reliability failures shall not exceed the values allowed by Exhibit 1-7. The Contractor shall assume that the overall level of maintenance shall be comparable to the periodic maintenance required for the Authority's existing AC propulsion cars as described in the Authority's Heavy Repair Manual, Chapter 15.

1.9.3 Operating Parameters

To establish design parameters, the following values are assumed (these design parameters shall not be considered as limits; the Authority will utilize cars to the extent required by service demands):

A. Average annual operating mileage of 65,000 miles per car.

B. Cars may be operated in trains of 2 to 8 cars and be utilized 6 days per week, operating between the hours of 5:00 AM and 1:00 AM.

C. Cars will be in service a minimum of 300 days per year during the prescribed hours.

D. Apparatus that is not de-energized when the console control lock is turned off will be left on during standby or layover periods. Such apparatus is to be designed for continuous operation, which is defined as operation 24 hours per day, 365 days per year.

1.9.4 System Failure Limit Requirements

The Maximum Allowable Failures per Million Miles for each of the systems, subsystems and/or components is shown in Exhibit 1-7. These values assume both the mileage accumulated and the number of failures counted are used to calculate reliability, and satisfy the requirements defined in Section 1.9.5.

Exhibit 1-7 – System Reliability Requirements in Failures per Million Miles (FPMM)

System/ Subsystem	Maximum Allowable Failures Per Million Miles
Propulsion	30
Brake	18
Door	6
Coupler	2
Communications	6
ATC	8
Auxiliary Power	2
700 Volt Power	2
Heating Ventilation and Air Conditioning	13
Destination Signs/Graphics	4
Lighting	2
Truck	3
Traction Motor	1.5
Propulsion Logic	6
HVAC Control	6.4
Friction Brake Controls	9
Friction Brake Pneumatic/Hydraulic System	9
Converter	2
Radio	4
ATP	4
ATO	4
ATS	4
Door Operator	2
Door Control	4

Note: For car components and systems not covered in Exhibit 1-7, the failure rate in a 12 consecutive month period shall not exceed 10% of the population of that component or system. The assignment of components shared by two or more systems will be determined by the Authority.

1.9.5 Reliability Tests

To demonstrate that the failure limits of the equipment meet or exceed specification requirements, a reliability test program shall be carried out on all accepted cars.

Failure data from the Authority maintenance tracking database will be compiled by the Authority. The Contractor will be provided with a list of the chargeable failures against this reliability test monthly for the previous month. Failed parts will, to the extent possible, be made available for inspection by the Contractor. In addition, a monthly report will be provided listing the failure rate in failures per million miles for each of the systems under test. This report will cover the most recent nine-month period. After nine months, the report will be a rolling nine-month report with the oldest month being dropped and the new month added. This report will be used for the reliability assessment.

1.9.6 Reliability Assessment

At 10 months, 22 months and 34 months, the Authority shall produce a formal reliability assessment of the cars based on the failure data accumulated in the monthly reports. It shall include the Authority's evaluation of the performance of each system.

Within 60 days after the receipt of this report, the Contractor shall provide a formal reliability assessment response report *(CDRL 139)*, which at a minimum shall include specific discussions of the following:

A. A discussion of the predominant failure modes of those systems exceeding the allowable goal.

B. An assessment of the data provided, if the Contractor disagrees with the conclusions drawn by the Authority.

C. A complete list, with descriptions, of all modifications already performed, or in progress on each system.

D. Proposals for additional modifications to bring non-compliant systems into compliance.

E. A specific program plan to perform additional studies or modifications if such work is required.

Each car shall be included in the reliability test fleet for a maximum of three years or until the Authority determines that all systems, subsystems, and components listed in Exhibit 1-7 have passed the reliability test according to the criteria listed below. The car shall enter the reliability test group either three months or 10,000 miles after acceptance, whichever is later.

1.9.7 Monitoring Reliability

It shall be the responsibility of the Contractor to closely monitor the failure modes of all of the systems to ensure that the cars will meet the required goals. If at any time during the test, the failure rate of any system exceeds the allowable rate, it shall be the responsibility of the Contractor to seek modifications and changes which will bring the system into compliance.

The Contractor may request that the Authority review the status of any failure charged against reliability for compliance with the guideline of the test. These questions will be resolved in regular meetings between the Contractor and the Authority. Such meetings will be held monthly and may be held more frequently at the request of the Contractor. Problems with claims that cannot be resolved at the meetings shall be referred to the Contracting Officer for final decision.

1.9.7.1 Reliability Test Report

It is the responsibility of the Contractor to submit a monthly reliability test report *(CDRL 140)* to the Authority, summarizing the Reliability Test status. Each report shall contain, but is not limited to, the following information:

A. Analysis of failure modes occurring more than once in the reporting period, including the probable cause of the fault and what is being done by the Contractor to eliminate further failures.

B. A table summarizing the classification of failures recorded during that reporting period. Each failure shall be identified as chargeable, non-chargeable, or indeterminable. All non-chargeable failures shall be accompanied by an explanation as to why it is non-chargeable.

C. A description of the reliability growth modifications being implemented and being planned for implementation. The summary shall show which vehicles have received which modification.

1.9.7.2 Reliability Test Completion

The decision on reliability compliance shall be on a system, subsystem and/or component basis and shall rest with the Authority. A system shall be eligible to be judged as passing the reliability test when it meets the following criteria:

A. All cars have been in reliability test for at least nine consecutive months.

B. The system has been in its final configuration for at least nine months and has achieved the acceptable goal for at least nine consecutive months.

The Contractor shall be responsible for performing any modifications required to bring the vehicle and systems into conformance with these reliability goals. The Contractor's responsibility for these modifications shall include all costs for materials, necessary labor for removal and replacement, and testing associated with the required corrective action. Such action shall be in accordance with the Special Provisions.

At the conclusion of this test, it shall have been demonstrated that each and every system and subsystem is in full compliance with the reliability goals. In the event that the goals are not attained, the Authority will make whatever repairs it deems are necessary, at the Contractor's expense, in order to achieve the reliability goals.

1.10 MAINTAINABILITY REQUIREMENTS

A maintainability analysis for all systems on the car shall be submitted to the Authority. *(<u>CDRL 141</u>)* This analysis shall be the basis for development of maintainability tasks, maintenance procedures, methods, and techniques. This analysis shall establish the maintenance concepts to be incorporated in the design, taking into consideration safety, reliability requirements, accessibility of apparatus for maintenance, and the skills available for performing maintenance tasks. The maintainability analysis shall show all tasks required of each level of maintenance, i.e., 10,000 miles, quarterly, semiannually and annually, the task frequency, the time required, skill levels and the necessary support equipment. The maintainability analysis shall be a continuing effort during design and shall provide data for consideration in the review of the design of each system. The maintainability analysis shall be presented during design reviews and kept up-to-date during design and construction of all cars. Updated maintainability analyses are to be furnished to the Authority every 90 days.

All subsystems and components serviced as part of periodic preventive maintenance shall be readily accessible for service and inspection. Accessibility of components shall be inversely proportional to frequency of maintenance and repair of that component. No active electrical or mechanical components that can possibly require maintenance shall be structurally embedded without convenient access for repair or replacement. In the design of the car, the Contractor shall not require that maintenance be provided more frequently than at 10,000 mile intervals, except where permission has been given by the Authority for a shorter interval. A minimum number of different lubricants shall be required for the car. Different styles or sizes of lubrication fittings shall be used to prevent the inadvertent introduction of the wrong lubricant at any point. Where possible, lubricants for equipment furnished under this Contract shall be the same as those used for equipment on the existing cars.

1.11 SAFETY REQUIREMENTS

1.11.1 <u>System Safety Program Plan</u>

The Contractor shall develop a System Safety Program Plan (SSPP) that defines activities, management controls and monitoring processes to be utilized by the Contractor to ensure that safety considerations, compatible with other system requirements, are incorporated into the design of the vehicle in order to minimize the potential for accidents. *(<u>CDRL 142</u>)*

The SSPP must demonstrate that the Contractor has a clear understanding of the System Safety requirements and has an organization in place that is capable of meeting the requirements and verification thereof through completion of the specified safety analyses.

The SSPP shall be structured in accordance with MIL-STD-882D, Task 102, and shall contain the following information as a minimum:

A. Specific information showing how the Contractor shall verify attainment of system safety requirements during design and test phases.

B. Organizational relationships and personnel responsible for system safety. The Contractor's System Safety Engineer shall report to or have direct access to the Contractor's Program Manager.

C. Detailed listing, description, and schedule of specific tasks.

D. Procedures for the reporting, recording, and resolution of hazards identified during the design, installation, and testing.

E. Schedule indicating key milestones to ensure that system safety activities are performed in a timely manner.

F. Procedures for the Contractor's system safety personnel to review and approve design changes and top-level drawings.

G. Describe the hazard categorization and safety design standards as specified herein.

1.11.2 Safety Analysis

To design for safety entails analyzing the proposed design of systems, subsystems, and lowest level replaceable unit (LLRU). Consideration of the effects of their interfaces and interrelationships with such factors as facilities, support equipment, operational procedures and environments, and maintenance programs should be examined. During the design phase, the safety analyses performed by the Contractor shall accomplish the following:

A. Identify potential hazards and establish appropriate safety criteria

B. Assess the design, based on safety criteria

C. Modify proposed designs to satisfy the criteria, if necessary

D. Demonstrate compliance with the criteria.

All safety analyses identified in this section shall address the interfaces between systems.

1.11.2.1 Preliminary Hazards Analyses

A Preliminary Hazards Analysis (PHA) is a systematic, high-level examination of proposed system elements to identify and classify potential hazards to the overall transit system. A PHA addresses the vulnerability of system functions; it is not an assessment of any particular hardware or software design. A PHA is qualitative and is conducted using experienced engineering judgment. The purpose of the PHA is to develop safety design requirements for the system and establish the framework for subsequent safety analysis. It provides information about potential hazards and assigns hazard severity categories for each.

A PHA *(CDRL 143)* will be prepared by the Contractor during preliminary engineering and approved by the Authority. The Contractor shall perform a PHA on each of the following subsystems: ATC, Propulsion, Brakes, Auxiliary Electric, Communications, Doors, Trucks and Suspension, Coupler and Draft Gear.

In addition to those hazards identified by the Contractor, the following hazards shall be considered Category I or II:

A. Doors open on wrong side of vehicle.

B. Door opens with a vehicle speed greater than 2 mph (setting for zero speed relay) and brakes are not commanded.

C. Door closes on person and indicates door closed and locked.

D. Door interlocks erroneously indicate door is closed and locked.

E. Train moves in wrong direction.

F. Complete loss of friction brakes.

G. Complete loss of dynamic brakes.

H. Loss of friction and dynamic brakes on a truck.

I. Propulsion is not removed when requested.

J. Loss of safety grounds, or other failure, that exposes persons to injurious voltages.

1.11.2.2 Failure Modes and Effects Analyses

A Failure Modes and Effects Analysis (FMEA) is a systematic, comprehensive, bottom-up evaluation that analyzes the effects of potential failures in a subsystem, as installed, from design data. The procedure assesses the impact of these failures on subsystem and system operation, and consequently on the operational safety of the transit system. Based on the PHA, all subsystems that can cause or contribute to Category I or II hazards will require preparation and submittal of an FMEA by the Contractor. *(CDRL 144)* Information provided in the FMEA shall include:

A. A system overview including schematics.

B. A complete list of LLRU that will be analyzed.

C. Identification of single-point failures and hazard-level categorization, which should confirm the adequacy of fail-safe design features.

D. Identification of potential hazards due to significant multiple failure conditions involving latent and undetected failures.

E. Identification of additional analyses, such as fault trees, or design changes that may be required.

F. Documentation of the effect of significant design changes.

The FMEA should be considered a concurrent part of the system design process. The FMEA should be started early in the design effort, even though little design detail is normally available at that time. The FMEA will thus begin at a relatively high level, and will be iteratively expanded and revised as the design progresses. As it is being developed, the FMEA systematically challenges the design by probing the ways the system can fail and assessing the effects of these failures. This provides continuing insights into possible design weaknesses that may warrant modification. Such modifications can then be readily implemented as a natural part of the design development cycle. As the system design progresses through the development phase, and design modifications are made in response to discovered needs, the FMEA is updated to reflect the changed design and is used in the process of evaluating and approving the changes.

1.11.2.3 Operating and Support Hazard Analyses

The purpose of the Operating and Support Hazard Analysis (O&SHA) is to evaluate the adequacy of procedures. The O&SHA examines the potential for hazards introduced by human errors. The analysis is applied to operating and maintenance procedures for critical systems to ensure that unwanted system effects are not caused by operator errors or incorrect maintenance. The O&SHA is carried out in a similar fashion as the FMEA, except that "tasks" and "error modes" are examined instead of "components" and "failure modes."

Each O&SHA should begin with a description of the procedure selected for analysis, and a listing of all the tasks or subtasks within the procedure. Each task is systematically evaluated for potential errors and their effects on the subsystem and transit system. The analysis will identify specific tasks within each procedure that are prone to critical human errors, and make recommendations for reducing or eliminating the chances of those errors.

All operating and maintenance procedures for vehicle subsystems that can cause or contribute to Category I or II hazards shall be analyzed by the Contractor with an O&SHA. Analyses should be performed early in the design process so that results can have a meaningful impact on final designs.

1.11.2.4 Fault Tree Analyses

The Contractor shall perform Fault Tree Analyses (FTAs) to quantify the probability of each Category I and II identified in the Contractor-prepared PHAs and listed in Section 1.11.3.1. The FTAs must consider all interfacing items, which in conjunction with the analyzed system, can lead to the occurrence of the identified hazard.

1.11.3 Hazard Categorization and Safety Design Standards

This section describes the hazard categories and corresponding acceptable probabilities established by the Authority. To establish measures of safety for purposes of certification of vehicles, the Authority has established certain standards that must be met in order for a design to be judged safe.

1.11.3.1 Hazard Categories

All identified vehicle hazards will be categorized into one of four hazard severity levels, as follows:

A. Category I (Catastrophic). Equipment failures, human errors, and/or external circumstances that result in multiple fatalities, destruction of vehicle, or damage to terminal or track segments such that affected segments of the Authority cannot operate for an extended period. Category I hazards will result in what the public would consider a major accident or catastrophe, such as destruction of a train with fatalities. Effective Operator corrective action is not realistically possible. Train operation probably ceases systemwide.

B. Category II (Critical). Equipment failures, human errors, and/or external circumstances that would result in extensive damage to the Authority's equipment, higher workload or physical distress such that the Operators could not be relied upon to perform their tasks accurately or completely, or adverse affects on the traveling public, including passenger injuries. The train or affected fixed facility is in jeopardy unless proper corrective action occurs quickly enough and is effective enough to prevent the condition from progressing to Category I.

C. Category III (Marginal). Equipment failures, human errors, and/or external circumstances that would reduce the capability of the Authority or the ability of the Operators to cope with adverse operating conditions to the extent that there would be, for example, a reduction in safety margins or functional capabilities, nondisabling damage to the Authority' equipment, a significant increase in operator workload or in conditions impairing operator efficiency, or some minor injury, discomfort or danger to the traveling public. Although safety margins may be significantly reduced, for example because of loss of redundancy or forced operation on backup systems, the trains, fixed facilities, or personnel are not in *immediate* danger. A subsequent increase in the hazard requires an additional failure or gross error by the Operators.

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

1.11.3.2 Acceptable Hazard Probability

It is not possible to remove all potential hazards from a transit system, and therefore a means for determining which hazards are acceptable is required. In general, the more severe the hazard, the more unlikely it should be. For the Authority's vehicle, the following requirements have been established:

A. Category I hazards should not be expected to occur during the entire operational life of the vehicle. Assuming that the transit vehicle fleet will accumulate 4,000,000 operating hours over a 35-year operating life, the probability of Category I hazards shall be shown through analysis to be less than 1.0×10^{-9} per car-hour of operation.

B. The probability of Category II hazards shall be shown through analysis to be less than 5.0×10^{-7} per car-hour of operation.

C. Category III hazards shall be resolved using standard fail-safe engineering practices.

D. No mitigating measures are required for Category IV hazards.

1.11.3.3 General Safety Design Criteria

Criteria for system design, for all equipment with safety-critical characteristics, and for operational procedures shall assure that system safety objectives are implemented throughout design development, testing, delivery, operations, and maintenance.

The following criteria shall be incorporated by the contractor as a minimum:

A. Potential or actual hazards identified through analyses shall be mitigated in accordance with the following order of precedence:

1. Design out, or design to minimize, the particular hazard
2. Use of safety devices
3. Use of warning devices
4. Use of special procedures.

B. No single point failure shall result in a Category I or Category II hazard. Multiple, latent, undetected failure modes shall be considered as a single point failure.

C. Vehicle design shall include component interlocks wherever an out-of-sequence operation can cause a Category I or Category II hazard.

D. Emergency equipment for public use shall be clearly identified and accessible.

1.11.4 Fail-Safe Design Requirements

Fail-safe circuits shall be based on closed-loop principles; e.g., broken wires, damaged or dirty contacts, a relay failing to respond when energized, or a loss of power supply energy shall not result in unsafe conditions.

Self-detecting component or system failures shall cause the train to stop or run at a safer, more restricted speed than that permitted with no failure.

Component or system failures which are not self-detecting shall not cause unsafe conditions, even if added to other failures.

Any number of simultaneous component or system failures attributable to the same cause or related causes shall not cause unsafe conditions.

Any component or wire becoming grounded or any combination of such grounds shall not cause unsafe conditions.

The use of microprocessors in vital circuits shall be as approved by the Authority.

Should an alternative for a relay or device specified for vital circuits, as defined by the AAR Manual Part 55, be proposed for a use that is an independent direct item replacement for the relay or device specified, the alternative will be evaluated on the basis of its physical materials and construction, electrical characteristics, circuit analysis, reliability, and other technical data accompanying the submittal. The acceptance of such an alternative does not preclude the requirement for further factory and field tests to determine that the alternate device, in actual operation, complies with the specified fail-safe criteria. Should the alternative device fail to meet the fail-safe criteria, the Contractor shall furnish the specified relay or device to meet the requirements for a vital circuit in the service intended at no increase in cost to the Authority.

Should an alternative be proposed for a specified system, or components thereof, whose function affects the safety of train operation and because of its magnitude and integration parameters precludes absolute fail-safe engineering analysis, the Authority will require definitive factory and field tests and documentation of research and development tests, prior to granting approval of the alternative. The acceptance of such an alternative system subsystem does not preclude the requirement for further factory tests and field tests to determine that the alternate system or subsystem, in actual operation, complies with the fail-safe criteria. Should the alternate system or subsystem fail to meet the fail-safe criteria, the Contractor shall furnish the specified system or component at no increase in cost to the Authority.

Electronic fail-safe circuit design shall provide protection against the following types of component failures:

A. Two-terminal devices: Open, short, partial open, or partial shorts

B. Multi-terminal devices: Any combination of opens, shorts, partial opens, or partial shorts

Any amplifier breaking into spurious oscillations shall not result in an unsafe condition.

Filters used in fail-safe circuits except for code-rate detectors shall be passive and shall be designed to prevent undesired signals from passing through the filter at a level which could cause unsafe conditions even in the event of component failures within the filter. Filters used for code rate detectors shall meet the requirements specified in Section 11.2.

Fail-safe equipment proposed for this contract must be proven by in-service experience or made available for type acceptance testing. Type acceptance testing of components shall consist of bench tests on breadboard or prototype units as directed by the Authority. Type acceptance testing of systems or subsystems shall consist of bench testing of operational systems or subsystems and/or field testing of same at the discretion of and as directed by the Authority. All expenses incurred during type acceptance testing, except for expenses incurred by the Engineer, shall be borne by the Contractor.

1.12 WARRANTY

1.12.1 General

Warranty provisions are to be in accordance with the Special Provisions.

1.12.2 Subcontracts

The Contractor shall obtain from the subcontractors providing any items of major equipment ("major" equipment is defined as traction equipment, brakes, air conditioning equipment, heating and cooling controls, door operators and controls, trucks, couplers, destination signs, lighting, journal bearings, batteries, converters, air compressors, public address equipment, communication equipment, and automatic train control equipment) the same agreement with regard to warranty that the Contractor is required to extend to the Authority. In addition, the Contractor shall obtain, from each of those subcontractors, written certification that the method being used for installation and connection of that subcontractor's equipment by the Contractor is satisfactory to the subcontractor.

SECTION 2
DIMENSIONS, WEIGHTS, DRAWINGS, SPARE PARTS

TABLE OF CONTENTS

SECTION 2

DIMENSIONS, WEIGHTS, DRAWINGS, SPARE PARTS

2.1 DIMENSIONS, WEIGHTS, AND MISCELLANEOUS DESIGN PARAMETERS

2.1.1 Dimensions

Length of car from a point midway between the A and B cars of a married pair to the front coupler face	75 feet, 0 inches
Distance, center-to-center of trucks	52 feet, 0 inches
Width of car at floor	10 feet, 0 inches
Maximum width of carbody	10 feet, 1-3/4 inches
Height, top of rail (TOR) to top of plymetal floor, measured at the bolsters *(See Note 1)*	40 inches
Minimum radius of track curve *(See Note 2)*	225 feet
Minimum length of tangent between reverse curves	*(See Note 3)*
Shape of vertical curves	Parabolic
Length of vertical curves	*(See Note 4)*
Maximum height of top of roof	10 feet, 10 inches
Minimum vertical clearance inside car at center	6 feet, 9 inches | MOD 3
Minimum vertical clearance inside car at low ceiling area	6 feet, 4 inches
Coupler height above TOR *(See Note 5)*	22-1/2 inches
Side door clear opening width *(See Note 6)*	50 inches
Minimum height, side door openings, over plymetal floor	6 feet, 4 inches
Minimum height, end door openings, over plymetal floor	6 feet, 3 inches
Minimum width of end door opening, clear	30 inches
Wheel diameter - new wheel	28 inches
Maximum grade	5%
Most restrictive crossover	No. 6 with 14-foot track centers
Maximum number of cars in train (normal conditions)	8
Maximum superelevation	6 inches
Gauge, tangent track and curves with radii of l,425 feet and greater *(See Note 7)*	4 feet, 8-1/4 inches
Wheel gauge (Nominal)	55-11/16 inches
Truck wheelbase, minimum	84 inches
Truck wheelbase, maximum	92 inches
Normal load (AW1), 81 persons at 150 lbs. each	12,150 lbs.
Full load (AW2), 175 persons at 150 lbs. each	26,250 lbs.
Crush load (AW3), 232 persons at 150 lbs. each	34,800 lbs.
Absolute maximum load (AW4), 252 persons at 150 lbs. each	37,800 lbs.

Note 1: Tolerances on this height are given in Sections 3.3.17 and 14.2.11.

Note 2: No spirals will be used between circular curves and tangent track in yard and shop areas.

Note 3: The most severe reverse-curve situation is that in which two No. 6 turnouts (of the same hand) face each other with 13.53 feet of tangent track between the points and 250-foot radius curves (in the same direction as the turnout) that continue beyond both frogs.

Note 4: The minimum length of vertical curve is determined by the formula $L = (G_1 - G_2)\ 100$ where L = Length in feet and $(G_1 - G_2)$ = Algebraic difference in grade in percent. No vertical curve will be less than 200-feet long.

Note 5: The tolerance on coupler height is ± 5/8-inch, which includes the tolerance on the car floor height with the air springs inflated.

Note 6: Clear opening is the width of the widest object that can be passed through an open door.

Note 7: The gauge is widened on curves of less than 1,425-foot radius.

2.1.2 Design Considerations

The carbody, trucks, and attached equipment shall be designed so that under the most extreme combinations of broken and deflated springs, lateral and vertical motion, and roll, permitted by the suspension system, the maximum possible dynamic outline shown on Contract Drawing 97936-017, will not be exceeded. A clearance of at least 1-1/2-inches shall be provided between truck parts, including wiring, and carbody parts under the most unfavorable conditions of track curvature, wheel wear, lateral and vertical motion and roll, and broken and deflated springs. Except as otherwise allowed in Section 14, no part of the trucks or truck-mounted equipment shall be less than 2-1/2-inches above the horizontal plane formed by the tops of the rails under any combination of conditions, including fully-worn wheels and maximum possible primary and secondary spring deflection.

Under the most restrictive combination of track conditions, the clearance between adjacent cars (except at the anti-climbers and couplers) shall not be less than 3 inches under maximum buff conditions, and not less than 1/2-inch after coupler or drawbar has telescoped and anti-climbers have engaged. Car end angles shall be designed to provide this clearance.

2.2 VOLTAGE

The nominal third rail voltage of the Authority's system is 700 VDC. Except as otherwise specified herein, all specification requirements shall be met or surpassed at all voltages from 700 VDC to 780 VDC. Performance requirements for the Heating, Ventilating and Cooling System, specified in Section 7, shall be met at 700 VDC. Propulsion system performance standards in acceleration and deceleration, as defined in Section 10, shall be met at 650 VDC. Vehicle brake performance shall be met regardless of the third rail voltage. All equipment shall operate without damage for any duration at any voltage between 430 VDC and 860 VDC.

All equipment, except where otherwise stated, shall operate such that the ratio of actual performance to specified performance is not less than the ratio of the actual voltage to the rated operating voltage for the equipment.

Where the term "nominal third rail voltage" or "700 VDC" is used throughout the specification, it is intended only to describe circuits operating at the third rail potential (as opposed to, for example, the battery potential) and shall be understood to indicate a voltage range of 430-860 VDC.

Where the term "battery voltage" or "37.5 volts" is used throughout the specification, it is intended only to describe circuits operating at the low voltage potential (as opposed to, for example, the third rail potential) and shall be understood to indicate a voltage range of 23-42 volts.

All car equipment shall be protected from damage due to transient over- and under-voltage conditions, which may exist in the actual operating environment or as a result of the Contractor's design. Unless otherwise specified, the Contractor and its suppliers will be expected to provide transient suppression based on their experience in similar applications.

2.3 WEIGHT

The weight of a car, which is complete in all respects but is without passengers or Operator, is called its "Ready-to-Run" weight (AW0). The maximum Ready-to-Run weight of any married pair of cars shall not exceed 155,000 lbs. The difference in Ready-to-Run weight between "A" and "B" cars of a married pair shall not exceed 1,000 lbs. Assessment of liquidated damages based upon weight in excess of these maximum weights shall be as set forth in the Special Provisions. See weight test requirements in Section 1.8.4.1

2.4 ENVIRONMENTAL CONDITIONS

The transit vehicle shall be capable of being operated at the specified performance levels and stored without equipment degradation under the following environmental conditions:

A.	Ambient Temperature:	-5° F to 105° F
B.	Relative Humidity:	20% to 100%, including conditions of condensation
C.	Maximum Rainfall:	8 inches in 24 hours
D.	Snow Accumulation Above Running Rail:	10 inches
E.	Maximum Snowfall:	15 inches in 24 hours
F.	Maximum Wind Speed:	80 mph (operational), 120 mph (storage)
G.	Glaze or Freezing Rain:	Two or three times per year

The temperatures shown only represent ambient temperature conditions.

The effect of increased temperatures due to solar radiation on the carbody and heat produced during operation of equipment under the environmental extremes specified above must not result in degradation of equipment performance or equipment reliability.

2.5 SPARE PARTS

See Contract Special Provisions.

2.6 DIES AND PATTERNS

Dies, patterns, and molds used in the construction of the cars shall not be destroyed or otherwise disposed of without first offering the Authority the opportunity to acquire them.

2.7 INTERCHANGEABILITY

To provide maximum car availability, all apparatus shall incorporate easily interchangeable modules and component boards to the maximum extent possible.

All similar subassemblies, and all replaceable components within subassemblies, shall be physically interchangeable between like cars.

The design of equipment and replaceable components shall be such that, after calibration by the bench test equipment (Section 12.3), installation on any car shall not cause any car system performance characteristic to change.

Use of local adjustments to compensate for resistance, etc., of components external to the equipment being replaced, should be avoided wherever possible; but may be provided subject to approval by the Authority. Component boards, which have devices to permit such adjustment, shall be semi-permanently attached to the equipment chassis.

All interchangeable modules and component boards shall be mechanically keyed in such a manner as to make it impossible to insert any such module and component board into other than its correct location on the proper chassis.

2.8 CONTRACT DRAWINGS

The following Contract Drawings are a part of this Specification:

Drawing No.	Drawing Title
97936-i	Index of Contract Drawings
97936-001	Side Elevation and Floor Plan
97936-002	Carbody Cross Section – Normal Ceiling Area
97936-003	Cross Section – “F” End Low Ceiling Area
97936-004	Carbody Cross Section at Center Door
97936-005	Cab End Elevation and Contour
97936-006	Non-Cab End
97936-007	Reflected Ceiling Plan
97936-008	Operator’s Cab
97936-009	Operator’s Console Control Panel
97936-010	Operator’s Console Indicator Panel
97936-011	Operator’s Auxiliary Control Panel
97936-012	Operator’s Circuit Breaker Panel
97936-013	Trainline Circuit Breaker Panel
97936-014	Two Passenger Seat
97936-015	Back-to-Back Passenger Seat
97936-016	Speaker Grilles
97936-017	Dynamic Outline
97936-018	Wheel – 28-inch Diameter Steel
97936-019	Coupler Electric Head Arrangement
97936-020	Schematic Diagram, Door Control
97936-021	ATP Block Diagram
97936-022	ATS and ATO Block Diagram
97936-023	Carborne Monitoring and Train Length Systems

Drawing No.	Drawing Title
97936-024	ATC Direction Sensing and Back-End Door Command Circuits
97936-025	ATC Undercar Equipment Layout
97936-026	Daily Safety Test Unit and Connector Wiring
97936-027	Approximate ATC Wiring Requirements
97936-028	Train-to-Wayside Communications Block Diagram
97936-029	Third Rail Details
97936-030	Audio Interconnections for Carborne Communications Equipment
97936-031	ATO Test Unit Block Diagram
97936-032	Typical Marker Arrangements
97936-033	Lateral Offset Requirements
97936-034	Contact Rail Protection Cover
97936-035	Contact Rail Fixation, Tangent/Superelevated Track
97936-036	Contact Rail Fixation, Superelevated Track

Drawings depicting the layout and profiles of the Authority track lines are available at the request of the Contractor.

SECTION 3
CARBODY

TABLE OF CONTENTS

Section **Page**

Section	Page

Section	Page

SECTION 3
CARBODY

3.1 GENERAL

3.1.1 <u>Arrangement</u>

The cars shall be designed to operate in two-car units or “married pairs.” Each married pair shall consist of an “A” car and a “B” car, and shall be capable of operation in either direction.

The end of each car that is always coupled to the other car of the married pair is the “R” end; the opposite end is the “F” end.

The arrangement and dimensions of the car shall conform to the Contract Drawings.

Equipment and apparatus on the car shall be arranged so that lateral imbalance does not exceed 25,000 inch-lbs. The difference in weight of the two ends of the car shall not exceed 1,000 lbs., measured at the trucks.

Apparatus requiring inspection or attention more often than once a year shall be accessible and replaceable without removal of other apparatus. All underfloor apparatus shall be arranged to be accessible from maintenance pits or from the side of the car. Apparatus requiring attention more often than every 30 days shall be accessible from the side of the car. The frequency of required service shall determine degree of equipment accessibility.

3.1.2 <u>Physical Protection</u>

Appropriate screens and guards shall be provided where required to protect underfloor apparatus from flying ballast or similar missiles. Where screens or guards, because of their arrangement, afford the opportunity for buildup of trash and other foreign material, the path of entry to the inside of the screened or guarded area shall be blocked with some form of screening that will exclude foreign material but will not interfere with ventilation. Screens and guards shall be easily removable.

Splash guards shall be provided where required to protect underfloor apparatus, such as resistors and control boxes, from wheel splash.

All current-carrying parts connected to circuits with potential of more than 150 volts, except contact shoes and their attachments, shall be insulated, or located or guarded to prevent accidental contact, and doors and cover plates guarding said apparatus shall be securely fastened in place and the inside and outside marked with the word “DANGER” and the normal voltage of the circuit. Switches connected to circuits operating at potentials in excess of 150 volts and, which should not be operated under load, shall be so labeled.

3.2 CARBODY STRUCTURE/MATERIALS

3.2.1 <u>General</u>

The carbody shall be constructed entirely, except as otherwise specified, of either stainless steel or aluminum alloy.

3.2.2 <u>Materials</u>

If the carbody is constructed of stainless steel, A.I.S.I. Types 201L or 301L shall be used for all structural and exterior parts (excluding the end underframe and “F” end cap).

If the carbody is constructed of aluminum alloy, structural members (excluding the end underframe components) shall be made of alloy 6061-T4 or T6 or 5083-H111. Gusset plates shall be made of alloys 6061-T6 or 5083-H321, H323, or H343. Side sheets and roof sheets shall be made of alloys 6061-T6; 5083-H321, H323, or H343; or 5052-H32 or H34. Alloys 5251, 3003-H14 or H16, Alclad 3003-H14 or H16 or Alclad 3004-H14 or H16 may also be used for roof sheets. The structural use of any 2000 series and 7000 series alloys, and of aluminum castings of any alloy is expressly prohibited. All surfaces of all aluminum portions of the carbody, except exterior surfaces, shall be properly cleaned and given one coat of zinc chromate primer. An alternative primer may be used providing that data on all of the characteristics of the material are provided, it is shown to be equivalent or better than the zinc chromate primer specified, and the alternative is approved by the Authority. Use of stainless steel and aluminum shall comply with all requirements of Sections 15.3 and 15.6, respectively.

Regardless of the Contractor's selection for carbody material, such material must not be etched by the environmental conditions that exist in the Washington Metropolitan Area and its subway tunnels to the extent that the original appearance of the car cannot be restored by normal washing. This requirement shall extend for the duration of warranty period, as specified in the Special Provisions.

Alternative materials to those specified in any part of Section 3 will be considered, providing the Contractor submits details of the material using a U.S.-recognized trade name or UNS number with properties in English, along with evidence that the proposed alternative material is equal or superior to the specified material in strength and performance for its intended application. For alternative carbody materials, evidence of satisfactory performance shall address the effects of the chemical contents of water leaching through tunnel linings.

The carbody material shall maintain its original appearance and physical characteristics, even if unwashed for periods as long as 3 months, as may be the case in cold weather or for cars placed in temporary storage.

3.2.3 <u>Fastening Methods</u>

Stainless steel structural framing shall be assembled by means of resistance welding or arc welding.

Aluminum alloy structural framing, where visible to passengers, shall be assembled by means of arc welding, or flush rivets. Where not visible to passengers, lockpins and rivets with other head shapes are also acceptable. Adhesive bonding of structural elements is not permissible in either stainless steel or aluminum alloy structures.

Resistance welds, visible to passengers, shall be arranged in uniformly spaced patterns and shall display no discoloration, no displaced metal (weld "feathers"), and minimum indentation. All other exposed welds shall be finished sufficiently to be unnoticeable except by close visual inspection.

Rivets visible to passengers shall be arranged in uniformly spaced patterns, shall be no more obvious than resistance welds, and shall be sanded to match adjacent material.

MOD 1 | The use of dissimilar metals as defined in MIL-STD 889B shall be prohibited.

3.2.4 <u>Exterior Finish</u>

3.2.4.1 Unpainted

All exterior surfaces of the carbody shall, unless otherwise specified, be of smooth (not corrugated) unpainted metal, and shall have a horizontal, medium-grain sanded finish, similar to that on the Authority's existing cars. Trim pieces may, however, be sanded parallel to the long dimension of the piece. The grain size exterior finish shall be approved by the Authority. All sanded surfaces shall have the same finish, whether applied by machine or hand, or furnished by a Subcontractor.

3.2.4.2 Painted

All exterior surfaces to be painted shall be prepared according to Section 15.24.

The painted exterior treatment consists of, but is not limited to, a silver metallic cab end cap with red, white, and blue stripes. The "F" end door, headlight recess areas, and side window dead light areas are to be painted dark brown metallic. See Contract Drawings 97936-001 and 97936-005 for layout details. All paint colors and finishes must be submitted to the Authority for approval.

3.3 CARBODY STRUCTURE/ARRANGEMENT AND DETAILS

3.3.1 General

The carbody, including doors and windows, shall be watertight under all operating conditions, including passage through a car washer. Except for those produced by the ventilation system, no drafts shall be discernible at any operating speed.

All pockets formed by the construction of the carbody structure shall be self-draining to prevent collection of water.

The structure shall be so designed that no fatigue failures will occur within the 35-year anticipated life of the car when loaded to the specified "Full" loading condition. The car shall have no more than 1/2-inch to 3/4-inch positive camber between bolsters when empty, and shall not deflect to a negative camber greater than 1/8-inch maximum when loaded to the specified absolute maximum loaded condition. Positive camber shall form a circular arc between the bolsters and may be straight and tangent to the arc beyond the bolsters. Camber shall be measured from suitable points on the car structural side sills in the doorways; car roof, side frames and floor shall be constructed and connected so that camber is the same for all of these members.

In addition, the car structure shall be designed to be compatible with the characteristics of the Authority's other cars. The vehicle body shall protect occupants in the passenger compartment in the event of a collision between two trains or between a train and a wayside obstruction. This protection shall be provided by means of energy absorption devices and controlled, progressive, plastic deformation and/or buckling of the carbody ends. The compression strength of the main carbody structure enclosing the passenger compartment shall be greater than the compression strength of the carbody ends such that the main structure shall neither collapse, buckle, nor plastically deform until the sacrificial elements of the carbody ends have been permanently deformed.

Each carbody end shall include at least two corner posts, two collision posts and anti-climbing devices designed to prevent overriding and penetration into any passenger compartment in the event of a collision. The design of the ends shall be easy to repair. The preferred design would be a single frame that may be replaced as a unit in the event of collision damage.

3.3.2 Carbody

3.3.2.1 Strength Requirements

The main carbody structure enclosing the passenger compartment shall be capable of withstanding the following loading without exceeding the cited stresses.

A. Compression load of 200,000 lbs. The application and distribution of the compression load shall be as transferred by the carbody ends with the compression load originally being applied to the anti-climbers. This combined loading shall not cause stresses exceeding 90% of the yield strength in any member inboard of the carbody bolsters, or 100% of the yield strength in any member outboard of the carbody bolsters.

B. Static vertical loading corresponding to an AW3 loaded vehicle which shall not cause stress levels in any structural member to exceed 50% of the yield strength.

C. Fluctuating loads due to passenger loading, unloading and whole body oscillations in response to track irregularities. For design purposes, this loading shall be assumed to be oscillatory with a mean value of AW2 and an amplitude of ±20%. Stresses caused by this loading shall be below the fatigue strength for 10 million cycles with a safety factor of at least 1.1.

D. Coupler Anchorage. A compression load of 135,000 lbs., applied horizontally and parallel to the longitudinal centerline of the carbody, to the center reaction point of the coupler anchorage, shall result in no yielding of the main structure.

E. Jacking Pads. The empty car, without trucks, shall be capable of being lifted on diagonally-opposite corner jacking pads without permanent deformation in any element of the carbody structure or jack pads.

F. Collision Posts. The ultimate shear capacity of each collision post at the floor level shall be 300,000 lbs., applied anywhere up to ±15 degrees from the longitudinal axis. In addition, each collision post shall have sufficient capacity to withstand a load of 35,000 lbs. applied 18 inches above top of floor, anywhere up to ±30 degrees from the longitudinal axis, with no stress exceeding the yield point.

G. Corner Posts. The ultimate shear capacity of each corner post at the floor level shall be 75,000 lbs. for the “F” end, and 50,000 lbs. for the “R” end, at any angle from longitudinal to transverse. In addition, each corner post shall resist an inward load in any direction, applied 15 inches above the floor, of 17,500 lbs. at the “F” end and 12,000 lbs. at the “R” end, with no stress exceeding the yield point.

3.3.2.2 Crashworthy Design

The vehicle structure and supplemental energy absorption devices shall be designed to absorb maximum energy in a collision and transmit minimum accelerations to passengers without override or telescoping. The new vehicles must also be structurally compatible with the Authority’s existing vehicles. For design purposes, in a collision involving a train of 5000 Series vehicles moving at speed V, on level tangent track, impacting a stationary train with brakes applied, with the stationary train consisting of either 5000 Series or the Authority’s existing cars, and with either train containing any number of cars used in normal passenger service of any weight up to AW2, the following criteria shall apply:

A. For V = 5 mph or less, there shall be no damage to any vehicle or equipment, except for the coupler emergency release mechanism.

B. For V = 20 mph, damage shall be confined to the ends of the vehicles outboard of the bolsters and be easily repairable. The structure of the vehicles inboard of the bolsters shall remain intact, with no permanent deformation of any member; no passenger compartment shall rupture or suffer any opening through which passengers’ limbs may protrude; high voltage devices and associated connecting cables shall remain contained and shall not create electrical shock hazards to personnel; and there shall be no fire hazards.

C. The force required to initiate controlled deformation of the car ends outboard of the body bolsters shall not be less than 200,000 lbs. and shall not exceed 90% of the load required to break the bolster/side sill connection on the Authority’s existing cars. The force required to crush the ends shall also steadily increase as the deformation progresses without sudden reductions. The resulting deformations shall be symmetrical such that the vector sum of the crushing forces shall remain parallel to the longitudinal centerline of the car.

D. The underframe inboard of the bolsters shall withstand a longitudinal load of at least 300,000 lbs. without collapse or catastrophic failure.

E. The maximum longitudinal acceleration in the passenger compartment following a collision with V = 20 mph shall not exceed 4.0g.

The Contractor shall demonstrate that the vehicle will satisfy these requirements, by providing test data and/or validated mathematical model simulation.

3.3.2.3 Structural Analysis

The Contractor shall perform a structural analysis of the car/vehicle structure, body, truck and suspension elements, underframe, and equipment supports. *(CDRL 301)* The analysis shall be submitted for approval and shall include the calculated stresses, allowable stresses, and safety margins for structural elements under each of the specified loading conditions defined in the structural design criteria. The safety margin shall be defined as the allowable stress divided by the calculated stress, including safety factors required by the structural design criteria, minus 1.00. The analysis shall consist of a combination of manual and/or computerized calculations and finite element analysis. Finite element analysis shall be used, at a minimum, for any complex structural element that affects safety in a failed state. The analysis shall include at least the following:

A. Structural arrangements and layouts of the car/vehicle and truck elements. Materials and sizes of structural elements and the method of fastening shall be defined.

B. Diagrams showing externally applied loads and boundary conditions. Where finite element analysis is used, diagrams shall be provided showing the finite element mesh and its relation to the car/vehicle and truck structures.

C. Documentation showing the properties of the materials used in the vehicle structure. This shall include, at least, the guaranteed minimum yield and ultimate strengths, elongation, Young's modulus, and allowable fatigue stress data for each material.

D. Detailed stress calculations, including calculation of the safety margin, for each structural element.

3.3.3 Underframe

If the carbody is constructed of stainless steel, the underframe, except for the end underframe, shall be of stainless steel. If the carbody is constructed of aluminum, the underframe, except for the end underframe, shall be of aluminum, low alloy high tensile steel, or stainless steel.

3.3.4 End Underframe

An end underframe unit shall be used at each end of the car. It shall be designed to comply with the structural design requirements in Section 3.3.2. Approved drainage shall be provided for all cavities.

The design of the end underframe weldments shall provide for continuity of flanges and webs at any place where load-bearing members intersect. The end underframes shall be designed so that, in case of excessive impact, failure will be caused by buckling or crushing of structural elements in the region outboard of the coupler anchorage, rather than by shearing of structural elements or by failure of connections between elements.

A stainless steel anti-climber shall be provided as an integral part of the end underframe. It shall be designed so that cars, under compressive forces that cause the coupler automatic release feature to be actuated, will mate in a manner that prevents one car from climbing the other. This arrangement shall resist, using only three of the four "ribs," a vertical load of 75,000 pounds in either direction, combined with a longitudinal inward load of 125,000 lbs., without exceeding the yield strengths of the anti-climber and its adjacent car structure, when engaged with the anti-climber of one of the existing cars. Each rib shall be no less than 7/16-inch thick at its outer edge, in order to provide resistance to crushing. The design of the anti-climbers shall ensure that they remain attached to the vehicle after the crushable element is expended and the 75,000 lb. vertical load applies through the full stroke of the crushable element. The anti-climbing arrangement shall have the appearance shown on Contract Drawings 97936-005 and 97936-006.

The top surface of the front end anti-climber shall contain holes suitable for anchoring the emergency ladder specified in Section 5.13. The holes provided must drain water outside in such a way to prevent entry of water into floor panels or insulation and to prevent formation of ice.

3.3.5 Subfloor

A stainless steel subfloor shall be provided over the full length of the car.

3.3.6 Side

A formation in the side sheathing shall run the full length of the car, below the windows, as shown on Contract Drawings 97936-005 and 97936-006. The ends of the formation shall be closed off to give a finished appearance at doors and at the ends of the car. If necessary, cosmetic trim shall be used around the doorway to obscure the welded areas.

3.3.7 Skirt

A fixed skirt shall be provided.

3.3.8 End Construction – Design Requirements

Car end structures shall be provided with vertical collision posts, at the sides of the end door openings, which comply with the structural requirements in Section 3.3.2.

Each collision post shall have a section modulus about the carbody transverse axis of at least 4.5 in.^{3} for 110,000 psi yield stress material, or a proportionately greater value for material of lesser yield stress.

The collision posts shall be connected to the roof structure and the connections and supporting structure shall be adequate to resist either one separately, or both collision post top reactions simultaneously, without exceeding the yield strength of the load-carrying connections and supporting members, when the posts are loaded at a line 18 inches above the top of the end sill to which they are attached with loads sufficient to develop the yield strength of the post material. The connections at the tops of the collision posts shall also be designed to develop sufficient longitudinal, vertical, and bending strength that if the collision posts should be overloaded in bending to their ultimate strength, the top post connections and supporting structure will resist without failure the longitudinal, vertical, and bending loadings to which they are subjected.

Transverse structural members shall be used to reinforce the end frames at the bottoms of the end windows. These members shall be securely fastened to the collision posts and to the corner posts, and structural shear panels shall be provided between the end sill top surface and the bottoms of the transverse structural members, to resist the torsional shear loading resulting from the specified diagonal jacking loading of Section 3.3.2.1. Corner posts shall be connected to principal side frame longitudinal members.

3.3.9 Cab (“F”) End

The cab end shall be arranged and contoured as shown on Contract Drawing 97936-005. Details of the contours must be approved by the Authority prior to manufacture. The end sheathing shall be of stainless steel, aluminum alloy, or glass-fiber reinforced polyester plastic. See Section 3.9 for windows and Section 8.2 for headlights, tail lights, and marker lights. No visible caulking shall be used in the connection of the end to the sides and roof. Glass-fiber reinforced plastic used in the end sheathing shall conform to the fire-resistance requirements of Section 15.25.

3.3.10 Non-Cab ("R") End

The non-cab end shall be arranged and contoured as shown on Contract Drawing 97936-006. It shall be sheathed with the same metal used as the basic carbody material.

3.3.11 Roof

Roof sheets may be longitudinally corrugated in the area above the sight line (which line is on the surface of the roof, extending no greater than 37 inches from the longitudinal center line of the car). All parts of the roof shall be of sufficient strength as not to suffer any permanent deformation when passing through a mechanical car washer. The roof structure shall be designed to support the air conditioning apparatus, ducts, conduit, lighting fixtures, headlining, stanchions and other equipment, and shall, in addition, have sufficient strength to support, without permanent deformation, concentrated loads of 250 lbs., applied by personnel working on the roof, at intervals of 30 inches apart. Deflecting plates shall be installed at the ends of a corrugated roof over the end doors, to prevent water from cascading between cars. MOD 2

3.3.12 Underfloor Boxes

Boxes underfloor shall be of painted carbon steel, aluminum, or stainless steel. Boxes shall be provided with top-hinged doors, which shall have suitable means for ready removal. Means shall be provided to ensure that door hardware remains captive. The doors shall be gasketed to be water- and dust-tight, where required by the nature of the apparatus contained therein. Doors on underfloor boxes shall be interchangeable between the corresponding boxes on different cars and, to the extent possible, between boxes on the same car. Fiberglass reinforced polyester plastic may be used for underfloor doors and, if used, shall conform to the fire resistance requirements of Section 15.25. All underfloor boxes shall have drain holes with cotter pins.

Outer vertical faces of boxes and apparatus mounted along the side sill shall all be equidistant from the longitudinal centerline of the car; that is, shall all lie in the same vertical plane; unless the Contractor can show that a deviation from this requirement is needed to achieve balanced weight distribution. This will not apply to boxes and apparatus extending below 16-7/8 inches above top of rail, which shall be located to allow for track curvature as directed by Contract Drawing 97936-033.

Unless otherwise approved, devices enclosed in underfloor boxes and enclosures shall not be fastened directly to the walls, roof, or floor of the box or enclosure. Hardware, including latches and hinges, used to secure doors on underfloor boxes and enclosures shall be made of stainless steel. All mounting hardware for access plates shall have captive fasteners. All equipment enclosures shall have ready maintenance access to components and wiring.

Unless otherwise approved, all access covers and doors shall be provided with quick-release, spring loaded latches that operate with a toggling-type action. The latches shall be arranged so that they are protected from flying debris from the road bed and shall not violate the car dynamic envelop if not engaged.

Heat-sensitive equipment and materials shall be so located or shielded that they are not adversely affected by heat-producing equipment with the cars stopped or moving at any speed.

3.3.13 Underfloor Equipment Supports

Supports for underfloor apparatus, pipes, conduits, and boxes shall be of low-alloy high-tensile steel, aluminum alloy, or stainless steel; aluminum supports shall be wrought, extruded, or forged aluminum alloy. Where possible and appropriate, supports for heavy apparatus shall rest on horizontal flanges of side sills and center sills.

Unless otherwise approved, underfloor apparatus shall not be supported by bolts in tension. An exception to this rule is made in the case of resistance grids, which may be supported by bolts in tension if the connecting leads are strong enough to hold the grids should the bolts fail. Apparatus requiring removal and replacement for other than accident damage shall be supported so that both bolts and nuts are accessible. Bolts shall be not less than 3/8-inch diameter. Dissimilar metals shall not be used at connections requiring disassembly for removal and replacement of equipment. Equipment supported on resilient mounts shall have safety straps or other devices for support in case of failure of the resilient mounts. No equipment shall be supported by bolts in holes tapped in the underframe. Underfloor equipment supports shall be designed to provide adequate fatigue strength for the life of the car, but in no case shall these supports be designed to withstand less than 2g lateral, 5g longitudinal, and 3g vertical loads, based on the ultimate strength of the material.

All underfloor equipment shall be grounded to the carbody.

3.3.14 Gutters

Water deflecting gutters shall be installed on the roof along the entire side of the car and over the end doors. The gutters shall be continuous to ensure drainage at the corners of the car.

3.3.15 Jacking Pads

Jacking pads shall be provided in eight locations on each car; on both sides of the car, 53 inches from the longitudinal center line, and 31-1/2 inches toward the end of the car from the transverse centerline of each body bolster, and at each corner of the car. Jacking pads shall be at least 4 inches wide by 11 inches long with an anti-slip bottom surface, shall extend 1/2-inch to 1-inch below the bottom of the skirt, and shall be usable without removing or hinging any part of the skirt. Adequate clearance shall be provided around the jacking pads to permit use of the Authority's standard shop jacks. The 11-inch dimension of the jacking pad shall be parallel to the side of the car. It shall also be possible to raise one end of the car with truck attached, for re-railing purposes, with the other end resting on its truck, by means of a jack placed under the end sill without causing permanent deformation.

The vertical strength of the jacking pads and supporting structures shall be sufficient that the weight of the car can be supported on only two pads, without permanent deformation of the carbody or the jacking pads. The jacking pads and their supports shall have a strength in all directions in the horizontal plane of at least 10% of the vertical strength.

3.3.16 Truck Connection to Body

A truck safety mechanism shall be provided to produce a connection between carbody and trucks such that the trucks will be raised with the carbody, unless intentionally detached. All structural members of the carbody which serve to provide a connection between the truck and the carbody shall not fail when subjected to a 150,000-lb. horizontal load as specified in Section 14.4.

Bolster-locating radius rods shall not be used to provide any part of this strength.

The truck safety mechanism shall not create an electrical connection between the truck frame and the carbody except possibly when the car is raised on jacks.

3.3.17 Floor Level

The height of each of the four corners of the carbody shall not be in excess of 1/4-inch above or below nominal, as measured at the center of the side door threshold nearest each corner of the car. This applies to the combined effects of car lean (due to equipment imbalance) and carbody "twist," but does not include permissible variations in height attributable to the air spring height-control valves, given in Section 14.2.11 and primary spring deflection.

3.3.18 Vibration

Structural body and panel natural frequencies shall be sufficiently removed from primary excitation frequencies to preclude any damaging resonant vibrations at all speeds and power conditions up to 110% of maximum cruise speed.

3.4 OPERATOR'S CAB

3.4.1 General

The "F" end of each car shall be equipped with a full-width Operator's Cab, as shown on Contract Drawing 97936-001. When in use by the Operator, the cab door will be in the transverse position to exclude passengers from the cab area. In other locations in the train, the cab door will be swung to a longitudinal position to close off the console and other controls, and the aisle and the two-passenger seat on the left side of the cab area will be available to passengers.

A window with 1/4-inch-thick tinted (7-12%) laminated sheet shall be provided in the longitudinal cab partition between the cab door and the "F" end body end door. It shall be as wide as possible, and shall extend vertically from a height 1-1/2 inches from the top of the cab console to within 1-1/2 inches of the cab ceiling.

3.4.2 Apparatus and Appointments

The cab shall enclose the following apparatus, described elsewhere in this Specification: (this list is not necessarily complete.)

A. Adjustable Seat – See Section 3.11.7
B. Fire Extinguisher – See Section 5.6
C. Windshield Wipers Control – See Section 5.7.1
D. Visor, moveable type – See Section 5.7.2
E. Cab Curtain – See Section 5.7.5
F. Emergency Ladder – See Section 5.13
G. Third Rail Shoe Paddles – See Section 5.14
H. Heater – See Section 7.2.5
I. Heated Windshield – See Section 7.2.6
J. Reading Light – See Section 8.1.5
K. Circuit Breaker Panel – See Section 9.7
L. Operator's Auxiliary Control and Indicator Panel – See Section 9.7.2
M. Operator's Control Console – See Section 9.7.2
N. Trainline Circuit Breaker Panel – See Section 10.6.6
O. Handbrake – See Section 10.9
P. ATP Cutout Switch – See Section 11.2.1.4
Q. Radio Loudspeaker – See Section 13.5.1
R. Passenger Call Loudspeaker – See Section 13.5.1

3.5 UNDERSEAT MOUNTING OF APPARATUS

Wells shall be provided in the floor under the back-to-back seats. Where the following equipment is mounted interior to the car, it shall be located as indicated below. Alternative locations for the equipment may be proposed, subject to approval by the Authority.

Left Front Seatwell

General Door Control Panel
PA Amplifier and its Power Supply
MOD 3 Radio (“B” Car only)
Front Truck Brake Cylinder Cutout
Front Brake Control Air Supply Cutout

Right Front Seatwell

Propulsion Logic
Layover Heat Thermostat
ConsoleLamp Dimmer Power Supply (“A” Car only)
VCU Display Unit

Left Rear Seatwell

MOD 3 Friction Brake Electronic and Pneumatic Logic
Front and Rear BCP Quick Disconnect Fittings

Right Rear Seatwell

Brake Status Unit Relays
Manual Upcoupling Lever
Third Rail Insulating Paddles
Rear Truck Brake Cylinder Cutout
Rear Brake Control Air Supply Cutout

MOD 2

Seatwell-mounted equipment shall be protected from spillage of liquids by a polycarbonate or other approved shield incorporated into the bottom of the back-to-back seat.

Insulation, with equivalent thermal and acoustic properties to that provided in the floor, shall be provided under and around the wells. See Section 3.12 for Insulation. Insulation shall also be provided to protect passengers from heat generated by underseat apparatus. Permanent gasket(s) shall be provided on the seat base or well; separate covers shall not be used. Other apparatus (except 700-volt apparatus) that does not produce noise or more than a modest amount of heat may also be located therein. The foregoing is not intended to preclude the installation of heaters operating on 700-volt circuits under seats.

3.6 CEILING AND SIDE LINING – INTERIOR FINISH

3.6.1 General

Wherever specific lining materials are called for, it is only for the purpose of establishing a level of strength, rigidity, cleanability, durability, and resistance to scratching and marking, and does not necessarily indicate that these materials will meet the required flammability and smoke emission standards, as defined in Section 15.25. Conformance with the flammability and smoke emission standards of Section 15.25 is the responsibility of the Contractor.

“Anti-squeak” tape shall be used between linings and any structure to which they are attached or with which they come in contact. The anti-squeak tape shall be reliably secured to prevent displacement. Where linings cover apparatus requiring even infrequent maintenance, they shall be fastened with approved fasteners in a manner allowing ready removal and replacement. Lining materials shall be supported sufficiently to prevent sagging and drumming.

Colors and patterns of interior materials shall be as approved by the Authority.

Unless otherwise specified, all interior exposed surfaces, including seats, shall have an approved hair cell texture finish. Color shall extend all the way through all lining materials except melamine.

Access to all apparatus mounted within the carbody shall be provided by the use of access panels or doors. It shall not be necessary to remove cab partitions to maintain any part of the "F" end evaporator-blower arrangement.

3.6.2 Moldings

Moldings shall be used to cover all joints, unless otherwise approved. "Snap-on," "H-type," plastic insert, or other approved types having no exposed fasteners shall be used. Moldings shall be hard-surface plastic, plastic-coated aluminum or steel, or aluminum or steel coated with polyester powder coating as available from Oxyplast Limited, or approved equal, in a color and gloss matching the adjacent lining.

3.6.3 Lighting Fixture Supports

Lighting fixtures shall be supported from the car structure. Linings shall not be used for this purpose.

3.6.4 Normal Ceiling

The portion of the ceiling between air distributors, except for the low ceiling under the evaporator-blowers at the ends of the car, shall be constructed of 3/8-inch thick, integrally colored melamine-faced plymetal with particle board core, or approved equal. This area of the ceiling need not be curved as shown on carbody cross section drawing number 97936-002, if approved by the Authority.

Transverse joints shall be spaced no closer than 4 feet apart.

The sharply-curved portion of the ceiling outboard of the light fixtures, except at the door pockets and door openings, shall be constructed of integrally colored melamine-faced 0.081-inch aluminum or 1/8-inch thick balanced-type melamine-faced plastic or approved equal. Alternatively, this portion of the ceiling may be formed by extensions of the window masks. At the door pockets and door openings, this portion of the ceiling shall be formed of molded glass-fiber reinforced polyester, or approved equal.

3.6.5 Low Ceiling

The low ceiling under the evaporator-blowers shall be formed of 3/8-inch thick, integrally colored melamine-faced plymetal with particle board core, or approved equal. It shall be composed of the minimum number of pieces consistent with the need for access to equipment. Longitudinal joints in the low ceiling area are permissible only at light fixtures. Exposed, but inconspicuous, approved quick-acting, captive fasteners shall be used for access. Panels under the air conditioning evaporator units shall be hinged and equipped with clear plastic covered safety chains with spring clips, to avoid injury to maintenance personnel.

3.6.6 Window Masks

Window masks for side and end windows shall be constructed of 0.125-inch minimum thickness match-metal-molded fiberglass-reinforced polyester or approved equal. Across the bottom of the sash, the panels shall have the outlets for warm air discharge specified in Section 7.2.3. The window masks shall be so shaped as to eliminate window sills and other dirt collecting projections. The outlet holes shall have a maximum diameter of 7/32-inch. If window glazing or mounting arrangement will not permit discharge outlet holes, they shall be located in the wainscot panels.

3.6.7 Wainscot Panels

Side and end lining below window masks shall be covered with 0.125-inch minimum thickness integrally colored, unbalanced melamine with fire retardant added. Joints in the wainscot panels are permitted only behind back-to-back seats. If the warm air discharge outlet holes can not be located in the window mask, they shall be located in the wainscot panels. The outlet holes shall have a maximum diameter of 7/32-inch.

3.6.8 Door Pockets

Door pockets shall be constructed, from the floor to the ceiling, of plymetal, melamine-faced on the side exposed to passengers and stainless or aluminum facing on the side not exposed to passengers and shall be at least 3/8-inch thick. The melamine facing shall continue, without joints, to junctions with the window mask, the wainscot panel, and the windscreen.

If doors are provided for readily available maintenance access to the door operators, 4 of the 12 doors or panels shall be designed to hold Authority system maps ("map" doors) and the remaining 8 (7 on the "A" car) shall be designed to hold advertising cards ("ad doors").

The "ad" door shall be constructed of plymetal and shall have a full-height stainless steel piano hinge and two coin-operated captive quarter-turn fasteners to secure it in the closed position. The exposed surface shall be melamine, with a 20-inch-wide, 21-inch-high opening in the center to take a standard 21- by 22-inch card. The opening shall have no bright metal trim. The advertising card shall be insertable from the front of the door by merely manipulating the card.

The "map" door shall be constructed of plymetal and shall have a full-height piano hinge and two coin-operated captive quarter-turn fasteners to secure it in the closed position. At Doors 2 and 11, it shall be arranged to hold a system map approximately 31-1/2 inches wide by 36-1/2 inches high. At Doors 3 and 10, the system map is 31-1/2 inches wide and 33-1/2 inches high, and contains a notch to accommodate the passenger emergency door release handle specified in Section 6.3.3. The map shall be protected by a sheet of clear polycarbonate and enclosed so that airborne dust and dirt is not blown between the polycarbonate sheet and the map. The enclosure shall provide for periodic removal and replacement of the maps. The enclosures for the maps at Doors 3 and 10 shall provide for a continuous seal in the notched area around the emergency door release handle. A coin-operated fastener is one that has a slot wide and deep enough that a U.S. five-cent piece (nickel) can be used to turn it.

3.6.9 Windscreens

A windscreen shall be provided at entrance doorway numbers 1, 3, 4, 6, 7, 9, 10 and 12, as shown on Contract Drawings 97936-001 and 97936-004. The windscreen shall be glazed in its upper portion, and shall be of melamine-faced plymetal below. A vertical stanchion shall be provided at the aisle edge of the windscreen, as shown on Contract Drawing 97936-004. Glazing in windscreens shall be 1/4-inch laminated safety glass, and shall be easily replaceable.

At the outboard edge of the windscreen, provision shall be made for the threshold lights described in Section 8.1.4. Threshold lights shall have polycarbonate lenses and stainless steel or aluminum bezels.

3.6.10 Partitions

Operating compartment partitions, except for glazed areas, shall be constructed of 1/2-inch thick plymetal, integrally-colored melamine-faced on both surfaces. Other construction techniques will be considered acceptable if approved by the Authority. Cab partitions shall be as shown on Contract Drawing 97936-003.

3.6.11 Equipment Cabinet

A cabinet to house the handbrake operator and the ATP cutout switch shall be provided at the left-hand side of the cab. It shall be constructed of melamine-faced plymetal and its rear wall shall be formed by the cab partition. It shall have a sloping top. It shall have whatever doors are necessary to gain free access to the handbrake and other apparatus located within, and a tamper-proof polycarbonate window shall be provided so that the position of the ATP cutout switch can be determined without opening any door. The doors shall have stainless steel piano hinges and locks operable by the door key. MOD 2

3.6.12 Repair Procedures

Repair procedures for all lining materials shall be submitted for approval, simultaneous with submission of the first liner drawings using that material. *(CDRL 302)*

3.6.13 Passageways

Access to doors which are accessible to disabled users shall comply with CFR 49, 1994, Part 38. In cars where such doorways require passage through a vestibule, such vestibule shall have a minimum width of 42 inches.

3.7 FLOOR

3.7.1 Construction

The floor shall be constructed of 3/4-inch overall thick plymetal, composed of exterior type, grade B-B or better, 5-ply plywood using resin glued fir, solid and jointed cores and crossbands, and faced on both sides with 0.020-inch thick stainless steel.

The floor panels shall be composed of pieces as large as possible and shall extend the full width of the vehicle. Transverse ship-lap joints shall be located over the structural members. There shall not be any joints in the top or bottom face skins of the panel. All exposed edges of the panels, including openings for ducts and conduits, and joints between panels shall be waterproofed and sealed. Floor panels shall be insulated from the metallic structure by elastomeric tape. Reinforcements and tapping plates for any above-floor attachments shall be provided on the underside of or within the plymetal floor.

3.7.2 Floor Coverings

Wool carpeting, as described in Section 15.9.2, shall be installed throughout the car except in the cab.

Unless otherwise approved, the carpeting shall be bonded to the padding over its entire area, and, except for the side door entranceways, the padding shall be cemented to the plymetal floor only in sufficient area to prevent its movement. In determining the areas in which the padding is to be cemented to the plymetal floor, consideration shall be given to the need for removal and replacement in areas of heavy traffic, i.e., the aisle between transverse seats and the entire width of the car between longitudinal seats, with the minimum amount of scraping of cement.

In the side door entranceways, the carpet described above shall not be cemented to the floor, but shall, instead, be removable, without the use of tools, for cleaning. The carpet shall have the necessary stiffness to lie flat.

Wherever permanent carpeting joins the replaceable carpeting, and at door thresholds, provisions shall be made to retain the replaceable carpeting and to insure against tripping hazards.

All floor coverings shall be laid in accordance with the specifications of its manufacturer.

3.7.3 Walkway and Thresholds

The side door thresholds and the end door walkways shall be of cast aluminum with abrasive grit cast in. The side door thresholds shall incorporate guides for the sliding doors. These guideways shall have cleanout slots for the continuous discharge of accumulated debris. Thresholds will be designed to be self-cleaning, and shall drain to the outside. The thresholds shall be heated with self-regulating devices
MOD 1 operating on AC voltage to maintain a surface temperature of no greater than 50°F whenever ambient
MOD 3 temperatures drop below freezing. The self-regulating heaters shall activate automatically, without the need for intervention by operating or maintenance personnel.

The configuration and depth of the door tracks in the threshold shall be sufficient to provide for carbody deflection as occurs between no load and absolute maximum passenger load without resulting in door binding. There shall be no less than 1/4-inch engagement between door and threshold and no less than 1/8-inch clearance between door and threshold under the most extreme conditions of passenger load.

At all door openings, the floor shall make a weathertight connection with the threshold plates.

3.7.4 Rubber Flooring

Continuous, smooth sheet rubber flooring, 1/8-inch thick, as described in Section 15.9.1, shall be installed in the cab.

3.8 DOORS

3.8.1 Side Doors

Each car shall be designed with three, bi-parting sliding-type doors on each side. The doors shall be located as shown on Contract Drawing 97936-001. Each side entrance door panel shall contain a stationary window as shown on Contract Drawing 97936-001. Doors shall be weatherstripped completely, including at the top and bottom, so as to effectively exclude water under operating conditions and while passing through a mechanical car washer. The exterior and interior of the side doors shall have a sanded finish, grain horizontal, matching that of the car sides.

The side doors shall be opened and closed by door operators, which are described in Section 6.2.

Side doors shall be supported at the top and guided at the bottom. The hanger shall be of a type in which there is no change in magnitude or direction of load path through the bearing when a misalignment occurs. The hanger shall be adjustable for height and for 1/4-inch lateral travel at each corner. Ready access to these adjustments shall be provided.

It shall be possible to remove and replace a door leaf without removing windscreens. Door leaves of the same hand shall be interchangeable.

Each side entrance door panel shall be equipped with a neoprene rubber edge of an approved design, which shall interlock with the edge on the adjacent door panel so as to provide a tight seal against the passage of air, water or sound to the car interior. This door edge shall be sufficiently soft to avoid injury to fingers. Operation of the obstruction-detection system is described in Section 6.6.

A stainless steel drain pan, which drains to underneath the car, shall be provided in the bottom of each door pocket to prevent the accumulation of water.

3.8.2 Body End Doors

A hinged door shall be provided at each end of the carbody, between the collision posts. Doorways connecting adjoining cars in a multi-car train shall be connected by an aisle with a minimum clear width of 30 inches to one or more spaces where wheelchair or mobility aid users can be accommodated. The door shall have a fixed rectangular window as shown on Contract Drawings 97936-005 and 97936-006, and shall have a latch and lock. The latch shall have a lever-type operating handle on both sides of the door. It shall be possible to lock the door by means of a door key, which is described in Section 5.9.2, from either side of the door, at the option of the crew member; and to unlock it from either side of the door. The door and hardware shall be designed and weatherstripped with adjustable weatherstripping to prevent drafts, noise, and entry of water, even when at the front of a train. The door shall be equipped with a surface mounted, hydraulic, rack-and-pinion type door closer which shall have a finished rectangular anodized aluminum cover, a cast iron case, and separate and adjustable control valves for closing speed, latching speed, and backcheck. It shall have adjustable spring power adequate to fully close the door when released from the half-open position. The end door threshold shall have two 1/2-inch inside diameter drain holes, one at each end. The louvers in the grille shall be positioned to limit air drafts in the area of the seated operator.

In addition to the above, the door at the "F" end shall be equipped with two wedge-type latches having lever-type handles for operation from both sides of the door. These additional latches are for use when the door is at the front or rear of a train, and handles shall be arranged so that vibration shall not cause the latch to move to the opposite position, while either engaged or disengaged. Latched and unlatched positions of handles shall be the same as on the existing cars.

3.8.3 Cab Door

A hinged door shall be provided in the longitudinal cab partition. It shall swing into the aisle. It shall have a fixed rectangular window in the upper portion, as shown on Contract Drawing 97936-003, and its top edge shall clear the underside of the ceiling by at least 1/2-inch while its bottom edge shall be raised above the floor for clearance of the floor covering. A self-locking latch shall be provided which will require a door key for access to the cab from the aisle, but will permit exit from the cab by turning a tee handle only. The lower portion of this door shall contain a louvered grille for ventilation purposes.

The cab door shall be able to be latched in two positions: transverse, creating a full-width cab at the front end of the train; and longitudinal, to enclose the console and other controls and to permit use of the aisle and the two-passenger seat on the left side of the cab area by passengers. The cab door shall also be able to be swung at least 90 degrees beyond the transverse position into the passenger area, to facilitate egress.

Door stops, or other swing limiting devices, shall be provided to prevent the door from damaging itself or other parts of the car and shall not present a tripping hazard.

3.8.4 Door Construction

Side and end doors shall be of plymetal, honeycomb, or hollow metal construction, internally reinforced and joined into an integral unit by resistance welding. The cab door shall be of melamine-faced plymetal.

The outside of the "R" end door and both sides of side doors shall be faced with metal of the same specification as is used for the car structure with finish to match. The outside of the "F" end door is to be colored as shown on Contract Drawing 97936-005. The inside of both end doors shall be covered with melamine to match the interior of the car.

Body end and side doors shall be able to sustain a load of 200 lbs. concentrated in a 4-inch square area and applied perpendicularly to the plane of the door at the center of the front edge, while the door is supported at both ends, with a maximum deflection of 1/4-inch and no permanent deformation. Joints and edges shall be sealed against entry of moisture. Reinforcements shall be provided for the attachment of all door hardware and operating arms. Doors shall be free of internal vibration, shall not vibrate in their supports and guides, and, if hollow, shall be insulated as to comply with Section 3.12.

Side door window corners shall have the same radii as the passenger side windows and shall be formed out of inside and outside door sheets with edges formed inwardly and welded together.

3.8.5 Door Hardware

Exposed portions of latches and locks on the inside or outside of the car shall be constructed of white bronze, stainless steel, or anodized aluminum. Internal parts of the locks shall be bronze or stainless steel.

Wedge-type latches on body end doors shall be of a design which will not permit injury to fingers in being operated.

Swing-limiting devices, rollers, or stops shall be provided as required to prevent damage in the event that the cab door and the body end door are both opened at the same time.

The exterior portion of the lock on the "F" end door shall be colored to match the door.

3.8.6 Alternate Door Pocket Arrangement

If the valance-mounted side door operators are used, as described in Section 6.2, hinged valance panels (18 per car) above and adjacent to each passenger side door opening shall be provided.

Hinged valance panels shall be easily removed and shall be secured using a half hinge design and captive fasteners that require no tools to operate in the event it is necessary to gain access to the door cut-out mechanism. Quarter-turn, coin slotted fasteners are preferred on adjacent hinged valance panels.

Two safety straps shall be provided for each of the valance panels.

The straps shall be located at approximately the quarter points of the panels and shall be as short as possible without interference with the operation of the panels or the side door mechanism. The straps shall be connected to the carbody on one end. At least one end of each strap shall be removable so that the panel can be completely removed from the carbody for maintenance.

The straps shall be coated or covered steel cable with compression type ring-lug terminals.

3.9 WINDOW CONSTRUCTION

3.9.1 Passenger Side Windows

Passenger side windows shall be fixed. The Contract Drawings 97936-002 and 97936-003, are intended to depict only the appearance of the sash, not the design details.

Construction of the sash shall permit easy replacement of glazing from inside the car. Glazing shall be retained in an endless GRS rubber or neoprene section, and shall be arranged for easy reglazing without the need for sealing compounds.

The windows shall not leak water, either into the interior of the car or into the car structure.

3.9.2 Operator's Side Windows

The side window at the cab and the side window directly opposite on the other side of the car shall be a two-piece vertically split, horizontally sliding sash. The sash shall slide to enable the operator to lean out and view the side of the train with ease. A minimum clear opening width of 12 inches shall be provided when the window is fully open. A latch, operable from the inside only, shall be provided to hold the window closed. On the side opposite the cab, a door key shall be required to open the sash. It shall, however, be possible to close the window from outside the car, and it shall automatically latch when closed. The front half of the sash shall be movable and shall be located on the inside track.

3.9.3 End Windows

End windows at the "F" end shall be of the single, laminated safety glass, fixed type. The glass shall be set in a stainless steel or anodized aluminum frame having an inside clear opening smaller than the glass so that it cannot be forced into the car. It shall be retained in a continuous neoprene glazing section, and shall be replaceable from the outside of the car without the need for sealing compounds.

End windows at the "R" end shall be fixed type, constructed the same as the passenger side windows.

The shape and placement of the windows shall be as shown on Contract Drawings 97936-005 and 97936-006, which are intended to depict only the appearance of the window, not the design details.

3.9.4 Door Windows

Side entrance doors and body end doors shall be equipped with windows of the single laminated safety glass fixed type set in neoprene glazing strips, and having no separate sash.

Side door construction shall permit easy replacement of glazing from inside the car.

The "F" end body end door shall have an inside opening smaller than the glazing size so that the glass cannot be forced into the car.

3.9.5 Sign Openings

The glazing at destination signs shall be supported directly in the car structure with neoprene glazing strips, and having no separate sash.

3.9.6 Windscreens

Glazing in upper part of windscreen shall be arranged as shown on Contract Drawing 97936-004.

3.9.7 Cab Partitions and Door

Glazing in cab partitions and cab door shall be supported directly in neoprene glazing strips, with no separate sash.

3.10 GLAZING

3.10.1 General

All passenger windows shall be a double glazing assembly consisting of 1/4-inch safety glass and 1/4-inch polycarbonate with an air gap that prevents touching under all atmospheric conditions. The safety glass will be sufficiently tinted and positioned to the outside and the mar-resistant polycarbonate (GE MR-5000 or equal) shall be inside.

All double-glazed side passenger windows shall be hermetically sealed units. The two pieces of glazing shall be separated by an air gap. A spacer bar filled with a desiccant shall be placed within the air gap, parallel and adjacent to the edges of the glazing material. A butyl sealant shall be used as the primary vapor sealant on both sides of the desiccant spacer. The edges of the window unit shall be sealed with a polyurethane sealant along the entire perimeter, filling all voids.

Glazing in windows and doors shall have the following characteristics:

Location	Thickness (inch)	Visible Light Transmission	Type/Color
Side Windows, Passenger Area including sliding window opposite cab	1/4-inch + 1/4-inch	40% to 50%	Bronze Tint Laminated Sheet and Clear Polycarbonate
Side Window, Cab	1/4-inch + 1/4-inch	Clear	Laminated Sheet and Clear Polycarbonate
End Window, "R" End	1/4-inch + 1/4-inch	40 to 50%	Bronze Tint Laminated Sheet and Clear Polycarbonate
End Window, "F" End, Passenger Side	See Section 15.8	Clear	Laminated Sheet
End Window, "F" End, Cab Side	See Section 15.8	Clear	Laminated Sheet
Windows, Cab Partition	1/4-inch	7 to 12%	Bronze Tint Laminated Sheet
Windows, Destination Sign	1/4-inch	Clear	Laminated Sheet
Windows, Windscreen	1/4-inch	Clear	Laminated Sheet
Side Doors	1/4-inch	40 to 50%	Bronze Tint Laminated Sheet
End Door, "R" End	3/8-inch	40 to 50%	Bronze Tint Laminated Sheet
End Door, "F" End	See Section 15.8	Clear	Laminated Sheet
Cab Door	1/4-inch	7 to 12%*	Bronze Tint Laminated Sheet
"Map" Panel	1/8-inch	Clear	Polycarbonate

* Visible light transmission for cab door window may be modified if necessary to meet the requirements of Section 5.7.6.

All polycarbonate shall have an approved abrasion resistant coating equal to General Electric MR-5000 or Dow Tuffak CM-2.

Glazing shall be as specified herein and in Section 15.8. All edges of glazing shall be ground smooth and rounded.

3.10.2 Glazing Seal Sections

Glazing seal sections shall be designed to permit easy replacement of broken glass or polycarbonate without the use of grease or of a compound that stains, while making a tight weather seal. Glazing details shown in drawings are intended only to depict appearance. Glazing sections shall be continuous and shall provide proper edge engagement for polycarbonate under all temperature conditions; square corners shall be formed by injection molding.

Glazing strips shall meet the Flame Spread Index of the flammability guidelines in Section 15.25 and have the mechanical strength and other characteristics required consistent with the lowest smoke generation possible.

3.11 SEATS

3.11.1 General

Passenger seats shall be arranged as shown on Contract Drawing 97936-001. The required appearance of the seat is shown on the Contract Drawings 97936-014 and 97936-015. Bottom and back cushions shall be duplicates of and physically interchangeable with the cushions now installed in the Authority's existing cars. The dimensions, shape, and mounting arrangements will be defined by the bottom and back cushions from the existing cars, two of each of which will be furnished to the Contractor by the Authority. The Contract Drawings 97936-001, 97936-014 and 97936-015, shall be followed for dimensions and mounting arrangements. The Operator's seat shall be located as shown on Contract Drawing 97936-001.

3.11.2 Construction

Seat framing shall be constructed of suitable gauge stainless steel, painted carbon steel, or aluminum. Edges exposed to passengers, operators, or maintenance personnel shall be rounded smooth. Exposed back pans shall be formed of 1/8-inch thick integrally colored glass-filled polycarbonate, or approved equal. Alternatively, back pans of glass-fiber-reinforced polyester may also serve as seat shell. Exposed back pans shall have an approved hair cell texture finish.

Backs shall be recessed, for knee room, in the lower portion, as shown on Contract Drawing 97936-014.

Arm rests shall be provided at the aisle side of each transverse seat and at the side away from the windscreen of each longitudinal seat. The armrest required shall be an integrally-colored formed thermoplast, which shall be capable of taking high impact loading and surface abrasions, shall color-match the seat upholstery, and shall be wear-resistant. The exposed surface of the armrest shall have a surface texture to match the seat upholstery. The armrest shall be of both right-hand and left-hand configurations to properly fit the seat and clear the cushions.

3.11.3 Seat Supports

Transverse seats, except back-to-back seats and seats at the end of the car, shall be supported solely by the side frame of the car. None of the supporting structure shall be visible.

Back-to-back seats shall be supported by full base enclosures of steel. Transverse seats at the ends of the car and longitudinal seats shall be either installed on supports, which shall be covered with a full enclosure, or supported by full base enclosures of steel or aluminum. These enclosures shall be entirely covered on exposed surfaces with carpeting identical to that used on the floor of the car. The enclosures shall have grilles where necessary for ventilation of apparatus housed therein and for the discharge of heat from floor heat elements contained in the seat enclosure. The grille design shall have the approval of the Authority.

The design of all seat enclosures shall allow a minimum of 2 inches toe space from the seat edges.

The attachments of seats to the side frame or to the wall shall be designed so as not to create dirt-holding pockets.

3.11.4 Cushions

Each seat bottom cushion and seat back cushion shall be constructed as an assembly. The bottom cushion assembly shall consist of a support plate made of suitable gauge stainless steel, painted carbon steel or aluminum. A molded or fabricated neoprene foam cushion shall be glued to that plate and the entire combination shall be then covered with fabric-backed vinyl upholstery on all exposed surfaces. This covering shall be mechanically secured to the cushion support plate.

The seat back cushion shall consist of a suitable gauge aluminum back plate with the neoprene foam cushion being glued to it and the entire combination then covered with the fabric-backed vinyl upholstery as specified above.

Both the seat bottom and back cushion assemblies shall have painted spring steel retention clips attached to their back surfaces. When the cushions are installed to the seat structure these clips shall engage with that structure and thereby securely hold the cushion assembly in place insuring that they will not cause any noise during car operations. The overall dimensions of the cushion assemblies shall be within ±1/4-inch tolerance except that the fit of the cushions into the seat shall not have visible gaps. It is expected that the Contractor will work very closely with the Authority to achieve approval of the seat.

The cushions shall be manufactured of one-piece molded or fabricated neoprene foam. The back cushion shall be of Medium density with an Initial Load Deflection (ILD) value of 30 ± 8 lbf, and the bottom cushion shall be a Firm density with an ILD value of 40 ± 8 lbf when tested to ASTM-D-1055-90 in a 70°F ambient temperature to 25% compression. These values are for the completed cushion assemblies including the upholstery material and the mounting plate.

MOD 3 Unless otherwise approved, the seat upholstery material shall be made of transportation grade woven fabric-backed vinyl with a weight of 38 ounces per linear yard. The material shall be capable of passing all of the following physical tests for textile products which come from the Federal Test Method Standard No. 191, latest revision. Values shown are minimum allowable for testing in both warp and filling directions.

A.	Test No. 5106, Tensile Strength:	110 lbs.
B.	Test No. 5110, Seam Strength:	85 lbs.
C.	Test No. 5134, Tear Strength (tongue):	10 lbs. warp; 12 lbs. fill
D.	Test No. 5136, Tear Strength (trapezoid):	36 lbs. warp; 42 lbs. fill
E.	Test No. 5660, Colorfastness (100 hours):	No Change
F.	Test No. 5970, Adhesion:	10 lbs.

Abrasion tests on this material shall satisfy the requirements of Federal Specification CCC-C-700F, Class 2 Option (b), Treatment a.l.

3.11.5 Handgrips

A full-width stainless steel tubing handgrip shall be provided on the back of all transverse seats, except that only one handgrip shall be provided at back-to-back seats and no handgrip shall be provided at transverse seats at the ends of the car.

3.11.6 Access to Apparatus

Convenient access, for Authority personnel only, shall be provided to any equipment located under seats.

Where equipment is located under longitudinal seats or transverse seats at the end of the car, the bottom cushions shall be removable. If access to the equipment is facilitated thereby, back cushions shall also be removable.

Where equipment is located under back-to-back transverse seats, the entire seat assembly, above the level of the bottom of the seat cushions, shall be hinged. Hinges shall be designed to support the full weight of the seat if the safety straps are disconnected. The axis of the hinge shall be longitudinal and the seat assembly shall be able to be rotated 110 degrees and then removed, if desired, for better access, without the need for any tools. A torsion or gas spring shall be provided to assist in raising the seat assembly and shall insure that the seat assembly will remain open during maintenance. The spring shall provide at least one-half the effort needed to raise it. The spring shall be removable with the seat assembly. Safety straps, permanently coupled at one end, shall be provided to limit the seat assembly travel to 20 degrees past the vertical position to prevent over-extension of the spring.

3.11.7 Operator's Seat

The Operator's seat shall be designed to maximize Operator comfort and be compatible with the space constraints of the cab. It shall allow rotation from the normal forward facing position at least 90 degrees toward the left to face the car centerline. No arm rests shall be provided. Cushions shall be of neoprene foam, covered with transportation grade fabric-supported vinyl and of a quality equal to that used on the passenger seats. The seat design shall be demonstrated in the cab mockup for approval of the Authority.

The Operator's seat shall provide adjustments of a height range of 17 inches to 20 inches and not less than 4 inches for fore-and-aft movement. None of the moving parts of the seat shall require lubrication. Location of the seat, both vertically and horizontally, shall be established using the Cab mock-up.

3.11.8 Flip-Up Seat

A padded seat shall be provided on the rear surface of the left side of the cab partition. The bottom cushion shall be held normally in the stored (flipped-up) position by springs or wave washers so that the adjacent area is available to a passenger in a wheelchair, but it shall be readily lowered to the sitting position and held there with the minimum force or weight. The bottom and back cushions shall have at least 1-inch-thick padding. Seat bottom and back angles shall approximate those of the other passenger seats if space permits.

3.11.9 Strength Criteria

Seats and their attachments to the carbody shall withstand, without permanent deformation, the loads to be expected in transit operation, but in no case less than the following:

Location	Load
Seat back, perpendicular to plane of back, either direction, 3-inches below top of back:	465 lbs. per person
Seat bottom, vertical downward, center of seat:	310 lbs. per person
Seat bottom, vertical, downward, center front of seat:	250 lbs. per person
Arm rest, horizontal, both directions, perpendicular to length of car:	155 lbs.
Arm rest, vertical downward:	250 lbs.
Handhold, in any horizontal direction:	310 lbs.

3.11.10 Interchangeability

All seat bottom cushions, seat back cushions, and same-hand armrests shall be completely interchangeable.

3.12 INSULATION

3.12.1 General

The floor, roof, sides, ends, and doors of the cars shall be thermally and acoustically insulated. The materials used for this purpose shall be at least as fire resistant as glass fiber insulation. Material used for vibration damping shall meet the flammability and smoke emission requirements specified in Section 15.25.

Glass fiber insulation which is in contact with aluminum shall be of the boro-silicate type. Insulation used in the roof, sides and ends shall be retained in position by the use of approved mechanical fastenings.

3.12.2 Heat Transfer

The heat transfer through the carbody (doors closed) shall not exceed 1,000 BTU/hour/°F, with an air velocity at the surface of the car of 5 mph or greater, and measured in accordance with Section 7.8.2.2.

3.13 ATC APPARATUS LOCKER

3.13.1 Location

The ATC apparatus shall be located in the "A" car housed in a floor-to-ceiling cabinet in the sidewall directly behind the Operator's cab and between it and the first side door.

The depth of the cabinet shall be the minimum possible, in order to provide the greatest amount of visibility to the Operator to view the passenger compartment of the car.

3.13.2 Cabinet

The cabinet housing the ATC apparatus shall be constructed of 1/2-inch thick melamine faced plymetal with doors of the same material for access to equipment, and the necessary grilles or louvers for air circulation. Ventilation fans, if necessary, shall be provided for equipment cooling. Fans shall be provided with the required guards for protection of Authority employees. Cabinet doors shall have stainless steel piano hinges and locks operable with the standard door key. A diagram identifying the various components within the ATC cabinet shall be applied to the inside of the cabinet door.

3.14 BETWEEN CAR BARRIERS

The ends of all cars shall be equipped with an ADA-compliant barrier on both sides to prevent passengers from inadvertently walking off the platform and falling between the cars. The barrier design shall minimize wind resistance, be rattle-free when the car is operating as lead car of a consist, and shall permit the cars to operate compatibly when coupled to existing Authority vehicles, which do not have ADA barriers installed. The style and placement of the barrier shall be approved by the Authority.

3.15 TESTS

3.15.1 Watertightness Test

All areas of the car sides, ends, and roof, including doors and windows, shall be given a complete test for watertightness. The tests shall be made before installation of sound deadening material, thermal insulation, and interior finish. 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 per minute shall be delivered to each square foot of surface being tested, and the nozzle velocity of the water shall be not less than 150 feet per second. Any water seepage occurring in the nose seal area between the door leaves will require the approval of the Authority.

The Contractor may defer the watertightness test until the complete carbody is assembled. The Contractor may use individual tests to demonstrate the watertightness of large components such as sides, roofs, and ends, with supplemental testing of the carbody restricted to proving the watertightness of connections between tested components and of doors and windows and other areas not previously tested.

All spray applications shall run for 10 minutes before the inspection for leaks begins, and shall run continuously during the inspection.

Underfloor boxes that are required to be watertight shall receive a water test similar to the watertightness test of the carbody. The watertightness test shall be successfully performed one time on the individual boxes prior to installation underfloor, in a manner simulating the conditions as would be expected with the boxes mounted on the car, and again during the test of the complete carbody. During test of the boxes after installation, the required spray is to be directed at the exposed sides and ends of the boxes as would normally occur during car washing operations.

The fresh air intake ducts in the car roof shall be tested once, in a similar manner, with ventilating fans running at full speed, to determine the effectiveness of the water-excluding features of the ductwork. On all cars the fresh air intake ducts shall be water tested for workmanship.

The traction motor lead connections specified in Section 10.3.14 shall also be given a water test. The water flow rate and velocity shall be as specified for the carbody water test.

3.15.2 Body Compression and Vertical Load Tests

A. The first carbody structure shall be tested to prove compliance of the structure with the Specification. The carbody shall be structurally complete, and shall exclude such items as exterior and interior trim, windows, doors, seats, lights, insulation, and interior lining. Underfloor apparatus, however, may be installed.

B. During the compression test, the carbody shall be supported on trucks or a simulation thereof to allow longitudinal movement. The carbody shall be loaded with sufficient dead weight to bring the total body weight up to that of a ready-to-run car. This loading shall be distributed in proportion to the distribution of weight in the finished car. The pressure of the testing machine shall be applied by hydraulic power and the force measured by a means independent of those producing the force, to eliminate errors due to friction. Sufficiently recent calibration of the measuring device shall be available to assure accuracy to within ± 1%.

The test load of 200,000 lbs. shall be applied to the anti-climber, at its center, by means of a ram not over 24 inches in width. The load shall be applied in these steps: 50,000 lbs., 100,000 lbs., 150,000 lbs., 175,000 lbs., and 200,000 lbs. The load shall be reduced to not more than 4,000 lbs. after each step. Strain gauge readings shall be taken at each load increment and at each relaxation of load. The ram shall be supported, but shall remain free to move longitudinally with respect to the car end. Cushioning means, such as lead sheets, shall be provided to assure uniform bearing on the anti-climber.

In a similar manner, a test load of 135,000 lbs. shall be applied to the coupler anchor. For the purpose of determining compliance with this Specification, a member shall be considered as having developed permanent deformation if the yield point or yield strength in the appropriate direction—tension or compression—as published or otherwise issued by the material manufacturer is reached or exceeded. For material for which the manufacturer publishes a yield point, strain gauge readings taken as directly proportional to the claimed yield point stress shall be used to determine whether or not the point has been reached.

For material for which the manufacturer publishes a yield strength, strain gauge readings corresponding to a directly proportional reading for the yield strength plus 0.002 inch per inch shall be used to determine whether yield has occurred, but this is allowed only in the case of first-time loadings of such members. For the second and subsequent loadings of material for which the manufacturer of that material publishes a yield strength, yielding shall be determined by multiplying the measured strain by the manufacturer's published modulus of elasticity and comparing the result with the manufacturer's published yield stress. In all cases, for the calculation of strain at the published yield point or yield strength values, the modulus of elasticity shall be taken as the manufacturer's published value.

If a reading indicating attainment of the yield point or yield strength is found on any strain gauge, the Contractor may request a retest prior to redesign; and the Authority may grant this request with the provision that up to four additional strain gauges in the same general area will be required to determine the effects on surrounding material of the plastic deformation that has presumably occurred, and to determine whether stress values as great as the published yield point or yield strength are reached in the retest. If the high reading has been accompanied by visible evidence of distress in the member, a design correction will be required regardless of strain gauge values indicated in any retest.

The zero point for strain gauge readings may be the readings found after relaxation of total buff loads up to the 200,000 lbs. provided that no reading encountered at intermediate load levels shall have indicated attainment of the yield point or yield strength. If such a reading has occurred at a lower level, the additional strain gages required in the paragraph immediately preceding may be required prior to imposition of the 200,000-lb. load.

During the compression test, vertical deflections shall be measured in the region of the side sill by means of a wire stretched between the car corner posts. This wire shall be fastened at one end and kept tight at the other end by means of a weight, with the wire passing over a pulley. Deflections shall be measured to the nearest 0.01-inch, using scales with mirrors located at the body corner posts, at bolsters, and at the center of the car. Equivalent methods for measuring deflection, equally accurate, may be substituted for the foregoing. Deflections shall be considered as the average of the readings taken on both sides. The deflection measured at any preliminary load application may be disregarded to eliminate the influence of whatever friction may be present. Deflection between bolsters and center of car shall be determined by plotting the data determined above.

C. The same carbody shall also be subjected to a vertical load test. During this test, strain gauge readings shall be zeroed with the empty carbody shell at no load. The zero point for the strain gauges may be established after relaxation of a preload equivalent to 1g (carbody ready-to-run weight) plus absolute maximum passenger load (37,800 lbs.) providing that no loadings encountered at intermediate load levels shall have indicated attainment of the yield point or yield strength. If such a reading has occurred at a lower level, the additional strain gauges may be required prior to imposition of the maximum loads. A test load equal to the ready-to-run weight of the carbody (1g) plus the absolute maximum passenger load is to be applied to the empty carbody shell, the test load being applied in five increments. The test loads may be applied by means of weights or jacks, and shall be distributed in proportion to the distribution of weight in the finished car.

During the vertical load test a measurement of carbody camber is also to be made with the empty shell, with the empty shell loaded to the ready-to-run weight, and with the carbody at absolute maximum passenger load. Camber shall be as required in Section 3.3.1.

All side doors on one side of the car shall be installed, complete with operators, thresholds, and all sealing and weatherstripping; and at each increment of test load the doors shall be opened and closed electrically by means of the operators. Any failure to operate at the prescribed speed, or any indication of binding, shall require corrective action to be taken, by the Contractor, to the car structure, to the door arrangement, or both. During this same test, the changes in transverse width of the car at the belt rail and top of the door due to door post bending and changes in the dimensions of the door opening due to carbody shear loads shall be measured and recorded.

The car will be considered to have met the specification with respect to vertical load if:

1. Plotted vertical deflections (measured on both sides of the car midway between bolsters and taken as the average thereof) did not deviate, at any load increment, from a straight line, drawn from the origin to the deflection at the absolute maximum passenger load, by more than 5% of the deflection at the absolute maximum passenger load.

2. Maximum recorded stresses in principal structural elements did not exceed the corresponding allowable stress values which have been selected by the Contractor and approved by the Authority prior to starting the test program.

3. Recorded residual vertical deflection between bolsters, following removal of the maximum vertical test loading, does not exceed 0.03-inch.

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

5. The carbody positive camber, as measured during the vertical load tests, is 1/2- to 3/4-inch between the carbody bolsters with the carbody shell loaded with a test load equal to the ready-to-run weight of the carbody, and did not deflect to a negative camber greater than 1/8th inch when loaded so as to equal the ready-to-run car weight plus absolute maximum passenger load; and MOD 2

6. Side doors operated at the prescribed speeds without binding at all test load increments.

D. With the same strain gauges in place, the carbody, loaded to equal its ready-to-run weight, shall be lifted at diagonally-opposite corners until clear of all other support except at one other corner, to determine compliance with the torsional strength requirements of Section 3.3.1. Twist shall be measured; and the absence of permanent deformation shall be determined.

E. The following quantities of strain gauges shall be applied, at points agreed upon in advance with the Authority:

1. Compression Test: 75 to 100 gauges
2. Coupler Anchor Test: 20 to 30 gauges
3. Vertical Load Test: 75 to 100 gauges

SECTION 4
COUPLER, DRAWBAR AND DRAFT GEAR

TABLE OF CONTENTS

SECTION 4
COUPLER, DRAWBAR, AND DRAFT GEAR

4.1 GENERAL

4.1.1 Arrangement

A coupler, which provides fully automatic mechanical, electrical, and pneumatic connections between married pairs (including existing Authority cars), shall be provided at the “F” (cab) end of the car. A flanged drawbar shall be provided at the “R” (non-cab) end of the car. The coupler, drawbar, and draft gear shall be attached to the carbody using either clevis, ball, or other approved type anchorages.

4.1.2 Strength Requirements

The mechanical coupler, drawbar, and draft gear assembly shall be able to withstand loads of 135,000 lbs. in compression and tension with no permanent deformation.

The anchorage (the attachment of the coupler, draft gear, and drawbar to the car underframe) and the car underframe shall be able to withstand, without permanent deformation, all loads that can be transmitted to them by the coupler, draft gear and drawbar.

All parts of the coupler on which it is possible for a man to step in attempting to climb to the end door shall withstand, without permanent deformation, a vertical load of 360 lbs.

4.1.3 Geometric Requirements

The coupler, drawbar, and draft gear shall be designed and constructed so that coupled cars shall be able to negotiate the horizontal and vertical curves specified in Section 2.1, as well as all normal track irregularities, when all wheels on one car are fully worn and the air springs are deflated and all wheels on the adjacent car are new and the air springs are over-inflated—causing the trucks to contact the “up-stops.”

The gathering range of the coupler shall not be less than 3-3/8 inches in all directions with the coupler at the nominal operating height.

These requirements apply to new cars coupled together and new cars coupled to existing Authority cars.

4.1.4 Coupler Operation

The operation of the coupler shall be completely automatic when coupling. When cars are brought together so that the couplers are fully engaged mechanically, the couplers shall lock and the air and electrical connections shall be made automatically, with no further action required on the part of the Operator or others.

When the cars are coupled together, operation of the uncoupling valve or switch on either car shall effect an uncoupling. During the uncoupling cycle the electrical trainline connections to the coupler head shall be broken by the rotary switch specified in Section 4.9.

No brake application shall be caused on the part of the train from which an intentional uncoupling is initiated. On the other part of the train (and on both parts of the train, in the case of an accidental uncoupling) an emergency brake application shall be made by venting of air.

Provision shall be made for disconnecting the electrical trainline connections only, or for closing the air connection only, or both, without mechanical uncoupling. Disconnection controls may be combined with the coupler control. The air supply line to the coupler control manifold shall be protected by an air filter, equivalent to the filter on the Authority's existing cars. Closing of any air connection shall be between the carbody piping and any hoses, so that hoses can be removed without bleeding car air. End cock handles shall be lockwired in the open position.

Uncoupling valves or switches shall be designed to return from the uncoupling position when released. The control device shall be provided in the cab at the "F" end of the car. A guard shall be provided over each uncoupling valve or switch to prevent accidental operation.

Provision shall also be made for manual uncoupling of the coupler in the absence of air and electricity without the use of any special tools other than the manual uncoupling level handle defined herein. The manual uncoupling lever shall be operable from the side of the car by means of a nonconductive extension handle, which shall be provided to eliminate the need for individuals standing between cars. The manual uncoupling level handle shall be coated with OSHA Orange, as specified in Section 5.15, and shall be stored on the vehicle in accordance with Section 3.5. The manual uncoupling mechanism shall be able to be latched in the "uncouple" position, where it will remain until deliberately returned to the normal position. The latch used to hold the manual uncoupling mechanism in the "uncouple" position shall be wired in the inactive or stored position, requiring that the wire be cut or broken to use the latch.

4.1.5 <u>Drawbar</u>

The drawbar used at the "R" end of the car shall incorporate a flange connection to facilitate separation of married pairs without removal of the drawbar. Pneumatic connections shall be by threaded hose connections with swivel couplers at both ends. Electric jumper cables, as described in Section 4.7, and the pneumatic hoses shall be supported on the drawbar.

In the event of an accidental separation at the "R" end drawbar, an emergency brake application shall be made by venting of air on both parts of the train. If the design does not completely exhaust the air trainline under these circumstances, satisfactory valving shall be provided to ensure an emergency brake application. A catch bracket or other approved means shall be provided to prevent the drawbar from falling onto the roadbed should separation of the cars of a married pair occur.

It shall be possible to completely remove the coupling hose in the immediate area between the cars. Vented cutout cocks between the carbody piping and coupler hoses shall be provided. Closing of the cutout cock shall vent the hoses to permit their removal without bleeding car air. The cutout cocks shall be lockwired in the open position and shall be operable from between the cars.

4.1.6 <u>Material</u>

The coupler and drawbar shall be of high strength steel. Fasteners used in the construction of the mechanical, electric, and pneumatic couplers shall be stainless steel unless otherwise approved by the Authority.

4.1.7 <u>Drainage</u>

Drainage for rain and melted ice and snow shall be provided wherever it can accumulate.

4.2 MECHANICAL COUPLER

The mechanical coupler shall be a slack-free, hook-type coupler capable of coupling with duplicates of itself and shall be fully compatible in all respects with, and capable of coupling with, the couplers on the Authority's existing cars. The mechanical coupler design shall provide for the replacement of hooks, alignment pins, bushings, and other wear items.

The locking device of the coupler shall lock automatically when couplers are fully engaged, and shall be unlocked by power (or manually) when uncoupling.

4.3 DRAFT GEAR AND AUTOMATIC RELEASE FEATURE

4.3.1 Draft Gear

The draft gear shall be of the double-acting cushioned type, or approved equivalent, and shall be pre-loaded. Its deflection shall not exceed 1-1/2 inches per car-end before the automatic release feature described in Section 4.3.2 permits the coupler head to move back or the drawbar to collapse.

4.3.2 Automatic Release Feature

An automatic release feature shall be incorporated in the coupler and drawbar which, upon a buff load of approximately 125,000 lbs., will permit the coupler head to move back or the drawbar to collapse and the anti-climbers to engage and transfer the buff load to the car structure. Sufficient additional travel shall be provided so that no transverse load is taken by couplers, drawbars, and draft gear after the release feature has been actuated and anti-climbers engaged.

4.4 COUPLER SUPPORT AND CENTERING DEVICE

4.4.1 Coupler Support

The coupler draft gear shall be self-supporting and shall mount to the car underframe at the coupler anchorage. Alternatively, coupler carriers, which meet the geometric requirements of Section 4.1.3 and support the coupler at its nominal height, may be provided.

4.4.2 Centering Device

Couplers shall be equipped with a self-centering device, or a latch of approved design, which will hold the uncoupled coupler on the center line of the car, within a tolerance of one-half of the gathering range in either direction. The resistance of the centering device shall not interfere with the coupling operation. The centering device or latch shall be designed so that it can be disengaged, and the coupler moved manually, to permit coupling in circumstances in which the coupler will be off-center.

4.4.3 Wear Plates and Lubrication

Coupler and draft gear pivots and carriers shall be equipped with shims, replaceable bushings, wear plates, or other means of compensating for wear. Devices requiring lubrication shall be avoided but, if required, shall be designed so as not to require lubrication more often than annually.

4.5 PNEUMATIC COUPLER

A pneumatic connection for the brake air pipe shall be provided as part of the mechanical coupler head at a port in the bottom of the coupler face. This pneumatic connection shall be fully compatible with the pneumatic connection on the couplers on the Authority's existing cars.

4.6 ELECTRIC COUPLER HEAD

4.6.1 General

Nonretractable electric coupler heads shall be provided, mounted to the sides of the mechanical coupler. Each head shall have 86 contacts, arranged per Contract Drawing 97936-019. The electric coupler heads shall be so located and arranged that they will make all electrical connections, and be fully compatible in all respects, with the electric coupler heads on the couplers on the Authority's existing cars. The electric coupler heads shall maintain positive contact under all conditions, and shall be capable of withstanding all of the coupling impacts to which the car couplers will be subjected in service. Provision shall be made to safeguard the electric coupler heads from damage in the event of improper alignment when coupling.

4.6.2 Operation

Electrical isolation shall be accomplished automatically during normal operation by the use of a rotary switch, as specified in Section 4.9. An additional manually operated rotary switch shall be provided for electrical isolation only, as required by Section 4.1.4. The handle of the manually operated rotary switch shall be coated with OSHA Orange, as specified in Section 5.15.

4.6.3 Loop Circuits

Contacts for the necessary number of loop circuits, plus one spare loop circuit, shall be provided in the rotary switch. Loop circuit contacts shall be closed when uncoupled.

Contacts for the ATC system shall be provided; those piloting the coupler relay shall be double-break type. The coupler relay shall be of the vital type. Any failure shall cause the "coupled" condition to be indicated.

4.6.4 Contacts

Each electric contact shall be of sufficient ampacity to handle the maximum current to which it will be subjected, and shall be of the spring-loaded button-type, with a silver contact face. Spring pressure for each electrical contact shall be the same as that used on Authority's existing cars. It shall be possible to remove electrical contacts from the face of the electric coupler for maintenance purposes.

Spare electric contacts shall each have a capacity of at least 30 amperes.

4.6.5 Protection

Electric coupler contacts shall be protected by steel covers, which will be held tightly closed by springs and automatically pivot clear during the coupling of cars. The covers shall operate automatically when coupled with, and shall be fully compatible in all respects with the electric head covers on the couplers on the Authority's existing cars. The covers shall be coated OSHA Orange, as specified in Section 5.15, with the phrase "DO NOT STEP" stenciled over the orange vertical faces in 1-inch-high black letters.

Suitable seals shall be provided to exclude moisture from the contacts when the covers are closed, when coupled to duplicate electric heads, and when coupled to electric heads on couplers of the Authority's existing cars.

4.6.6 Connections

Connections to the back of the electric coupler contacts shall be by means of service-proven terminals, and shall be accessible for maintenance. Individual contacts shall be clearly and permanently identified on the front and rear of the electric coupler face by engraved or embossed letters/numbers located adjacent to each. The lettering shall be the largest possible compatible with electrical coupler design. Fifty templates containing the contact identification information shall be provided for shop use. The templates shall be fabricated from rigid, nonconducting material and perforated so that they can be slipped over the array of contacts while maintenance checks are performed.

Connections from the electric couplers to the carbody shall be by means of multiple conductor cables or enclosed wire bundles. Locking-type plugs and receptacles shall be provided at the trainline junction box and strain relief fittings provided at the electric coupler head. Plugs and receptacles shall conform to the environmental and performance requirements of Military Specification MIL-C-005015E, parts MS3400 and MS3406, Classes F or R. The plugs and receptacles shall be keyed to preclude the insertion of a plug into an incorrect receptacle. Critical circuits shall be so located as to minimize the effects of connector or jumper failure.

Within the trainline junction box, the cables connected to the receptacles shall terminate at terminal blocks. The cables shall contain conductors for, and the terminal blocks shall contain studs for, the spare contacts and shields.

4.6.7 Spare Trainlines

Ten spare wires shall be run from end to end of the car. They shall be No. 12, and two of them shall be shielded. They shall be plainly identified by means of nonconductive wire markers. The wires shall terminate in the trainline junction box at each end of the car but shall not be connected to terminal blocks. They shall be bundled neatly and clamped in an unused corner of the box.

4.6.8 Trainline Data Acquisition Module

A data acquisition module (DAM), to monitor the trainlines required in Section 12.6, shall be provided in the trainline junction box or other suitable location.

The listed trainline signals shall be monitored and stored with time and date stamping the DAM. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed network, to the central vehicle monitoring system equipment specified in Section 12.6. Non-volatile data storage shall be 15 minutes minimum. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VMS central unit (VCU). The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the trainline signals, analog or digital, to serial packages and store for transmission to the VCU via high speed network or RS485, in accordance with Lon Works serial data communication or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

4.7 "R" (NON-CAB) END ELECTRIC JUMPER CABLES

At the "R" end of the car, electrical car-to-car connections shall be made by means of jumper cables, which shall be supported on the drawbar. Both ends of the jumper cables shall be fitted with plugs and the carbodies shall be fitted with receptacles, as specified in Section 4.6.6, and shall provide sufficient wires to make all active connections plus a total of at least 20 spare wires. Spare wires shall be No. 12 and four of them shall be shielded. Separate jumper cables shall be used for low-level communication circuits.

A trainline junction box shall be provided at the "R" end of the car. It shall contain terminal blocks with studs for the spare conductors, shields, and the active conductors.

4.8 GAUGES

Six sets of gauges, which will provide acceptance standards for every surface critical to the operation of the coupler, shall be provided to the Authority when the first car is delivered.

4.9 ROTARY SWITCH

A rotary switch shall be used at the “F” end to automatically perform the breaking and looping of circuits, and the closing and opening of pneumatic lines specified herein. It shall contain contacts for the specified numbers of spare trainline circuits and spare loop circuits in addition to the circuits in use. Operation of the contacts shall be sufficiently rapid to avoid damage by arcing.

Provision shall also be made for manual operation of the switch and to prevent the switch creeping from the “On” or “Off” position. The manual handle shall be coated OSHA Orange as specified in Section 5.15. The rotary switch enclosure shall also serve as the trainline junction box specified in Section 4.7.

4.10 COUPLER ADAPTORS

The Contractor shall furnish a total of 4 adaptors capable of coupling at one end to the couplers described herein, and at the other end to a standard AAR coupler at its proper height.

4.11 STEP

A nonslip step shall be provided on top of the mechanical coupler for use in entering the train through the end door.

4.12 TESTS

All tests shall be documented and shall meet the requirements of Section 1.8. Trainline tests specified in Section 1.8 shall be performed on each pair of cars utilizing a pair of the Authority’s existing 4000 Series cars.

Coupler anchors shall be compression tested, as specified in Section 3.15.2, and shall be in accordance with the manufacturer’s recommended procedures.

SECTION 5
MISCELLANEOUS CARBODY ITEMS

TABLE OF CONTENTS

Section **Page**

SECTION 5
MISCELLANEOUS CARBODY ITEMS

5.1 INTERIOR SIGNS

5.1.1 Interior Sign Materials

All signs and numbers shall be reverse silk screened with black gloss paint on a durable polycarbonate plate. The plate shall be installed to adhere strongly to all surfaces.

Decals, where used, shall be of a design that will adhere strongly to textured surfaces, shall be sealed on all edges, and shall be printed on the adhesive side to prevent rub-off and deterioration from cleaning solutions.

5.1.2 Interior Sign Style

Unless otherwise specified, all lettering on signs visible to the public shall be Helvetica Medium, upper and lower case.

5.1.3 Car Number

Car numbers shall start at 5000. Even numbers shall be assigned to "A" cars, with the next higher odd number being assigned to the "B" car in the married pair.

Car numbers of 2-inch high, black gloss numerals shall be applied on the inside of both end doors, on the passenger side of the cab door, and in the cab within sight of the Operator. Positioning of the car numbers shall be similar to that on existing Authority cars and as approved.

Car numbers shall also be applied at passenger call stations (push-to-talk) as specified in Section 5.1.6.

5.1.4 Interior Door Labeling

Side door leaves on each side of the car shall be numbered consecutively starting at the "F" end. Doors on the right side of the car shall be numbered 1 to 6; doors on the left side of the car shall be numbered 7 to 12. Black gloss, 2-inch high door numbers shall be placed on the adjacent windscreen, at the top outboard corner of the plymetal lower portion. Where windscreens are not present, the door numbers shall be applied at an equivalent height on the wainscot panels adjacent to the door post.

5.1.5 Maps and Advertising Cards

Frames for the display of Metro system maps shall be provided at door pockets 2, 3, 10 and 11. The frame assemblies shall be manufactured of aluminum extrusion with powder coating to match the interior paneling in color. The frame assemblies shall have a clear polycarbonate protective sheet to protect the replaceable map, and the edges of the frame shall provide a seal to prevent the entrance of dirt, dust, and moisture. The maps will be provided and installed by the Authority after delivery of the cars. The remaining door pocket locations shall be designed to display advertising cards required by Section 3.6.8.

5.1.6 Passenger Notices

Passenger notices, listed in Exhibit 5-1, shall be applied at the locations shown.

Exhibit 5-1 – Passenger Notices

Wording and Arrangement	Location/Color/Notes
PLEASE DO NOT LEAN ON DOOR	Over each side door and on passenger side of cab door/Black Gloss
No Passage Except in Emergency	On the door closer of each end door/ Red Gloss
In any Metro station or train it is unlawful to: • Smoke • Play a radio or other instrument except when connected to an earphone • Eat or drink • Carry any animals, flammable liquids or other dangerous articles • Spit or litter	On the low ceiling below header at each end of the car/Black Gloss
Priority Seating for Senior Citizens and People With Disabilities	Over the longitudinal seats adjacent to doors 4 and 9/Black Gloss/Letter size and spacing shall meet the latest ADA requirements
For Emergency Only Push to Talk This is Car XXXX	On the passenger call station at each end of the car/Red Gloss/Note–insert Car Number for "XXXX"
EMERGENCY DOOR RELEASE LIFT COVER PULL HANDLE DOWN	On the cover of the passenger emergency door release lever for doors 3 and 10/ Red Gloss

5.1.7 Frames for Notices

Frames for the insertion of Public Hearing Notices shall be provided over the side windows at four locations in the car, over each back-to-back seat. The measurements of the Notices are 9 inches high by 28 inches long. The frame assemblies shall have a clear polycarbonate protective sheet to protect the replaceable notice insert. Notices shall be easily inserted and removed within 1 minute. The edges of the frame shall also protect the insert from intrusion of dirt, dust and moisture. The frames shall be constructed of plastic of the same color as the liner to which it is applied, so as to be as unobtrusive as possible when no Notice is inserted.

5.2 EXTERIOR SIGNS

5.2.1 Logotype

The Authority's Logotype shall be applied to the outside of the car, as shown on Contract Drawing 97936-001.

5.2.2 Car Number

The car number shall be applied to a plate on both sides of the car at both ends, as shown on Contract Drawing 97936-001.

5.2.3 Equipment Signs

Underfloor apparatus shall be marked by means of embossed metal plates, welded or mechanically fastened to the apparatus, and with the lettering in a contrasting color. Each air brake reservoir shall be designated. The outside of each apparatus box shall be marked with a designation of each major item of apparatus contained therein. All cut-out cocks, switches, fuses and junction boxes shall be designated. Warning advice, including the normal maximum voltages of circuits therein, shall be provided on the outside of boxes containing electrical apparatus energized at greater than battery potential. Identifying labels for switches, circuit breakers, terminal strips and indicating lamps shall be metal, plastic, or vinyl with lettering of a contrasting color.

5.2.4 Exterior Sign Materials

Except as otherwise specified above, exterior signs and numbers shall be of exterior type decorative vinyl film. Where a logotype is applied to vinyl film, it shall be protected by the final lamination of clear vinyl film. Vertical edges of vinyl film shall be protected by being extended under the glazing rubber at windows.

5.2.5 ADA Accessibility Symbol

The international symbol of accessibility shall be displayed on the car exterior, adjacent to the door posts at the doors numbered 1 and 7.

5.3 INSPECTION CARD FRAMES

A card holder shall be provided on the inside of the cab door. The card holder shall be an open-top box having clear inside dimensions of 5 inches wide, 4-1/2 inches high, and 1/2-inch deep.

5.4 DESTINATION SIGNS

Three destination signs shall be provided on each car. The two side signs shall display the destination and line color on the outside of the car and shall be arranged as follows: One sign shall be on the left side of the car, above the side window forward of the center doors; one sign shall be on the right side of the car above the side window, rearward of the center door—both as shown on Contract Drawing 97936-001. One sign shall be on the front end of the car, as shown on Contract Drawing 97936-005, and shall display the line color by word and color.

Destination signs shall have white or yellow illuminated characters on a non-illuminated background and shall use electronic segment or LED type displays. MOD 2

Each side sign shall have a capacity for at least 48 different destinations and two special indications, "NO PASSENGERS" and "SPECIAL." The side signs shall also be programmable to display public relations messages. The side signs shall provide for at least 13 characters to spell the destination, and two color columns immediately before the destination, capable of indicating one of five color codes (Red, Orange, Yellow, Green, and Blue) in addition to the destination; which will make the color code of the destination obvious at a distance of 15 feet (for side signs) and 50 feet (for front signs) to a viewer directly in front of the sign and at angles up to 45 degrees on both sides. The front sign shall provide for 6 characters to spell out the line color, and at least one color column on each side of the descriptive word. The colors shall not fade.

Intelligence for operating the color-code indicators at each destination sign shall be supplied from the destination sign logic at that sign, and shall be based on the destination selected. Power for operation of the line color indicators shall also be provided directly from the destination sign with which the indicators are associated. Line color indicators shall be extinguished or otherwise obscured if the sign "NO PASSENGERS" or "SPECIAL" has been selected. Line color indicators, if separate from the destination signs, shall be considered as part of the destination sign for the purpose of determining destination sign reliability. The destinations and colors will be designated by the Authority.

An area with a nominal size of 3 inches by 36 inches (3 inches by 24 inches for end sign) shall be available for wording. The working parts shall be interchangeable between side and end signs.

The signs shall be compatible with and operable by the contact circuits used on existing Authority cars. It shall also be possible for the control signals on the cars furnished with this order to operate destination signs on existing Authority cars. Signs shall operate on battery voltage.

Signs shall be controlled from the destination output (two, 4-bit digits) of the ATC in the leading pair of cars or from the output of a destination sign selector switch. The destination sign selector switch shall be provided in the Operator's auxiliary control panel; it shall permit disconnecting the destination sign trainlines from the destination output of the ATC, and imposing upon them the codes for the two special indications referred to above. This selector switch shall have three positions: "AUTOMATIC," "NO PASSENGERS," and "SPECIAL." The time required to change destinations shall not, with any combination of destinations, exceed 5 seconds at rated voltage. With a valid code input, 90% of all sign logic failures shall produce a black indication. A malfunction shall also be considered a failure if three or more segments, elements, or LEDs per sign do not function. A "00" code shall cause the sign to display a black indication. Response to any invalid code shall produce a black display.

A small display, providing 13 LED characters that duplicate the display of the side signs, shall be provided in the Operator's auxiliary control panel as shown on Contract Drawing 97936-011.

Access to the sign and color-coded indicators, for maintenance, shall be from inside the car, and shall provide for easy replacement and maintenance of all components.

5.5 CAR IDENTIFICATION SYSTEM

Automatic car identification labels shall be applied to both sides of each car, near the rear end, as shown on Contract Drawing 97936-001.

5.6 FIRE EXTINGUISHER

Two rechargeable fire extinguishers, each containing 10 lbs. of ABC dry chemical and equipped with a pressure gauge, shall be provided in each car, one mounted in the Operator's cab and the other mounted at the "R" end of the car, behind or beneath the rearmost seat on the left side of the car and accessible to passengers. The fire extinguisher shall bear the Authority's name.

5.7 CAB ACCESSORIES

5.7.1 Windshield Wipers

Heavy-duty, air- or electrically-driven windshield wipers shall be provided for the cab side "F" end window. They shall be able to clear the glass satisfactorily at speeds up to 80 mph, and in all normal wind conditions. The wipers shall be a parallel-motion type and shall cover the full width of the glass from 36 inches to 60 inches above the floor. The wiper operating mechanism shall be easily accessible and its control shall be located in the Operator's console. The control shall provide for two-speed motor
MOD 1 control. The high speed shall operate under the most severe weather conditions and the low speed shall be equipped with a variable timer. A "park" position shall also be provided.

5.7.2 Visor

An opaque visor shall be provided for the Operator's end window. It shall be easily operated, approximately 8 inches by 24 inches in size, shall be mounted on an extendable, double-ball-jointed arm, and shall remain in the selected position. When not in use, it shall be able to be stored unobtrusively near the cab ceiling.

5.7.3 Signal Buzzer

The cab shall be equipped with a buzzer for receipt of signals. It shall be energized, through a trainline, by the signal push-button in any cab in the train. The tone of the buzzer shall be the same as the tone of the signal buzzer in the existing cars.

The buzzer shall have a volume sufficient to be readily audible when the cab window is open under the highest ambient noise level conditions.

5.7.4 Overspeed Warning

An audible overspeed warning signal device shall be provided in the cab. The signal device shall function under command of the automatic train control apparatus as specified in Section 11.

5.7.5 Cab Curtain

An accordion-pleated curtain of opaque vinyl-coated fiberglass fabric shall be provided for the transverse cab partition window behind the Operator. The curtain shall be able to cover all or part of the window.

5.7.6 Cab Door Window

The cab door window shall be shielded or shaded in such a way to eliminate disruptive reflections on the windshield that originate from the passenger area with the cab door in the operating position; yet still permit passengers to effectively view the cab and to see forward through the windshield and body door window. The necessary provisions may be external to the window or internal.

5.8 HORN

5.8.1 Road Horn

A multiple-tone pneumatic horn, having a pleasing but authoritative tone, shall be installed under the floor at the "F" end of each car, with its control located in the Operator's console. The horn shall have an output of not less than 97 dBA at a distance of 100 feet in front, and consumption of not more than 28 cubic feet of free air per minute. The horn shall be a Leslie, or equivalent quality railroad horn, and its tone shall approximate that of the horn on the existing Authority cars.

5.8.2 Yard Horn

The road horn, referred to in Section 5.8.1, shall also function as a yard horn. In this role, it shall have an output of 70dBA to 80 dBA at a distance of 60 feet in front. Its control shall be the existing "BUZZER" push-button on the Operator's Auxiliary Control Panel from the keyed-up cab console. Alternatively, an electric horn similarly located and operated may be provided.

5.9 STANDARD KEYS

5.9.1 Control Key

Two control keys shall be provided for each car. The total quantity of control keys required for all the cars to be supplied under this contract shall be delivered to the Authority's Brentwood storeroom at the time of delivery of the first car. The control key shall operate the lock of the Operator's console, which shall activate the console and release a mechanical lock on the master controller.

5.9.2 Door Key

Two door keys shall be provided for each car. The total quantity of door keys required for all the cars to be supplied under this contract shall be delivered to the Authority's Brentwood storeroom at the time of delivery of the first car. This key shall operate the following:

A. Cab door lock
B. Body end door lock
C. Door-control key switch on Auxiliary Control Panel
D. Access panel for left-hand door controls

E. Environmental control set-up key switch
F. Door crew switch
G. Left-hand cab side window lock
H. Cab left-hand equipment locker door
I. ATC Equipment Cabinet

5.9.3 Lock Type

The car shall be keyed to match the Authority's existing cars. The Authority will provide a sample of each of the two keys, for the Contractor's use in selecting the locks.

5.10 EXTERIOR HANDHOLDS AND STEPS

5.10.1 General

Exterior handholds and steps shall be provided at the locations specified in Sections 5.10.2 and 5.10.3. There shall be not less than 2 inches clearance between the handholds and any part of the car, including the door and latch handles. Handholds and steps shall be attached to the carbody with not less than 1/2-inch diameter stainless steel bolts and nuts. Loop steps shall have at least 8 inches clear depth and clear height. The handholds and loop steps shall fall within the specified clearance envelope.

5.10.2 Handholds

Handholds are required at the following locations:

A. Three handholds, on "F" end collision posts, one 6 inches long and two, 15 inches long, as shown on Contract Drawing 97936-005 (total—three per car), for use when entering or exiting the car by the coupler step.

B. One outside handhold adjacent to center side door leaf number 9.

C. One handhold on "R" end collision post, 15 inches long as shown on Contract Drawing 97936-006.

5.10.3 Loop Steps

A loop step is required under the side door handhold referred to in Section 5.10.2. The left side of the loop step shall be approximately even with the centerline of the handhold; and right side shall be no more than 14 inches inside the door opening. The tread width (longitudinal dimension) of the loop step shall be a minimum of 12-1/2 inches. The step shall be at least 20 inches above the top of rail and shall fall within the allowable clearance envelope. The entire opening of the step shall be completely clear of any interference from any undercar components or appurtenances.

A step shall be provided as part of the coupler assembly in accordance with the requirements of Section 4.11.

5.10.4 Material

The exterior handholds shall be of one-piece construction, and made of 5/8-inch diameter stainless steel rod. The steps shall be made of stainless steel, with anti-slip treads having a minimum cross section of 1/2-inch by 1-1/2 inches.

5.11 INTERIOR HANDHOLDS

Interior vertical (stanchions) and horizontal handholds shall be provided as shown on Contract Drawings 97936-001, 97936-002, and 97936-004; except that the Contractor may propose alternate arrangements in the vicinity of the forward and rear side doors to enhance space utilization, passenger flow paths, and visibility of the “Next Station” signs of Section 5.16.

Interior handholds shall be made of stainless steel tubing or stainless-clad carbon steel tubing. Flanges, tees, and other fittings shall be made of stainless steel or anodized aluminum, and shall be as unobtrusive as possible and tapered like the upper stanchion flanges on the existing Authority cars. All screws shall be flush or recessed.

Vertical handholds shall be 1-1/2 inches in diameter; horizontal handholds shall be 1-1/4 inches in diameter. A minimum knuckle clearance of 1-1/2 inches from the nearest adjacent surface shall be provided.

Each vertical handhold shall withstand, without permanent deformation, a horizontal load of 300 lbs. applied in any direction at the midpoint of the handhold. Horizontal handholds shall withstand, without permanent deformation, a vertical load of 110 lbs. per lineal foot.

The height of the horizontal handholds shall be 76-1/2 inches from top of finished floor to centerline of handhold.

The short horizontal handholds, shown on Contract Drawing 97936-007, in the area adjacent to the door pockets housing door panels 2, 5, 8 and 11 shall extend from a T-fitting in the door entranceway vertical handhold in a longitudinal direction toward the center of the car; making a smooth curve into a fixation point in the ceiling at approximately the aisle side front edge of the transverse seat bottom cushion adjacent to the door pocket.

5.12 NOT USED

5.13 EMERGENCY LADDER

An emergency ladder shall be provided in each car for use in evacuating passengers in emergency situations. The ladder shall be of the same length as those on the 4000 Series cars, and shall hook into holes provided in the top surface of the front anti-climber, to prevent slipping. MOD 2

The ladder shall be stored behind the passenger seat in the cab area, accessible only to employees. If necessary, the ladder may fold or be sectional to permit storage. The ladder shall be nonconductive, shall have at least the fire resistance specified in Section 15.25 for interior materials, shall have nonskid feet, and shall have flat steps at least 3 inches deep. The ladder shall be constructed of glass-fiber reinforced polyester with sufficient strength to support a 300-lb. load. MOD 2

5.14 SHOE INSULATING PADDLES

Two, Authority-standard, third rail contact shoe insulating paddles shall be provided in each car—stored in a rack inside the right rear seatwell. The paddles shall be of a configuration that will permit a person standing clear of the car and outside the third rail to safely insert the paddle between the contact shoe and the third rail with the Authority’s third rail cover arrangement.

5.15 RAPID IDENTIFICATION COATING

In order to make various control points highly visible to aid in rapid identification, the following apparatus on each car shall have a permanent coating applied to match OSHA Orange paint (DuPont No. 93-082-DH or approved equal), or shall be painted with same:

A. One (1) coupler gathering horn: front end
B. Two (2) coupler electric head covers: front end
C. One (1) manual uncoupling lever handle
D. One (1) trainline isolation switch handle: under cab
E. Two (2) air-actuated rotary switch control handles: under cab
F. Eight (8) brake actuator unit “flags” and their sixteen (16) notches
G. Twelve (12) side door manual emergency release handles.

5.16 NEXT STATION SIGN

Two LED signs shall be provided to visually display the next station and the line, and to indicate on which side the doors will open. One sign shall be mounted in the high-to-low ceiling transition at each end of the car. The signs shall display the line color while the train is berthed at a station, the name of the next station as the train departs, and the side of the train that the doors will open on as the train enters the next station. Lettering shall comply with ADA display requirements.

The sign controller shall contain an internal map of the Authority’s system, identifying station sequence and exact distances between stations. The location of the train shall be obtained from the TWC message, which will contain a unique identifier for each station and platform side. Alternatively, independent wayside transponders may be used to establish train location and platform side, in which case the Contractor shall provide both wayside and carborne equipment. The sign controller shall interface with the required carborne systems to acquire train location information. The VMS may be used to interface with the sign controller and to distribute the messages throughout the consist.

SECTION 6
DOOR OPERATION AND CONTROL

TABLE OF CONTENTS

Section **Page**

SECTION 6
DOOR OPERATION AND CONTROL

6.1 SIDE DOOR OPERATION

6.1.1 General

The side doors shall be arranged for remotely controlled electric operation. The control shall be trainlined so that all the doors on either side of the train may be operated either automatically by the ATC apparatus or manually. In addition, the doors on the left-hand side only shall be operable manually by the use of a button located on the cab door-control panel beside the side window on the left side of the car, across from the Operator's console. Manual operation of the doors on the right-hand side only shall occur by the use of a button on the cab door-control panel beside the side window on the right side of the car in the Operator's cab. Refer to the Contract Drawing 97936-020, for required door control circuits.

Each vehicle shall contain a microprocessor-based door control system to control door and door signal functions. The microprocessor shall also monitor the status of the door control and signal system on the vehicle and shall store selected diagnostic information to be utilized by the vehicle monitoring system via a data acquisition module (DAM) as specified in Section 6.7.

The use of solid-state controls shall be maximized for the door system and therefore, except for fail-safe functions (zero speed, door closed and locked summary, and right and left motor control), the use of electromagnetic relays is prohibited. Indicator lights shall utilize LED clusters for illumination where possible.

6.1.2 Selector Switch

A three-position selector switch shall be provided as part of the Operator's circuit breaker panel. The switch shall be effective only in the leading cab in the train, and shall permit the Operator to select one of the following methods of door operation:

A. Doors opened and closed by commands from ATC. (Manual override shall be possible except to open doors on the "wrong" side.

B. Doors opened by commands from ATC (with manual override), and closed manually by means of any activated cab door-control panel. (It shall not be possible to manually open doors on the "wrong" side.

C. Doors opened and closed manually by means of any activated cab door-control panel.

6.1.3 Door/Train Speed Interlock

The door controls shall be interlocked with the ATC system zero-speed relay so that the doors cannot be opened unless the train speed is less than 2 mph. The interlocking shall be accomplished on each car individually by the removal of power from the door-control panel, the door-opening buttons, and the door operators at speeds over 2 mph. Power removal at speeds over 2 mph shall be a vital function accomplished in a fail-safe manner.

6.1.4 Door/Traction Interlock

The traction controls shall be interlocked with the door signal lights (Section 6.4) so that the train cannot be moved unless two sensing switches of each door panel-the first checking that the door is closed and the second that the door is locked-indicate that all doors are closed and locked. The trainline circuit performing this interlock (door/traction) shall be a fail-safe, double break circuit with two trainline wires to provide maximum protection against erroneous door-locked signals. This interlock shall continue until the zero speed indication ceases, so that pushing a door leaf back as a train first begins to move will stop the train. After the zero speed circuitry indicates the car is no longer at zero speed, movement of the door's push-back feature will have no effect on train movement. This circuit shall change polarity with each change in leading end in order to be able to detect grounds. Brakes shall be applied at Braking Level 4 whenever the door/traction interlock trainline circuit is open. See Section 10.6.10 for additional description of this circuit.

6.1.5 Circuit Separation

All door-control circuits for one side of the car shall be separate and distinct from those for the other side of the car. There shall be no shared components unless specifically called for herein.

6.1.6 Compatibility

Door-control signals shall be fully compatible in all respects with door-control signals on existing Authority cars so that new and existing cars can be mixed in any order in a train and all doors will function as specified. All doors-closed trainlines shall be pulsed momentarily when motion is detected.

6.1.7 Door/Master Controller Interlock

Controls shall be arranged so that if, in manual operation, the master controller is advanced to a power position while any or all doors in a train are open, obstructed, or unlocked, traction power will not be applied when all doors become closed, unobstructed, and locked until after the controller is returned to a coast or brake position.

6.1.8 Door Operator Cut-out Switch and Lock

A combination door operator cut-out switch and lock shall be provided at each side door operator so that in the event of failure of the door operator, the door operator can be made inoperative and the door leaf mechanically locked in the closed position. A bypass switch shall also close the "door closed, unobstructed, and locked" signal circuit at that door operator but shall not reduce the effectiveness of the Obstruction-Detection System on the remaining doors. This bypass switch shall be accessible through the door operator access panel. The Cut-Out Switch shall also disable the visual indicators (Section 6.5) on the affected door when either of its door operators are cut-out.

6.1.9 Door/Traction Interlock Bypass

A door/traction interlock bypass switch shall be provided in the Operator's switch panel to permit moving the train in the event of side door/traction interlock circuit failure. The switch shall be sealed in the normal position, requiring that the seal be broken to bypass the interlock.

6.1.10 Cut-out Switches

A cut-out switch shall be provided in the cab to allow disabling the automatic and manual door operation on a selected portion of a train. Placing this switch in the "Cut-Out" position in any cab other than the leading cab shall disable door operation from that cab to the rear of the train. Door open and close indicators in the operating (lead) cab shall not be affected by placing this switch in the "Cut-Out" position. Placing this switch in the "Cut-Out" position in either cab of the operating (lead) pair shall not disable side door operation in the lead pair.

6.1.11 Trainlines

Doors shall be opened and closed by signals on two 37.5 VDC trainline wires on each side of the train. Energization of these wires (at least 300 milliseconds) with voltage of one polarity shall open the doors on that side, and energization with voltage of the opposite polarity shall close them.

6.1.12 Power Source

Door controls shall operate on nominal 37.5 VDC.

6.2 SIDE DOOR OPERATORS

Each side door leaf shall be actuated by a separate 37.5 VDC electric operator. The operator controls shall be in a self-contained local control panel mounted either in the wall within the area of the “map” and “ad” doors or in the valance panels above and adjacent to each side door. A red LED indicator shall be located in the valance panel above each door leaf and shall be illuminated whenever its associated leaf is either open, obstructed or unlocked. All adjustments shall be readily available from the exposed side of the operator.

The operator and the operating linkage or the worm screw shall be arranged so that the net force on an obstruction during closing shall not exceed 31-1/2 lbs., measured statically at the mid-point of door travel. The operator and operating linkage or worm screw shall provide sufficient damping to keep the door from bouncing off the stops at the end of the opening and closing cycles.

The speed of the door shall be such that from the moment of energizing the door operator to the moment of the completion of the operation, including the cushioning, the time shall be 1.5 seconds maximum for opening. The closing time shall be adjustable from 2.0 to 2.5 seconds.

All limit switches used in the door operator shall be of the replaceable unit type. They shall be actuated by gross movements of the operator mechanism. The design and installation of these switches shall be such that if they are replaced, no adjustments will be necessary to obtain proper functioning nor will adjustments be possible.

The door-locked indication shall be given only after the door has been mechanically locked.

The door mechanism shall incorporate a spring loaded push-back feature allowing 1-1/2 inches of push-back per panel at a force of 20 lbs. to 24 lbs., even if the door is locked.

Any resistors for current limiting purposes in series with the door operator motor shall be accessible and mounted near the local control panel.

For sidewall mounted operators, all pivot points and bearings of the multiplying lever(s) shall be integral parts of the operator package. The connection to the side door leaf shall be by means of a self-aligning arm. For valance mounted operators, each door leaf shall operate by means of a worm screw.

A mechanical device shall ensure the locking of each door panel in the door closed position. Locking shall be automatic.

6.3 DOOR CONTROL SWITCHES

6.3.1 Cab Controls

Door control push-buttons shall be provided at two locations in the cab. One pair of buttons (one for “open” and one for “close”) shall be provided on the auxiliary panel to the right of the Operator and shall control the doors on the right side of the train only. The second pair of push-buttons shall be provided on the door-control panel at the left side of the car opposite the Operator’s console (see Contract Drawings 97936-008 and 97936-011). All push-buttons shall be barrier type.

The door controls shall require the activation of the door key switch in the auxiliary panel or the activation of the control lock on the master controller to make either the “open” or “close” push-buttons operative. It shall be possible to remove the key after the doors have been opened and have the doors remain open, and to close and lock the doors from a different master door-control panel than that from which they were opened.

A door-control panel shall be provided at the forward of the left side window, opposite the Operator's console. It shall be protected by a flush hinged cover. The cover shall have a lock operable by a door key, and it shall be possible to remove the key after the cover is open and to lock the cover by merely closing it. The panel shall be energized only when the adjacent Operator's console is energized or the auxiliary control panel has been energized by insertion of the door key. This panel shall be fitted with two barrier-type push-buttons, one to open and one to close the doors on the left side of the train only; an "ALL DOORS CLOSED" indicator light. This panel is also fitted with an Emergency Stop Button (mushroom).

It shall be possible for the Operator in the leading cab to forestall the opening function, by holding the "Close" push-button, and to forestall the closing function, by holding the "Open" push-button, when the commands for these functions are being initiated by the ATC.

The door-control push-buttons shall be of the spring-return type and circuitry shall be arranged so that once the button is held down for at least 300 milliseconds the operating cycle will be completed even if button is subsequently released.

See Section 9.7.2 for additional details of the door-control push-buttons.

6.3.2 Crew Switches

Key-switch stations for crew use to open and close a door leaf shall be provided inside and outside of the car adjacent to door leaf numbers 2, 8, and 9 for controlling operation of that door leaf. The exterior crew switches shall be watertight and shall be located at a height of 60 to 65 inches above the rail and 12 to 18 inches from the edge of the door opening, for operation by an employee standing either on the ground or on a station platform. Keyholes on the outside of the car shall be provided with spring-closed covers to insure weathertightness. Interior crew switches shall be flush mounted in a convenient but inconspicuous location in the windscreen or side wall near the door leaf it controls. Door leaves shall be operated by momentary activation of the crew switch with a door key. It shall be possible to remove the key with the door in either the open or closed position.

When a door panel has been opened (or closed) by an outside (or inside) crew switch, it shall be possible to close (or open) it by the adjacent inside (or outside) crew switch or by operation of the normal trainline door control from any master door control switch panel, and the door shall thereafter function normally.

6.3.3 Emergency Door Operation

All side doors shall be so arranged that they may be manually opened for emergency exits. The release lever or handle shall be inside the car, but located behind the door operator access panel. The handle shall be coated OSHA Orange as specified in Section 5.15.

Door leaves number 3 and 10 shall also be arranged for passenger emergency opening through the actuation of a lever located at a convenient operating height at the rear of each door pocket between the map and the rear edge of the door pocket panel. The emergency operating lever (passenger interface) shall be painted red and shall be visible through a clear polycarbonate window in a fiberglass framed door covering the lever. The cover door shall be sealed and shall be hinged at the top. Operation of the lever will first require the breaking of the seal and opening of the cover door. The emergency lever operating mechanism shall be interlocked with the car's zero speed circuitry so that the emergency lever cannot be activated until the train is stopped. However, loss of ATC power at zero speed shall not inhibit emergency door operation.

6.3.4 Emergency Door Opening Device Access Panel

If required and in order to provide access for maintenance to the emergency door opening lever operating mechanism, the upper portion of the door pocket at door leaves number 3 and 10 shall be arranged with removable panels. The panels shall be of the same finish and construction as the door pocket and shall be secured with Phillips-head screws. Panels shall be finished with aluminum moldings along their edges. The arrangement shall be submitted to the Authority for approval.

6.4 DOOR SIGNAL LIGHTS

6.4.1 Outside Door Signal Lights

A red indicating LED cluster in an unpainted bright metal tubular housing shall be provided above the center side door on each side of the car. The light shall be visible from both ends of the train. The housing shall conform to clearance requirements and shall be of a design which will not be damaged by car washing machines. The light shall have sufficient brightness so that it will be obvious to a person with normal visual acuity whether the light is on or off in bright sunlight at a distance of eight car lengths on tangent track.

The circuitry shall be arranged so that the light will be illuminated when any door leaf on either side of the car is open, obstructed, or unlocked.

6.4.2 Threshold Lights

The threshold lights, referred to in Section 8.1.4, shall be illuminated at all times when the adjacent door leaf is open, obstructed, or unlocked at doors 3, 4, 9, and 10. At all other doors, where only one windscreen is provided, the threshold lights shall be illuminated at all times when either door leaf is open, obstructed, or unlocked.

6.4.3 "Doors Closed" Indicator

Indicator lights shall be provided in the control console and in the left-hand door-control panel. The circuitry shall be arranged so that in any panel which has been activated with either the door key or the control key, the light shall be illuminated when all side doors, on both sides of the train, are closed and locked.

When a panel is not activated, the light shall be extinguished.

6.4.4 Lamps

Door signal lights shall use cluster-type LEDs, while door threshold lights shall have long-life lamps, per Section 8.1.4.

6.5 DOOR WARNING AUDIO AND VISUAL INDICATORS

A door operation audio and visual warning system shall be provided for the car. When doors are ordered closed, either manually or automatically, auditory and visual warning signs shall be provided to alert passengers of closing doors. MOD 2

The electronic door chime system shall not interfere with the public address (PA) system. There shall be six separate speakers, one being located above each side door. There shall also be six door operating indicator lights, one located at each side door opening, which shall be clearly visible from inside and outside the vehicle. MOD 1

Door-opening and closing voice announcements shall be provided in conjunction with door chimes. Voice recording shall be as provided by the Authority. On door-opening, the trigger signal is simultaneous for the voice command and the doors opening. On door-closing, the voice command is triggered by the door chime signal before the doors close.

A verbal announcement, i.e., "Please stand clear of the doors. Thank you." (to be provided by the Authority), shall be initiated whenever the doors are commanded to close before they are fully open and whenever the door open/door close pushbuttons are operated in rapid sequence (e.g., twice within 3 seconds).

6.5.1 Closing

MOD 2 Door closing voice announcement, in conjunction with door chime tones shall sound upon receipt of a command to close the doors. To provide for a waiting period after the second tone, the door shall begin to close at the end of a period which shall be adjustable from 0 to 4 seconds beginning at the command to close. In parallel with the door warning chime, upon receipt of the door close command, the door operation indicator lights shall commence pulsing on and off and continue pulsing until the doors are closed and locked. The door operation indicating lights shall remain extinguished during the opening cycle.

6.5.2 Opening

The circuitry shall be so arranged that pressing the door-opening button in any active master door control panel will stop the operation at any time in the closing cycle and cause the doors to reopen. Once the doors are fully open, the closing cycle shall be restored to its starting point. If the door-closing button is pressed before the doors are fully open, the doors shall close without going through the warning chime/light and timing cycle.

6.6 OBSTRUCTION DETECTION SYSTEM

The door operators shall be equipped with an obstruction detection system for passenger protection during the door-closing cycle. The obstruction detection system shall be sufficiently sensitive to detect the presence of either a 3/4-inch diameter bar or a 3/8-inch thick by 3-inch high bar, when either one is located between the leaves.

Each door leaf shall have a spring-loaded linkage, in its connection to the door operator, to limit the force developed by the door at the end of its closing cycle, and to permit easy extraction of clothing or other articles smaller than can be detected. This linkage shall permit each leaf to be pushed back a maximum of 1-1/2 inches with a force not exceeding 24 lbs., even if the door is locked. The obstruction sensing system shall not be overridden by sequentially holding back the door panels against the push-back feature in the nearly-closed position.

MOD 3 An obstruction shall be detected either through the measurement of the door operator motor current by the electronic door control or through the use of a timer, the timing cycle of which shall be adjustable from 2 to 5 seconds. It shall begin timing when the door operator is energized to close, and the presence of an obstruction shall be assumed if the door-closed switches have not all closed before the timer has completed its cycle.

The following two methods of operation shall be available to the Authority:

A. When the door has started to close, the detection of an obstruction at either leaf shall cause both leaves of that door to reopen fully one time. After a waiting period, which shall be adjustable from 0 to 2 seconds, the door shall again attempt to close.

B. When the door has started to close, the detection of an obstruction at either leaf shall cause both leaves of that door to reopen for approximately 0.25 seconds, one time, and immediately attempt again to close.

The door controls shall be connected to provide method B above when the cars are delivered, but it shall be possible for the Authority to convert to the other method by the addition or removal of a jumper wire or the relocation of a connection on a terminal strip on either the operators or on the door control interface panel or other approved method.

The detection of an obstruction during the second closing attempt, in either of the above methods of operation, shall not reopen the door or remove power from the operators, but shall continue to lock out the traction control as described in Section 6.1.4. The warning chime shall not sound during the second attempt to close. It shall be possible for qualified personnel to easily disable the obstruction detection system.

6.7 VEHICLE MONITORING SYSTEM (VMS) INTERFACE

The input and output signals from each critical door and door control system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

6.8 TESTS

The doors and their operating equipment, including voice announcements, shall be checked and adjusted, in accordance with manufacturer’s recommended procedures, on cars to assure smooth and proper functioning and alignment, attainment of the specified speed, closing and push-back forces, and proper functioning of control signals and interlocks.

All tests shall be performed and documented to meet the requirements specified in Section 1.8.

SECTION 7
HEATING, VENTILATING, AND COOLING

TABLE OF CONTENTS

Section **Page**

SECTION 7
HEATING, VENTILATING, AND COOLING

7.1 GENERAL

Temperatures in this section are given in degrees Fahrenheit (°F). In each case, temperatures shall be measured and reported in degrees Fahrenheit, and compliance with the Contract requirements determined by comparison with the appropriate specified Fahrenheit value.

An Environmental Comfort System (ECS) shall be designed and installed in each car to automatically provide the specified control of interior temperatures with any ambient temperature from -5°F to 105°F at the specified wet bulb conditions, with or without solar gain or variable internal heat loads such as passengers, miscellaneous electrical apparatus and lights. The ECS shall be designed to start and operate within the voltage ranges specified in Section 2.2 at any exterior ambient condition between -5°F and 105°F. Except as otherwise specified herein, the ECS shall be powered by the auxiliary power system (APS) and operate within the voltage ranges specified in Section 2.2.

Overhead fans shall continuously introduce a minimum of 1,400 cfm total fresh air into the car whenever the auxiliary power of nominal 230 VAC, 3-phase is available and the ECS is energized. Overhead electric heat shall be provided to heat the fresh air and to provide an optimum amount of reheat during the modulated cooling cycle for extended humidity control. Dry expansion cooling and dehumidification coils will be provided upstream of the overhead heat elements. Convection type baseboard heating, under the ECS control, shall draw cool air from the floor to promote air circulation and an even temperature distribution within the car under normal operation, and to provide layover heating when required by the control system.

Both fresh and return air shall be filtered as specified. Conditioned air for each car will discharge into the main air distribution ducting and shall enter the passenger compartment via continuous slot air diffusers adjacent to the fluorescent light fixtures.

Each car shall have two completely independent cooling systems, one at each end of the car. Each independent system shall be capable of supplying conditioned air for the entire car in event of failure of the other unit. Temperature control for each car shall be from a single panel mounted under the car. A single temperature sensor shall be provided at the rear end of the car to control both systems.

Each overhead fan-coil-heater unit shall be located in the low ceiling area at each end of the car. Each unit shall draw fresh and return air locally and blow the mixture over the evaporator coils into the main distribution duct to the extreme ends of the car.

The compressor-condenser units shall be mounted beneath the car floor.

A refrigerant service box containing the pressure switches, required by Section 7.4.3 (K) and (L), and valved pressure gauge connections, accessible from the side of the car, shall be provided for each system.

The cooling system shall utilize a conventional vapor cycle using a refrigerant compatible with the United States Environmental Protection Agency (EPA) Standards. Compressor and evaporator capacity modulation shall be provided for temperature and humidity control and to minimize “short cycling” of the equipment.

The design shall be developed to achieve maximum efficiency.

7.2 HEATING SYSTEM

7.2.1 Overhead Heat

Overhead heat shall be provided by electrical heater elements, which are an integral and serviceable part of each of the overhead fan-coil units. The overhead heater elements shall be downstream from the cooling coils and shall be split into two stages, proportioned to provide the most efficient and economic operation for both the regular heating cycle and the reheat cycle.

The heater elements shall have adequate capacity to heat the total fresh air input a minimum of 60°F whenever the line potential is 700 volts or higher. Heater performance will be permitted to vary with line voltage deviation approximately in accordance with the ratio of the square of the voltage divided by the square of the rating voltage of 700 VDC. The elements shall be rated for operation within the voltage ranges specified in Section 2.2. They shall be finned round or rectangular section elements consisting of a corrosion-resistant sheath surrounding a uniformly spaced coiled nickel-chromium resistance wire embedded in a compressed and baked refractory material and adequately supported. The design shall provide for removal of individual elements for maintenance purposes.

In selecting the type of heater element to be used, the Contractor shall consider the thermal inertia (heat storage capacity) of the element and the impact of that inertia on the establishment of thermostatic control operational differentials so as to ensure compliance with the requirements of Section 7.5.4. The thermal inertia shall also be considered by the Contractor when establishing the location and set point of the thermostat specified under Safety Feature B of Section 7.2.2.

Electrical connections directly to the heater elements shall be via approved crimp connectors and bolted connections utilizing tinned, flexible, stranded copper cable of maximum 24 AWG strand size using silicone rubber insulation with two glass braids with a minimum 200°C UL continuous service certification. There shall be no exposed, uninsulated, or unprotected high voltage components, wiring, or terminal connections in the overhead area.

7.2.2 Overhead Heat Protection

Three safety features shall be incorporated into each overhead heating coil to prevent damage in the event air circulation stops. They are listed below, in order of precedence of operation:

A. An air flow sensing switch shall open the overhead heat contactor whenever air circulation is stopped or excessively reduced. This switch is to be located wherever it will react to failure of the blower, clogging of the filters, or blower or heating coils restriction or blockage.

B. A thermostat located in the heater plenum shall, upon the detection of temperatures higher than normal, open the overhead heat contactor and also open the overhead heat circuit breaker by means of a shunt trip. It shall be located within the plenum in such a fashion that it will not be actuated by residual radiation or heat stratification when the Environmental Control Relay (ECR) is de-energized during a heat cycle.

C. In the event the above two features fail to protect against a hazardous temperature rise, a non-resetting fusible link in the high voltage supply shall positively interrupt the high voltage heater circuit.

7.2.3 Floor Heat

Panel-type floor heat shall be provided using electric strip heaters mounted behind stainless steel heater guards along the side walls and longitudinal seats, at the floor. Air shall enter the heater guard through slots at the bottom, pass over the strip heaters, and rise by convection. Holes or slots shall be provided at the top of the heater guard so that a portion or all of the air will exit through the heater guard. Where the heaters are located under a window, a portion of the air shall rise through a vertical duct behind the wainscot lining and discharge through holes in the window mask, just below the window or through holes in the upper portion of the wainscot panel. The heater guards shall be designed to facilitate the convection flow of heated air, and to draw cooler air from the floor level. The floor heater system shall be designed to prevent interior surfaces with which passengers may come in contact from exceeding 125°F over the voltage ranges specified in Section 2.2.

The heaters shall be mounted with ceramic insulators with suitable provision for thermal expansion and contraction of the heater strip.

The strip heaters shall be uniformly distributed and arranged to provide two stages of floor heat. The capacity of the floor heat shall be adequate to maintain the specified carbody interior temperatures with the overhead heating and ventilation system inoperative whenever the line voltage is 700 VDC or higher. At voltages above or below 700 VDC, the heater performance shall be permitted to vary as the ratio of the square of the voltages. The elements shall be rated for operation in accordance with the voltage requirements in Section 2.2.

The electric floor heater elements shall be of the strip heater type consisting of a nickel-chromium resistance wire imbedded in a baked, compressed, refractory material, sealed with a rust resistant high heat transfer sheath.

Close to the element at the +700 VDC end of each series string of heater elements, there shall be an approved over-temperature sensor that shall be connected to a shunt trip coil in the breaker to protect that string. It shall disconnect power to the string if an over-temperature condition is present. The time constant of this protection shall be long enough to avoid nuisance trips due to intermittent high voltage caused by regeneration.

The front panels of the heater guard shall be constructed so that small sections may be removed for replacement of heating strips without dismantling the seats; and shall provide protection against the insertion of foreign objects.

The lower section of the heater guard shall be designed and constructed to prevent the accumulation of dirt.

7.2.4 Layover Heat

Layover heat shall be automatically provided to meet the winter average interior temperature requirements in Section 7.5.4, whenever the environmental control circuit breaker is closed and the ECR is de-energized. Layover heat shall be provided by floor heat only.

7.2.5 Cab Heat

The Operator’s cab shall be provided with a forced-air floor heater powered by the auxiliary power supply system. It shall operate within the voltage ranges specified in Section 2.2 and shall have the capacity to adequately maintain a temperature of not less than 70°F in the cab compartment with a -5°F exterior ambient temperature, overhead heat shut off, and the door and side window closed.

The cab heater housing shall be constructed of heat resistant material and shall utilize enclosed heater elements. A thermostat shall be provided to remove power to the heater elements in the event that excessive heat is developed. The cab heater and controls shall be fully accessible for repair and replacement through access panels that are easily removable. It shall not be necessary to remove or disturb other systems or equipment to gain access to either the heater or its controls.

Heater elements shall be rated for operation in accordance with voltage requirements in Section 2.2.

A three-position switch shall be provided in the Operator's cab for control of the cab heater. The switch shall provide "OFF," "MEDIUM," and "HIGH" positions. The fan speed shall correspond to the selected switch position.

The cab heater shall operate whenever a door key has been turned to the "ON" position in the auxiliary control panel in that cab and the cab heater control switch is in "MEDIUM" or "HIGH" position.

The cab floor heater shall be mounted under the console. The cab floor heater shall be designed to prevent surfaces, with which the Operator may come in contact, from exceeding 125°F over the voltage range specified in Section 2.2.

Overhead heat shall also be supplied to the cab under the control of the heating and cooling control system.

7.2.6 Heated Glass

The defrosting and defogging of the right side windshield shall be by means of electrically-heated glass operating on battery voltage. The heated glass shall be capable of clearing the entire surface of the window of ice, frost, and fog under the most adverse weather conditions specified. An "ON-OFF" switch shall be provided in the Operator's cab for the defroster. The circuit breaker for the heated glass shall be located on the Operator's circuit breaker panel between the circuit breakers for friction brake system and master controller.

7.3 VENTILATION

7.3.1 General

Ventilation of the car shall be accomplished by the evaporator blowers, powered by the APS, supplied as a part of the overhead air-conditioning evaporator units. Unless otherwise approved by the Authority, the blowers shall be coupled directly to the motor shaft using separate pillow block supports of the fan wheels. The Contractor shall consider the noise and vibration requirements when selecting the arrangement to be used. The fans shall be balanced to prevent excessive vibration.

Fresh air shall enter the car through screened openings on each side below the rain gutter and pass through ducts and filters into the evaporator plenum chamber. Recirculated air shall pass through grilles in the low ceiling, and through filters into the evaporator plenum chamber, where it shall mix with the fresh air. The evaporator blower shall force the mixed air through the evaporator and heater and into the main air duct specified in Section 7.3.5, from which it will be discharged into the car.

Baffle plates, if necessary, are to be located at least 8 inches from the filters and shall be used to control the volumes of fresh and recirculated air. If the location of a baffle plate is such that it must be removed for routine servicing, it shall be provided with guides and stops to ensure that it is returned to its original position.

A minimum of 1,400 cfm total of fresh air shall be introduced to the car whenever the auxiliary power of nominal 230 VAC is available. The recirculated air volumetric flow rate shall be determined by the following factors:

A. Pressurization requirements

B. Efficiency of blower and coil performance

C. A maximum temperature differential of 25°F between the car average interior temperature and the temperature of the air leaving the diffusers at the slot outlet.

D. Allowable temperature variation within the car or car section.

The ventilation system shall pressurize the carbody interior to a minimum of 0.15 inches of water, when all doors are closed, the car is not moving, and 230 VAC, 3-phase nominal line voltage is supplied for the blower motors.

The evaporator blowers shall operate whenever the car's ECR is energized, as specified in Section 7.5.1.

7.3.2 Air Diffusers

Air shall be discharged into the passenger compartment through continuous, flush, slot-type air diffusers, located in the ceiling. The air diffuser design shall direct the air to avoid undesirable impingement velocities on passengers.

The diffusers shall be designed to provide uniform distribution of air throughout the car. The diffusers shall extend longitudinally along both sides of the bottom of the main air duct. The diffusers shall be designed to provide a car interior which is free of objectionable drafts and one in which the air motion in the car interior does not exceed 40 feet per minute (fpm) in accordance with the AAR's "Recommended Specification For Air Conditioning" when measured in a plane 10 inches or more below the plane of the ceiling. The diffusers may be omitted in the low ceiling areas if the specified uniformity of interior temperatures can be met without them. The slot type diffusers shall be fixed and shall maintain the requirements of Section 7.5.4.

Air shall be discharged into the Operator's cab through a rectangular, flush, multiple-fin diffuser. The Operator shall be able to adjust the amount of air delivered to the cab without the use of any tools.

The diffusers shall be designed to create turbulence within the primary air stream, to ensure rapid mixing of primary air and car air. The efficiency of the diffusers shall be such that the initial temperature differential is reduced by at least one-half at a distance of 6 inches below the face of the slot-type diffusers, and 12 inches below the face of the cab diffuser.

All exposed surfaces of the diffusers shall be of unpainted, satin finish, anodized aluminum.

7.3.3 Air Grilles

Recirculated air shall be drawn in through grilles in the low ceiling areas.

The recirculated air grilles shall have cores and satin finished frames of unpainted stainless steel, and shall be provided with safety catches and limit chains. The grilles shall be designed to pass the required quantity of air silently.

The fresh air intake grilles on the exterior of the car shall be removable and shall be made of perforated aluminum or stainless steel plates. The size and style of the perforations shall be submitted to the Authority for approval. The grilles and their fasteners shall be flush with the skin of the car.

7.3.4 Air Filters

Fresh and recirculated air shall be filtered by 2-inch nominal thickness, industrial type, disposable, fiberglass viscous impingement-type filters. It is preferred that the filters be a commercially available standard size. If this is not feasible due to the plenum design, the filter size shall be selected for cutting from standard bulk rolls with minimum material waste.

Filter holders shall be provided to permit the use of both frameless and framed filters. The filters shall have adequate edge sealing to minimize filter bypass. Filter area shall be such as to limit filter face air velocity to a maximum of 300 fpm. Initial clean filter pressure drop shall be a maximum of 0.09-inch water gauge. The average efficiency shall be a minimum of 70% at a constant velocity of 300 fpm up to
MOD 1 0.5-inch water gauge pressure drop as tested in accordance with ASHRAE 41.3: 1989, Standard Method for Pressure Measurement. The filters shall be adequately supported to prevent blowout of the elements under clogged filter conditions.

7.3.5 Air Ducts

Fresh-air intake ducts shall be constructed of stainless steel, aluminum, or fire resistant plastic per the requirements of Section 15.25, and shall be sloped to drain to the outside of the car. Intake ducts shall be located and designed so as to exclude rain and snow without the need for filters used solely for that purpose; and to prevent car aerodynamics from affecting the direction and velocity of air flow through the ducts, regardless of train speed and the position of the car in the train.

The top and sides of the main air duct shall be constructed of stainless steel or aluminum. This duct shall be constructed with a diagonal splitter of the same material running the entire length, so that a separate duct is provided for each evaporator unit. The bottom of the duct shall be formed by the ceiling panels.

Flexible transition ducts shall be of neoprene-coated nylon or an approved equal. The transition ducts shall be fire resistant per the requirements of Section 15.25 and shall be able to withstand without damage the maximum temperature developed by the overhead heat unit before over-temperature cutoff.

Air velocities in the ducts shall not exceed 1,200 fpm. Acoustic insulation shall be used on ducts as required to control objectionable noise.

Metallic ducting shall not be connected directly to the metallic roof structure. Thermal insulating breaker strips of fire resistant plastic shall be used between the ducting and the structure to minimize heat transfer from or to the ducts.

7.4 COOLING SYSTEM

7.4.1 General

The car shall be cooled and dehumidified by electro-mechanical equipment having adequate capacity to cool the cars to the temperature specified in Section 7.5.4 under the following exterior ambient temperature and humidity conditions, and heat loads:

A. Ambient Temperatures

1. 95°F Dry Bulb (105°F Dry Bulb air into condenser)
2. 78°F Wet Bulb

B. Heat Loads

1. Normal car lighting and electrical loads (including fan motors).

2. 175 passengers at 450 BTU/hr per passenger at 54.0% sensible heat ratio.

3. Normal carbody heat transmission with 15 mph exterior air motion assumed.

4. A solar load of 14,000 BTU/hr, which will represent heat gain to the car interior by direct and diffuse radiation, convection and radiation from the window surface, and absorbed heat gain from the glazing and carbody structure.

Individual cooling systems, designed integrally with heating and ventilation, shall be provided for each end of the car. Failure of the individual subsystems shall not affect the operation of other subsystems.

7.4.2 Air Conditioning Evaporator Units

Cooling and dehumidification of the fresh and recirculated air shall be performed by evaporator units which are an integral part of each overhead fan-coil-heater unit. Each unit shall consist of a motor and centrifugal blowers, an evaporator, and heater section. Each of these elements shall be individually removable from the plenum for repair or replacement.

The evaporator coil fin assembly shall be housed in a rigid stainless steel frame. The coils shall utilize copper tubes, and copper fins of minimum thickness of 0.008-inch and minimum fin spacing of 0.10 inches. The coil area shall be maximized so that the average face velocity of air flow does not exceed 500 fpm; except that, when the coil area is limited by the low ceiling dimensions, air flow velocity exceeding 500 fpm may be approved if necessary to achieve specified cooling requirements. MOD 2 Condensate carry-over into the main duct shall be prevented. A removable condensate drain pan shall be provided beneath the evaporator coil and extend to beneath the thermal expansion valves and coil return elbows in order to collect condensation from the coil and suction line and any other surfaces subject to condensation. The condensate pan shall be of stainless steel with stainless steel fittings. It shall be suitably baffled and arranged to drain and to prevent water from spilling over into the ceiling area under any operating condition including acceleration or deceleration on the maximum grade. Condensate drain lines shall be readily accessible for cleaning and shall be of adequately sized copper tubing routed and sloped to provide positive drainage to the underside of the car. Discharge from the condensate drain lines shall be directly to the track bed. All cold surfaces, including condensate drain lines, coil housings, bottom side of condensate pans, refrigerant tubing and controls shall be insulated to prevent sweating due to condensation. Thermal insulation with closed cell foam meeting the fire-resistance standards of Section 15.25 shall be used for such applications.

Components to be included as a part of the evaporator unit are:

A. A liquid line solenoid valve (a single valve shall be used for each coil).

B. Modulating solenoid or pressure operated valves to reduce each coil's capacity, by reducing the number of active coil circuits. Alternatively, a full face coil may be used, with the first step of modulation to be a compressor speed reduction; on the condition that temperature and humidity control equivalent to the coil circuit reduction technique can be provided under all load conditions, and that the capacity reduction requirements of Section 7.4.3 are met.

C. Thermal expansion valves for the evaporator coil circuits, having external equalizers and internal superheat adjustment only. Minimum superheat shall be 9°F.

D. Brass bodied liquid line strainer and sight glass.

E. Capped Shraeder valve test fittings in each suction header adjacent to the expansion valve equalizer connections for test purposes.

Evaporator unit and its components shall be easily removable and serviceable for maintenance purposes.

The blower motors shall be of a design suitable for transit car application, operating from the APS and meeting the applicable requirements of this specification. Motors and their connections shall be easily accessible for removal and routine inspection and maintenance from inside the car. If speed-adjusting resistors are used, they shall be located underfloor. Motor insulation shall be 1,000 V, Class F or H rated. The motors shall have permanently lubricated ball bearings. A flexible safety ground strap shall be provided from the motor frame to the grounded carbody structure around the vibration isolation mounts.

7.4.3 Compressor/Condenser Units

Each car shall be equipped with two resiliently mounted, separate and complete, combined compressor/condenser units so arranged as to provide free rejection of heated air and to prevent the recirculation or intake of heated air into the condenser coil. Each unit shall include the following items:

A. Permanently lubricated, totally enclosed, transportation Class F or H, insulated, 230 VAC, 3-phase compressor and condenser fan motors.

B. A heavy duty, reciprocating, multi-cylinder transportation type compressor arranged for suction-pressure controlled unloading. A scroll type compressor may be used in place of a reciprocating compressor, subject to meeting all relevant requirements of the Specification. The compressor shall be fitted with cylinder liners and oil pressure actuated unloaders that operate to lift the suction valves from the valve seats. Valves shall be of the ring plate type. The compressor shall utilize screened force fed lubrication. The compressor crankcase body shall be fitted with removable crankcase heaters. The system shall automatically adjust its capacity under varying load conditions.

C. If an open type compressor is utilized, then an approved flexible coupling between the motor shaft and compressor shaft shall facilitate rapid compressor replacement.

D. A condenser fan. The direction of air flow shall be approved by the Authority for the specific application of the car.

E. A condenser coil housed in a stainless steel frame or approved alternate with suitable fan shrouding and protective screening. The coil shall be copper tube and copper plate fin construction with minimum plate fin thickness of 0.008 inches. Minimum fin spacing shall be 0.10 inches. The tube shall be expanded to positively retain the plate fins in position. The coil shall be designed with adequate capacity to provide a maximum condensing temperature no greater than 30°F above the condenser cooling air temperature under conditions of full rated load. The coil and coil ends shall be suitably protected against physical damage.

F. A serviceable filter-dryer assembly with adjacent service valves to provide for replacement of the filter core element.

G. A liquid receiver of sufficient capacity to receive the entire refrigerant charge (in combination with the condenser). The receiver shall be equipped with a sight glass to visually indicate refrigerant level.

H. A combination sight glass and moisture indicator located for convenient observation when servicing equipment.

I. A purge valve located at the high point of the high side system to provide purging of noncondensible gas.

J. Service valves for charging and for test gauge attachment.

K. High and low pressure cut-out pressure switches. The pressure switches shall be arranged to stop the compressor motor if the suction pressure falls below 10 psig or the discharge pressure exceeds 425 psig. The pressure switch settings and operating differential shall be adequately adjustable to obtain uniformity of setting on all cars.

L. A modulation pressure switch shall force the system into modulated cooling when the discharge pressure exceeds 400 psig rising. When the discharge pressure falls to 350 psig, full cooling shall again be allowed.

The compressor/condenser unit shall be resiliently mounted to the car underframe. Approved safety hangers or restraints shall be provided for the unit and the motor compressor if they are of the suspended type. Flexible copper ground straps shall electrically connect the compressor and condenser motor frame to the carbody structure.

The condenser unit coil, and the subcooler if provided, shall be proof tested at 500 psig minimum by the manufacturer.

Service manifold valves shall be provided in the compressor suction and discharge line connections to provide for isolation and replacement of the compressor without loss of refrigerant charge.

The units shall comply with the noise and vibration requirements of Section 16 of this specification.

7.4.4 Insulation

The top and sides of the main air duct shall be insulated with a minimum of one-inch thick, long-fiber, unfaced fiberglass insulation, cemented to the outside of the duct with waterproof adhesive. If the duct or adjacent parts are constructed of aluminum, the insulation shall be of boro-silicate fiberglass with a minimum density of 1.872 lbs./cu. ft.

Refrigerant suction and liquid lines shall be insulated. Refrigerant lines passing through the truck area underfloor shall be protected from damage by sheet metal guards, unless located above and protected by other equipment.

7.4.5 Piping Design and Installation

Refer to Section 15.15 for piping materials.

The Contractor shall follow the procedures of ANSI Code B31.5, latest edition, and as recommended by the manufacturer of the air conditioning system in the design and installation of refrigerant lines. Refrigerant liquid and suction lines shall be insulated both above and below the floor using closed-cell foam insulation meeting the fire-resistance standards of Section 15.25 with approved joint sealant between lengths of insulation.

Vibration isolation shall be provided where any refrigerant line attaches to a resiliently mounted assembly and to the compressor. Vibration isolators beneath the car floor shall have an approved waterproof jacket to prevent icing of the flexible elements. Vibration isolators shall be installed in accordance with manufacturer's recommendations. All refrigerant lines shall be adequately supported to prevent vibration, chafing, fatigue, and stressing of joints.

The Contractor shall prevent dirt from entering the refrigerant lines during fabrication. After fabrication, the refrigerant lines shall be thoroughly cleaned of all dirt, moisture and foreign matter and sealed.

A minimum number of fittings shall be used, and all tubing shall be bent where necessary and practical by means of a tubing bending tool. All inaccessible tubing runs shall be without joints. All tubing shall be deburred after cutting.

Liquid line piping shall be sized to limit pressure loss under full load conditions to a value which will not induce flashing in the liquid line. Suction line piping shall be sized to provide a maximum pressure loss of 3 psi with full cooling capacity. No horizontal traps are permitted in the suction line.

When its installation is complete, the entire system shall be thoroughly tested to be sure that it is absolutely pressure-tight. There shall be no leaks permitted.

The system shall be evacuated and charged according to procedures approved by the air conditioning subsystem supplier and by the Authority.

7.5 HEATING AND COOLING CONTROL SYSTEM

7.5.1 HVAC System Activation

The heating and cooling control system shall be energized through the car's environmental control circuit breaker and ECR. The control system shall utilize a microprocessor with fault indications as approved by the Authority. Layover heat shall be controlled by the layover thermostat, whenever the environmental control circuit breaker is closed. It shall be necessary for the ECR to be activated as described below, for normal control of heating and cooling.

After the environmental control circuit breaker has been closed, it shall be possible to turn the ECR to the "ON" position, and thus activate the heating and cooling control system by the following methods:

A. By inserting a control key into the control lock key switch in the Operator's console, or a door key into the door and environmental control key switch in the auxiliary control panel, and turning either one to the "ON" position.

B. By inserting a door key into the door and environmental control key switch in the auxiliary control panel, turning it momentarily to the "ON" position, back to the "OFF" position, and removing the key.

C. By inserting a door key into the outside environmental control key switch, turning it momentarily to the "EC ON" position, back to the center "OFF" position, and removing the key.

The heating and cooling control system shall be energized continuously whenever the control key is in the "ON" position in the Operator's console or the door key is in the "ON" position in the auxiliary control panel.

7.5.2 HVAC System Deactivation

A time delay arrangement shall be provided which shall delay the de-energization of the heating and cooling control systems on all the cars in a train for a period adjustable from 5 minutes to 1 hour whenever the control key is turned to the "OFF" position in the Operator's console, or the door key is turned to the "OFF" position in the auxiliary control panel. If the heating and cooling control systems on the cars in a train have been energized by Methods B or C above, the time delay arrangement shall de-energize them automatically at the end of the preset time interval. The time delay arrangement shall be compatible with that used on the existing Authority cars.

It shall be possible to de-activate the heating and cooling control systems prior to the completion of the time delay at any time by either of the following methods:

A. By inserting a door key into the door and environmental control key switch in the auxiliary control panel, turning it momentarily to the "EC OFF" position, returning the key switch to the center "OFF" position, and removing the key

B. By inserting a door key into the outside environmental control key switch, turning it momentarily to the "EC OFF" position, back to the center "OFF" position, and removing the key.

The outside environmental control key switch shall have a spring return to the center "OFF" position from both the "EC ON" and "EC OFF" position; and the key shall be insertable and removable only in the center "OFF" position.

The door and environmental control key switch in the auxiliary control panel shall have a spring return to the "OFF" position from the "EC OFF" position; the key shall be insertable and removable only in the "OFF" position.

The time delay functions described above shall be trainlined. It shall be possible to activate the ECR in every car in a train from any point in the train; and to de-activate them from the same or any other point in the train. The trainline control of the environmental apparatus shall be compatible with that used on the existing Authority cars.

7.5.3 ECS Automatic Controls

The heating and cooling control system shall use microprocessor-based solid state controls to directly control solid state devices used for power switching. Accuracy and operating differential of all thermostats shall be sufficient to meet the specified car interior temperature requirements. The battery circuit logic and power contactors to control the heating, ventilation, and air conditioning shall be located in an accessible location beneath the car in an approved corrosion resistant steel enclosure with a removable cover and suitable weather seals. High and low voltage circuitry and wiring harnesses shall be separate and suitably permanently identified. High voltage apparatus adjacent to or part of reset or test devices shall be properly isolated to avoid accidental contact by maintenance personnel. Wire and wire insulation shall be of an approved type (according to Section 15) selected to meet the required ampacities for the ambient temperature conditions within the control box. Drain holes shall be provided in the bottom of the box to prevent accumulation of moisture. All wiring into the box shall be to approved terminal strips in accordance with Section 15.19.2. Multi-pin connectors in accordance with the requirements of Section 15 shall be used to the maximum extent possible. All wiring shall be permanently tagged or otherwise identified by wire number.

In the event running resistors or starting resistors are mounted exterior to the control box, suitable protective heat shielding shall be provided to prevent heat build-up within the control panel. Power resistors shall not be mounted within the control box but shall have adequate protective screening to keep out moisture and debris and to prevent accidental contact by maintenance personnel. Appropriate high voltage warning labels shall be attached to the protective screening.

Heat element cycling shall be minimized by staging the floor and overhead heat at an outside ambient temperature to be approved by the Authority when the basic vehicle design and minimum cooling capacity of the system are defined, and by optimizing the staging size used for reheat.

Blower fan contactor interlocking of the overhead heat contactors and the air conditioning compressor motor contactor shall be provided to prevent heater or compressor actuation unless the blower fans are energized.

All high voltage switching devices shall be rated for 1,500 VDC operation.

All relay coils shall have suppression networks at each coil to inhibit transients on the battery circuits.
Blocking diodes used in the low voltage control circuitry shall have a minimum 1,000 Peak Inverse Voltage (PIV) rating.

Indicating devices shall be provided to indicate that the controls are calling for one of the following operating modes: floor heat first stage, floor heat second stage, overhead heat first stage, overhead heat second stage, modulated cooling front end, modulated cooling rear end and full cooling. The indicating devices shall be located on the face of the heating and cooling control system box and easily visible.

The microprocessor shall also monitor ECM system signals and shall store selected diagnostic information to be utilized by the vehicle monitoring system via a data acquisition module (DAM) as specified in Section 7.7.

7.5.4 Winter-Summer Mode Selection

A Winter-Summer mode selector device shall be provided so that the average interior temperature range will be either 63°F to 67°F in Winter mode or 71°F to 75°F in Summer mode. The 4°F range is to provide a band in which a more specific temperature will be maintained within that range dependent on load and whether heating, or modulated cooling with or without reheat is required to balance the load within the range. When Winter or Summer mode is selected, the interior temperature shall not float between corresponding ranges required by Section 7.5.5, but will be driven by heat or by full cooling depending on mode selected.

7.5.5 Required Interior Car Temperatures

The following average temperatures (in °F) shall be maintained within the car interior depending on whether winter or summer mode has been selected and the Environmental Control Circuit Breaker (ECCB) is "ON."

ECR	Mode	Ambient Temperature (Wet Bulb)	Average Interior Temperature
OFF	Winter	-5° to 45°F	45° ± 3°F
ON	Winter	Above 5°F	63° to 67°F
ON	Summer	95°F or lower	71° to 75°F

The term "average temperature" means the arithmetic average of the temperatures at the 25 or more representative locations used for the tests described in Sections 7.8.1 and 7.8.2, which are read at any given time after the temperatures have stabilized. These locations are in areas in which the permissible variations are specified.

If the maximum exterior ambient dry bulb temperature of 105°F is exceeded, the cooling system shall have adequate capacity to maintain either the specified car interior temperatures or a temperature not higher than 20°F below ambient. Similarly, if the exterior ambient temperature falls below -5°F, the heating system shall maintain a temperature in the car not less than 60°F above the outside ambient.

The relative humidity in the car shall not exceed 60% under conditions of stable cooling loads when cooling is called for and the interior car temperature is 75°F or below.

The temperature in the Operator's cab, with the side window closed, the cab heater turned off, and the diffuser fully open, shall be controlled to the specified car interior temperatures during cooling and shall be no more than 10°F lower than the specified car interior temperatures during heating.

The following variations are the maximum that shall be permitted after the car interior temperatures have stabilized:

A. Over a period of 30 minutes, at any given point in the car, except in the entranceways, and at least 12 inches from the ceiling and 6 inches from the floor and walls: 2°F.

B. At any given time, among all points in the same horizontal plane from one end of the car to the other (except in the entranceways, where 4 °F variation is acceptable): 2°F.

C. At any given time, between any point approximately 48 inches above the floor and the corresponding point, directly under it, 6 inches above the floor: 2°F.

D. During a door opening of 15 seconds duration, at any point on the centerline plane of the car, on the seat side of and 4 inches from the plane of the side door windscreens, and 6 inches to 66 inches above the floor: 5°F. (This requirement shall not apply to simultaneous opening of the doors on both sides of the train.)

7.5.6 Alternative Humidity Control

The Authority is willing to entertain a proposal for use of a humidistat for humidity control. This device shall be capable of reliable operation in the transit car environment. It shall be suitable for operation at the steady state and transient voltages specified herein, be unaffected by shock and vibration as experienced during transit car operation, and be capable of operation without periodic maintenance or cleaning more than once per year. This device shall be able to respond to a 3% change in humidity within two minutes of the change in humidity.

7.6 APPROVAL

The detailed design of the system shall be presented to the Authority for information during the system final design review. Information to be submitted shall include the following:

A. Fan Curves: external static pressure vs. standard cubic feet per minute (SCFM) showing the RPM and BHP for 230 VAC, 3-phase nominal line voltage, 10% overvoltage and 10% undervoltage.

B. Evaporator Coil Design Criteria: entering and leaving wet and dry bulb conditions at the design saturated suction temperature. Wet and dry coil pressure drops shall be given at the specified flow rate. The dividing of the coil for modulated cooling (if used), and the number of rows and fins per inch shall be presented.

C. Compressor: the volumetric efficiency vs. absolute pressure ratio curves shall be presented along with the sweep volume of the cylinders. The design RPM shall be specified for 230 VAC, 3-phase nominal, 10% overvoltage and 10% undervoltage. Make and model number of the compressor shall be given.

D. Condenser Coil Design: air-to-refrigerant temperature differential, degrees of subcooling and pressure drop at the design conditions shall be specified.

E. Motors: current draw, horsepower and RPM versus percent load shall be given for 230 VAC, 3-phase nominal, 10% overvoltage and 10% undervoltage for the blower and compressor motors, and make and model number.

F. Pressures/Temperatures: design saturated suction and discharge temperatures shall be given at full load and 230 VAC, 3-phase nominal voltage. Pressures to be given include the saturated suction pressure setting for the unloaders and the high pressure and low pressure cut-out switch settings and differentials.

G. Evacuation and Test Procedures: equipment manufacturer's factory electrical test and evacuation procedures including leak testing.

H. Diagrammatics/Schematics: electrical schematics, wiring and piping diagrams showing resistance values of each resistor, contactor and solenoid valve coils, wire sizes, and piping sizings.

I. Vibration mount design selection.

J. Balancing criteria for motors and fans.

7.7 VEHICLE MONITORING SYSTEM (VMS) INTERFACE

The input and output signals from each HVAC system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in

Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

7.8 TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 1.8.

7.8.1 Air Conditioning Test

The following Air Conditioning tests shall be performed.

7.8.1.1 Qualification Test

The air conditioning system in one of the cars of the sixth pair shall be tested in an approved climate laboratory capable of being heated to and maintaining a temperature of 100°F and of maintaining any level of humidity between 25% and 90%. Temperature in the climate laboratory shall be uniform throughout; a maximum of 5°F variation will be permitted from the rail to 2 feet above the roof and from end to end of the car. Fans may be used to circulate air. Passenger load shall be simulated by means of heaters inside the car; solar and equipment loads shall be simulated by means of heaters inside or outside the cars. Humidity shall be introduced into the car.

The testing shall begin by "soaking" the car at 100°F for at least 16 hours; and the length of time required to stabilize temperatures, after air conditioning equipment is energized, shall be measured. Testing shall include a functional check of all apparatus including thermostats and controls, an air balance test, a pressurization test, and a temperature and relative humidity check to show compliance with the specified cooling requirements with the car operating at 700 VDC as required by Section 2.2. The proportion of fresh and recirculated air and the total volume of air delivered by the circulating fans shall be measured and recorded. Measurements shall be taken with the apparatus running at nominal voltage (700 volts) and at minimum voltage (430 volts). The current drawn by the equipment, its speed, and the line voltage shall be continuously recorded for each of the test conditions. After temperatures have leveled off (for each test condition) the temperatures at no less than 25 representative locations, including the operating compartment, shall be recorded every minute for 30 consecutive minutes in order to determine temperature variation as the cooling apparatus cycles. Tests shall be run at ambient temperatures of:

A. 65°F dry bulb; 60°F wet bulb
B. 80°F dry bulb; 75°F wet bulb
C. 95°F dry bulb; 90°F wet bulb

For each of the above temperature conditions, tests shall be run with full passenger load and full solar load simulated and also with neither of these loads. In all cases, equipment load shall be simulated.

7.8.1.2 Functional Test and Adjustment

The thermostatic operation of the air conditioning equipment in all cars shall also be demonstrated by test. Controls and dampers shall be checked and adjusted for even distribution and proper circulation of air in all cars.

7.8.1.3 Air Diffuser Test

The compliance of the diffusers with the qualities specified in Section 7.3.2 shall be tested in a laboratory prior to finalizing the design of the diffuser and, subsequently, in the air conditioning test referred to above, to confirm compliance in the actual car.

7.8.2 Heating Test

The following heating tests shall be performed.

7.8.2.1 Qualification Test

The heating system, including cab heating, in one of the cars of the sixth pair shall be tested in an approved climate laboratory capable of being cooled to maintain a temperature of 0°F. Temperature in the climate laboratory shall be uniform throughout; a maximum of 5°F variation will be permitted from the rail to 2 feet above the roof and from end to end of the car. Fans shall be used to circulate air. Circulating fans used during these tests shall develop air velocities of at least 5 mph as measured anywhere around the carbody 6 inches from the carbody surface. The testing shall begin by "soaking" the car at 0° F for at least 16 hours; and the length of time required to stabilize temperatures, after heating equipment is energized, shall be measured. Testing shall include functional checks of all apparatus including thermostats and controls, and a temperature check to show compliance with the specified heating requirements, including Layover Heat.

Tests shall be made at outside temperatures just above and just below the operating temperatures of the fresh air thermostats in addition to a test at 0°F. Heating tests shall be run at nominal voltage and at minimum voltage for each outside temperature condition. After temperatures have leveled off (for each test condition) the temperature at the same locations as cited in Section 7.8.1.1 shall be recorded every minute for 30 consecutive minutes in order to determine temperature variation as the heating apparatus cycles. Line voltage, and current and power drawn by the heating elements shall be continuously recorded. The specified car interior temperature requirements shall be maintained with the car operating at 700 VDC as required by Section 2.2.

7.8.2.2 Heat Transfer Test

Using the car's own floor heat elements only, heat transfer through the carbody shall be measured to verify conformance with Section 3.12.2. This test shall be performed as part of the Qualification Test above in the climate room held at 0°F, with the air in the climate room being circulated at a velocity of at least 5 mph, as measured 6 inches from any surface of the carbody.

7.8.2.3 Functional Test

In all cars the heating system shall be functionally tested. The operation of the thermostatic control system shall be demonstrated by test. Controls shall be checked and adjusted for even distribution and proper volume of heat.

7.8.2.4 Defroster Test

The ability of the cab heated glass windshield to comply with the requirements of Section 7.2.6 shall be demonstrated during the heating test described above.

SECTION 8
LIGHTING

TABLE OF CONTENTS

Section **Page**

SECTION 8
LIGHTING

8.1 INTERIOR LIGHTING

8.1.1 General

The passenger area shall be illuminated by two longitudinal rows of fluorescent fixtures mounted in the ceiling with additional short transverse fluorescent fixtures mounted over the end doors. In addition, incandescent fixtures shall be provided to illuminate the side door threshold when the adjacent door is open (Section 6.4.2).

The arrangement of the fluorescent fixtures in the ceiling shall generally be as shown on Contract Drawing 97936-007 and shall be subject to approval by the Authority.

All incandescent lighting shall operate on battery voltage. Overhead fluorescent lights, except for emergency lights, shall operate from 37.5 VDC using either a dedicated inverter or DC lamp ballasts and shall remain lit for a period of time compatible with load shedding times established in accordance with Section 9.2.5 during interruptions of primary power.

8.1.2 Intensity

The following minimum light intensities shall be met with new lamps and power sources at nominal values:

Location	Intensity
Reading plane, seated passenger, longitudinal seats and transverse seats nearest end of car	30 footcandles
Reading plane, standing passenger, most unfavorable direction	20 footcandles
Floor, fluorescent lights illuminated	15 footcandles
Floor, at side door threshold, from side of car to 12 inches inboard of the side, threshold lights illuminated, fluorescent lights extinguished	15 footcandles

The reading plane for a seated passenger is at a 45-degree angle, intersecting a horizontal line parallel to the seat back, 33 inches above the floor; for a standing passenger it is at a 45-degree angle, 51 inches above the floor.

The intensity values shall be verified on the first car during qualification testing.

8.1.3 Fluorescent Fixtures

The exposed portions of fluorescent fixtures shall be similar to the appearance of those on existing Authority rail cars and shall be subject to approval by the Authority. The fixtures shall be arranged for relamping from below, by means of a hinged door which shall contain the diffuser lens. The door hinge shall be made of metal and shall be able to withstand dropping the door to the open position without breakage. The fixture and door shall be sufficiently rugged to maintain their alignments and resist distortion during the life of the car; no door shall be more than 50 inches in length. Alignment pins shall be used between adjacent fixtures. The hinge shall be on the side of the fixture nearer the side or end of the car and shall be a concealed type. The door shall be held closed, on the side opposite the hinge, by a spring latch and/or by one or more captive, self-locking screws requiring one-quarter turn to lock. The fixtures shall not incorporate wireways.

Fluorescent lamp sockets shall support the ends of the lamps in such a way that vibration cannot cause the lamps to fall.

The fluorescent lighting, excluding emergency lights, shall meet the requirements of UL 935, Class P and shall be thermally protected and of the high-power-factor type. The lighting shall operate by means of one- or two-lamp lighting ballasts, which shall comply with Section 8.1.7. The fluorescent fixtures shall be on two circuits, staggered through the car; adjacent lamps or pairs of lamps shall not be on the same circuit.

Lamp shall be limited to 20-watt (F17T8WW), 30-watt (F25T8WW), and 40-watt (F32T8WW) sizes; they shall be type T-8 high efficiency rapid start having a rated life of 20,000 hours; and shall be Warm White in color.

The fixtures shall be resistant to entry of dust, moisture, and insects. The diffuser lens shall be made of UV-stabilized polycarbonate meeting the flammability requirements of Section 15.25. Prisms shall be utilized and shall be accurate to within 0.1 degree; radii of fillets shall not exceed 0.010-inch. Both top and bottom surfaces of the lens shall be covered with smooth sheets to facilitate cleaning. Alternative arrangements may be considered acceptable if approved by the Authority. If the lens is made of two or more plies, the edges shall be sealed to prevent entry of dust between the plies. Light output from the fixture shall be obscured at higher viewing angles so as to produce light output as follows:

Longitudinal Direction

Viewing Angle	Maximum Candlepower
50°	325
60°	200
70°	100
80°	30

The viewing angle is measured from a vertical line down from the fixture.

8.1.4 Threshold Lights

Each windscreen shall have a dual lamp incandescent fixture. The lamp beams shall be directed so as to illuminate the door threshold and the floor immediately inboard of the threshold.

Threshold lights shall operate on battery voltage and shall be controlled as required in Section 6.4.2. Resistors shall be used as required to reduce the line voltage to the nominal lamp voltage. Door threshold fixtures shall use S-8, double contact, bayonet base long life lamps, Chicago Miniature 895, or approved equal.

8.1.5 Cab Lighting

An incandescent reading light having an adjustable swivel base type mounting, similar to those currently in use on the Authority’s existing rail cars, shall provide at least 25 footcandles on the reading plane. This light shall be located in the ceiling of the cab above the Operator’s seat. It shall operate on battery voltage and shall be controlled by a switch in the cab. The reading light shall be so designed as to cause minimum interference with observation of the roadbed when in use at night. The cab reading light shall use a 15 candlepower, S-8, double contact, bayonet base, long life lamp, Chicago Miniature 895, or approved equal.

Illumination of the console controls shall be provided by lights built into the console as specified in Section 9.7.2.

8.1.6 Fluorescent Lighting Control

Fluorescent lighting shall be controlled by circuit breakers located in the Operator's circuit breaker panel and by a trainline-controlled lighting relay. It shall be possible to turn the fluorescent lights on or off throughout a train by the use of the train lighting switch in any cab in which the switch has been energized by the use of either the control key on the Operator's console or the door key on the auxiliary control panel. It shall be possible to remove the key after the lights have been turned on, and have them remain on; and to turn them off from a different cab than that from which they were turned on. The circuits shall be compatible with the circuits on the existing Authority cars.

A time-delay arrangement shall be provided which shall automatically turn off the fluorescent lighting, when there is no control key in the console at either end of the train, after a period adjustable from 20 minutes to 1 hour. This time-delay arrangement may be combined with the time delay arrangement used to de-activate the heating and cooling control systems, described in Section 7.5.2.

8.1.7 Fluorescent Lighting Ballasts

8.1.7.1 General

Ballasts shall be rapid start units which shall meet the requirements of UL 595 and ANSI C82. All ballasts shall be integral with the fluorescent fixtures and shall be approved for rapid transit car use. Ballasts shall have the ability to withstand the voltage fluctuations, including the most severe transients, inherent in this type of service. The ballasts shall operate at a frequency (minimum 20 kHz) above the audible spectrum and have electrical noise suppression to meet the EMI requirements of Section 1.4.5. The ballasts shall operate lamps with minimum detectable flicker with total harmonic distortion of less than 10%. Ballast shall be solid state electronic type with power factor greater than 98%. Lamp current crest factor shall be less than 1.7%. Ballast shall meet CFR for EMI/RFI (47 CFR 0-19, Ch I: 1998). Ballast shall also meet all applicable ANSI and IEEE standards regarding harmonic distortion and transient protection such as ANSI C62.41: 1980. The ballasts shall be equipped with individual fuse protection and shall have fuses that are accessible without requiring disassembly or removal of the ballast. The ballasts shall operate either rapid-start or trigger-start lamps, shall produce full rated lamp output, shall not shorten lamp life below normal, and shall not, in the case of two-lamp ballasts, be harmed by operation with one lamp missing or defective. Lamps shall start, even though light output is reduced, at 0°F with nominal voltage at the input. The sound rating shall be A or better.

MOD 1

A proposal for the use of throw-away ballasts may be submitted to the Authority for approval if sufficient data are included to attest to their reliability and cost-effectiveness.

8.1.7.2 AC Ballasts

In addition to the above requirements, AC ballasts shall be high efficiency, high power factor units which meet the requirements of Federal Efficiency Law 100-357. The AC ballasts shall use plug-in connectors keyed so as to prevent interchangeability with the DC static inverter ballasts on the existing Authority cars.

8.2 EXTERIOR LIGHTS

8.2.1 Position

Two headlights, two white running lights, two red tail lights, and two red running lights shall be furnished on each cab end. The headlights, tail lights, and running lights shall be located as shown on Contract Drawing 97936-005.

The headlights shall consist of two sealed-beam lamps, each 200 watts, nominal 30 volts, type PAR 56, mounted in a fixture which supports the lamp securely and is adjustable, with bezel in place, to permit proper horizontal and vertical alignment.

The headlight beams shall be set parallel to the centerline of the car; and 0 degrees, 15 minutes down from horizontal.

Prior to acceptance testing, the headlights on each car shall be aimed and adjusted to meet the specified beam characteristics.

The tail lights shall consist of two red sealed beam lamps, each 60 watts, nominal 37.5 volts, type PAR 46, mounted in a fixture similar to the headlights.

The tail light beams shall be set parallel to the centerline of the car and horizontal.

The white running lights shall use 15 candlepower, S-8, double contact, bayonet base, long life lamps, Chicago Miniature 895, or approved equal.

The red running lights shall utilize red LED clusters as approved by the Authority.

8.2.2 Source

The headlights, tail lights, running lights, and all indicator lights shall be arranged to operate on the battery circuit and shall not be wired in series. Resistors may be used as required in headlight, tail light, running light, and indicator light circuits to reduce line voltage to nominal lamp voltage.

8.2.3 Design

The red and white running lamps shall be designed for relamping from the interior of the car. All other exterior lights called for in this section and elsewhere in this specification shall be designed for relamping from the exterior of the car and shall feature easy maintenance access for rapid relamping. Headlight and tail light aiming shall be accomplished from the car exterior. The hardware used to permit relamping or aiming shall be captive.

The headlight and tail light enclosures, running lights, and indicator lights shall be designed so that they do not allow leakage of water into the carbody.

The running and indicator lamp assemblies shall utilize glass lenses and shall be designed to prevent damage to the assembly due to heat build-up.

The running lights shall be located on the end of the car as shown on Contract Drawing 97936-005. The beam spread of each light shall be no less than 20 degrees horizontally and 10 degrees vertically. The beam intensity shall be such that, when measured at the center of the beam of the white running light and at a test distance of 50 feet, it is no less than 300 candelas; the red running light shall be of the same fixture design as the white running light, and shall use a red lens.

8.2.4 Control

Control of headlights, tail lights, running lights, and console lights shall be automatic, through contacts in the electric coupler and a relay operated by the control key, so as to achieve the operations described below.

Both ends of a train shall display tail lights and red running lights at all times unless a control key is inserted at either end cab. When a control key is inserted in the control console, the tail lights and red running lights at that location shall be extinguished and the headlights, white running lights, and console lights shall be illuminated. No lights shall be illuminated at intermediate coupled ends. To allow for emergency operation of the train from other than the leading cab, a headlight by-pass switch in the Operator's circuit breaker panel shall permit extinguishing the tail lights and red running lights and illuminating the headlights and white running lights on the leading car. This switch shall be sealed in the normal position.

The headlights shall be arranged for dimming through resistances operated by a push button in the Operator's console. An indicator light in the console shall be illuminated when headlights are bright.

8.2.5 Indicators

Red illuminated indicators shall utilize red LED clusters, as approved by the Authority. To the maximum extent possible, other illuminated indicators shall utilize LED clusters. The color and intensity of the illumination shall be as approved by the Authority. Where LED clusters are not used, indicating lights shall feature 15 candlepower, S-8, double contact, bayonet base, long-life lamps, Chicago Miniature 895 or approved equal, powered from the battery system as described in Section 8.2.2. Exterior indicating lights shall be located as shown in Exhibit 8-1.

Exhibit 8-1 – Exterior Indicating Lights

Indicator Description	Indicator Color	Exterior Location
Front Truck Fault – Brake System	Blue (Top)	Rear Bulkhead Under Right Window
Brake System Fault	White (Center)	Rear Bulkhead Under Right Window
Rear Truck Fault – Brake System	Blue (Bottom)	Rear Bulkhead Under Right Window
Trainline Circuit Breaker Tripped	Amber	Rear Bulkhead Under Left Window
Brakes Released	Green	Rear Bulkhead Above End Door
Brakes Applied	Amber	Rear Bulkhead Above End Door
Door Status	Red	Car Side Above Center Doorway
Manual Mode	Blue	Car Side – Right
ATP Cut-Out	Amber	Car Side – Right
Propulsion System Fault	Blue	Rear Bulkhead Under Left Window

MOD 2

Unless noted otherwise, all car side indicating lamps shall be located near the top of the rear side of the car, similar in appearance and function to the Authority's existing cars, and shall be clearly visible from the lead cab of an eight car consist.

8.3 EMERGENCY LIGHTS

8.3.1 Location

Six of the longitudinal, 40-watt, fluorescent fixtures shall serve as emergency lights. They shall be located two in each entranceway at doors 1-2, 5-6, and 9-10.

8.3.2 Control

The six emergency fixtures shall be illuminated whenever the car's trainline-controlled lighting relay is closed. They shall not, however, be connected to any load-shedding device.

8.3.3 Power

Emergency lighting shall be powered from 37.5 VDC battery voltage.

SECTION 9
POWER SUPPLY AND MISCELLANEOUS ELECTRICAL APPARATUS

TABLE OF CONTENTS

Section **Page**

Section **Page**

SECTION 9
POWER SUPPLY AND MISCELLANEOUS ELECTRICAL APPARATUS

9.1 POWER SUPPLY

9.1.1 General

Electrical equipment shall be energized from the following power sources: (1) 700 VDC from the third rail; (2) nominal 37.5 VDC from an installed storage battery system, which includes a power converter operating on third rail power; (3) inverter(s) operating on third rail power; (4) 115 VAC, single-phase, 60 Hz from the auxiliary power system inverter.

9.1.2 Third Rail Source

Third rail voltage shall be used for propulsion, via inverters for AC drive; heating (except for cab heater); and as input to the battery system power converter and the auxiliary power system inverter(s). Except under fault conditions, the maximum current draw per car from the third rail shall not exceed 1,620 amps for more than 1 second.

9.1.3 Auxiliary Power System (APS)

9.1.3.1 General Requirements

Each vehicle shall contain its own auxiliary power system (APS). Each system shall consist of either a DC-AC inverter, located under the car, operating on the third rail power and servicing all AC auxiliary loads on the car, or a combination of a central inverter servicing several loads plus individual inverter-motor units each operating on the third rail power.

A microprocessor-based control system shall be utilized for the centralized system and shall monitor the status of the APS and store appropriate diagnostic information to be utilized by maintenance personnel. The diagnostic information, including system fault data, shall be retrievable either by direct readout at the equipment or by down load to a lap-top computer or portable test unit. The microprocessor shall also monitor power supply system signals and shall store selected diagnostic information to be utilized by the vehicle monitoring system via a data acquisition module (DAM) as specified in Section 9.10.

The APS shall be sized for continuous operation of the air compressor, air conditioning compressor, blower motors, and cab heater loads in addition to any other continuous auxiliary loads.

The design of the APS shall emphasize commonality of equipment between the “A” and “B” cars wherever appropriate.

The APS shall shut down when the steady state input voltage is out of the range specified in Section 2.2 and shall restart automatically when the steady state voltage is restored to within the specified range.

9.1.3.2 Voltage and Frequency Regulation

The nominal, steady state output of the APS shall be 230 VAC, 3-phase, 60 Hz, over the full range of input voltage and load.

The voltage waveform shall be sinusoidal with a maximum total harmonic distortion of 8%.

The phase-to-phase voltage imbalance shall not exceed 1% between phases.

9.1.3.3 Load Management

Load application, shedding, and reapplication shall be provided as an integral part of the APS. The priority of the load management system shall be to maintain the essential vehicle operating systems on-line for as long as possible during primary power anomalies. Loss of a single APS inverter on a married pair shall not result in loss of power to the air compressor. Load management details shall be as developed by the Contractor and approved by the Authority during the system design review process.

9.1.3.4 Fault Monitoring and Control

The controls for the APS shall be designed to prevent damage to auxiliary equipment, including the APS itself, resulting from:

A. High and low frequency
B. Over- and under-voltage
C. Out of tolerance voltage-to-frequency ratio
D. Frequent repetitive starts (limits to be defined by the equipment manufacturer)
E. Rapid variations and transients in line voltage or loads
F. All primary power interruptions
G. Harmonic distortion
H. Phase loss.

The control logic shall require the equipment to automatically restart following shutdowns caused by self-correcting failure conditions. Major faults shall latch the equipment off until repaired and reset by maintenance personnel.

Circuitry used to provide protection for voltage and frequency deviations shall be wholly independent of the circuits used to control voltage and frequency. The permissible range of voltage and frequency deviations shall depend on the requirements of the specific load components, but once established, these values shall be set in the circuitry and have a self-testing capability.

The fault monitoring system shall identify and record faults causing system shutdown in non-volatile memory circuitry. System fault data shall be retrievable by maintenance personnel either by direct readout at the equipment or by down load to a lap-top computer or portable test unit.

9.1.3.5 Additional Requirements

The system design shall satisfy and accommodate the following additional requirements:

A. The output of the APS shall be electrically isolated from the 700 VDC supply.

B. The design, selection, and installation of wiring and all AC equipment that is to be powered from the APS shall be coordinated with the output characteristics of the inverter so that the design life, performance, maintenance, and operation of any piece of equipment is not adversely affected.

C. Load shedding and restarting of the AC loads shall be coordinated to prevent delays when restarting equipment after a momentary interruption in the primary power to the inverter caused by a third rail gap.

D. The APS waveform generation scheme(s), output transformer quality, component mounting, acoustical shielding, and other parameters shall be optimized to minimize audible noise. Audible noise requirements are given in Section 16.

E. Input filter requirements of Section 10.6.7.1 shall be met.

F. EMI and RFI requirements of Section 1.4.5 shall be met.

G. The inverter(s) shall be supplied with nominal 700 VDC power from the auxiliary fuse through a protective circuit breaker and a suitable line isolation system. This system shall be the normal means of energizing the inverter. It shall be properly coordinated with the circuit breaker and auxiliary fuse to assure immediate interruption of any fault current with no damage to any equipment. Line isolation shall be achieved whenever the third rail shoes are not in contact with an energized third rail. The line isolation system shall be designed so that it does not interpret the presence of any on-car developed traction voltage as third rail voltage.

9.1.4 Battery System Source

Systems and components supplied with battery voltage include, but are not limited to, the headlights, tail lights, running lights, threshold lights, emergency lights, cab ceiling lights, instrument lights, temperature controls, destination sign controls and illumination, door operators and door controls, communications system, automatic train control, ATC power supply, and propulsion and braking controls. All subsystems or components supplied directly from the battery shall be capable of operation with subsystem or component input voltage at any and all values between 23 and 42 volts.

The Contractor shall be responsible for coordinating the design of all circuits and equipment operated at battery voltage to prevent damage or disturbance to function caused by electrical transients generated by any component connected to the battery system. To this end, the Contractor shall develop standards covering the entire frequency spectrum, defining the maximum allowable transients and interference that any subsystem may introduce on wires which lead to other subsystems, and defining the transients and interference which all subsystems connected to the battery system shall be able to tolerate without harm or degradation of function. The transient amplitudes that subsystems shall be able to tolerate shall be at least four times as great as the maximum amplitudes that any subsystem is allowed to generate. Prior to issuance of purchase specifications for battery system components, the Contractor shall develop and submit a plan for battery system electrical compatibility. *(CDRL 901)* Compatibility criteria contained in the plan shall be applied to the component purchase specifications.

Equipment and power circuits operated at battery voltage shall be designed so that sustained presence of any battery voltage from the maximum down to zero will not cause damage to any part of the car. This requirement shall not be taken as an indication that low battery voltage is expected to occur at any time during normal operation, but only as a means of avoiding excessive damage in the event that it should occur as a result of unpredictable events.

The battery system shall be designed to supply the heaviest possible combination of loads which can be applied thereto in an eight-car train. There shall be no more than 1.0-volt difference between battery terminal voltage and the voltage across the input terminals of each subsystem or component package fed from the battery assuming the largest currents which can occur (excluding faults) when battery voltage is 25 volts and auxiliary loads have not yet been shed. This 1.0-volt maximum drop shall apply to loads within the pair of cars supplied by the battery in question. When the battery system of one pair is the only source of power to the battery system loads of an adjacent second pair whose battery breaker has been tripped, the difference between the voltage at the first pair's battery and the input voltage to any load in the second pair shall not exceed 2 volts when the first pair's battery is at 25 volts. The B(+) and B(-) battery system trainlines cables shall be of stranded copper with conductor section area sufficiently large to accomplish the above functions. The design of the battery system shall provide battery charging compatible with the manufacturer's recommendation to ensure maximum battery life.

Load shedding will be accomplished as described in Sections 8.3.2 and 9.2.5.

9.2 STORAGE BATTERY

9.2.1 Battery Capacity

Each "B" car shall be equipped with a nickel-cadmium battery of a type to be approved by the Authority. The battery shall have at least 25 cells. Each cell shall have a steel case, and shall have sufficient excess water capacity to be able to endure 2 months of normal service without requiring the addition of water. The choice of ampere-hour capacity shall be the Contractor's responsibility subject to the limitation that the capacity shall be at least 230 ampere hours at the 5-hour rate and with cut-off at 1.14 volts per cell. The battery shall, at normal battery operating temperature, have sufficient capacity to:

A. Provide all 37.5-volt loads (including emergency lighting) when operating as a two-car train in the absence of battery charging voltage for a period of 40 minutes, including 20 station stops.

B. Maintain a terminal voltage adequate to operate all connected systems after 60 hours operation on a stored pair of cars with the Battery System Power Converter inoperative (assuming normal loading), heating control in layover position, and the control key removed.

C. Carry emergency lighting, communications systems, running lights, and any loads that cannot be shed by the use of cab circuit breakers and switches, on a two-car train standing still with no third rail power, for two hours.

Each of the above conditions is to be met beginning with a battery charged to 85% of capacity. The conditions need not be met cumulatively.

The batteries on all cars shall be connected in parallel through B(+) and B(-) trainlines of adequate capacity to handle the current required for operation of a pair of cars when operating as the leading pair under the conditions A through C above. The battery trainlines shall also be of adequate capacity to permit the power converter at one end of an eight-car train to charge all batteries in the train during layover. These requirements are in addition to the requirements specified in Section 9.1.4.

The battery system shall be complete with an approved over-temperature protective system to guard against possible damage to the battery, battery enclosure, and other car components resulting from excessive battery charging. It shall open the battery circuit breaker when over-temperature is detected. The temperature sensor shall be located so that the battery, battery box, and other components are protected, but nuisance trips avoided. Its location and mechanical protection shall prevent damage to the sensor during operation and all battery maintenance procedures.

9.2.2 Battery Box

9.2.2.1 General

The battery shall be carried in a box constructed of stainless steel located under the "B" car. The box shall be mounted with a system of guides and rollers so as to allow the battery box to roll out to the side of the car for maintenance.

The roll-out system shall be corrosion resistant and shall be provided with the necessary stops and locks to limit the travel of the battery box and retain it in both extreme positions. When rolled out, the entire top of the battery shall be exposed.

9.2.2.2 Box Interior and Construction

The box interior shall be lined with 3/16-inch to 1/4-inch thick "Insularc" insulating board or an approved alternate nonflammable, electrolyte-proof, insulating structural material. The box shall be ventilated to preclude the possibility of a build-up of hydrogen gas and shall also be equipped with a removable drain plug in the floor.

The box shall have a minimum 1-5/16 inches excess height and 3 inches excess length and width to permit later replacement by cells of different manufacture. The excess length and width shall be filled by blocks held in place by suitable hardware.

9.2.2.3 Battery Tray, Roll Out System and Locks

Within the battery box, the battery shall be mounted in roll-out trays to allow for easy maintenance. Each tray shall be provided with the necessary stops and locks to limit travel and to retain it in either the fully extended or fully housed position. The trays shall be designed to roll out without the use of any tools other than the tool required to unlock the trays. The box and tray design shall permit all trays to be in the extended position at the same time without deflection or damage to the slide system.

Tray roll-out system shall require approximately 25 lbs. force to move from the normal stowed position to the fully extended position or to return it to the normal stowed position. The tray mechanism shall not require maintenance more than once every 2 years to maintain the approximately 25 lbs. operating force.

The design of the locks shall prohibit locking unless the box and trays are in extreme, i.e., fully housed or fully extended, positions. It shall not be possible to unlock a tray unless the box is locked in the fully extended position.

The battery box and tray locks shall be electrically interlocked so as to prevent train movement at all times except when both the box and trays are locked in the fully housed position. The locks shall have sufficient strength to prevent movement of the battery box and trays during normal operation of the car when subjected to the specified forces and loads.

9.2.3 Battery Circuit Breaker

A battery circuit breaker of adequate capacity and approved design shall be mounted in an enclosure under the "B" car and as close to the battery as possible. The breaker shall be as specified in Section 9.7.1.3.

This breaker shall incorporate a shunt-trip device, which shall be used to disconnect the battery whenever the battery terminal voltage falls to a level that could result in battery damage. Shunt trip of this breaker shall cause a trainline specified by the Authority to become energized and a local annunciator light at the breaker to be illuminated. In no event shall this trip voltage be higher than 25.0 volts. Reset shall be manually at the breaker. Tripping on this basis shall function only to prevent battery damage which would otherwise occur due to cell reversal. All other devices connected to the battery system shall be designed to tolerate continuous presence of all voltages from 0 to 42 volts without harm.

9.2.4 Battery System Circuit Breaker

A circuit breaker of adequate capacity and approved design shall be provided in the Operator's cab to serve as a main service breaker for the battery system on each car. The B(+) and B(-) feeds to this breaker shall be taken from B(+) and B(-) trainlines.

9.2.5 Load Shedding

In the event of the loss of third rail power, the battery load shall be shed automatically after a predetermined length of time approved by the Authority, leaving the battery capacity able to meet the requirements of Section 9.2.1. Load shedding shall provide for the disconnection of all nonessential battery loads. Battery system power shall be available to the following essential systems, which shall not be shed, including:

A. HVAC controls and cab heater controls
B. Door controls
C. ATC power conditioning equipment
D. Exterior lights

E. Emergency lighting
F. Emergency brake controls
G. Pneumatic system protective heaters
H. Control lock interlock
I. Fault indicator lights
J. Friction brake
K. Radio
L. VMS VCU

9.3 NOT USED

9.4 BATTERY SYSTEM POWER CONVERTER

9.4.1 General

An approved static converter shall be furnished and installed on each “B” car. The converter shall provide the low voltage power for a pair of cars for battery charging, traction control, trainline control, and for all other auxiliary car circuits connected to the battery supply. It shall also supply power to the emergency fluorescent lighting. The converter shall have a constant voltage output capability at 37.5 VDC for any load demanded by a pair of cars, at any position in a train, for all third rail voltages specified in Section 2.2.

The converter shall be powered from the third rail supply and shall be capable of safe and reliable, performance at any supply voltage in the ranges specified in Section 2.2.

Reduction in performance between rated voltage and 430 VDC shall be limited to reduction in output current. Output voltage shall not be reduced below specified as long as load is less than capacity.

9.4.2 Design

The converter input and output negatives shall be isolated from one another so that the battery system negative will be connected to the third rail current return only via the grounding resistor specified in Section 9.6. All converter electrical circuit elements connected to the battery system, with the exception of any necessary transformers, shall be physically separated from all converter electrical circuit elements connected to the third rail and traction current return so that battery system circuits cannot be raised to third rail voltage by failure of any such things as electrical devices and insulation. Starting and proper operation of the converter shall not be dependent on the voltage at the converter output terminals.

The static converter shall have over- and under-voltage circuitry to turn the converter off for protective purposes when the third rail supply voltage is above or below the stated range. The converter shall be turned on automatically when the supply voltage returns to the normal operating range. The converter shall not be damaged by any sustained input voltages that may be impressed on it as specified in Section 2.2. In addition, the converter shall have sufficient protective devices on the input and output to avoid damage to the converter from whatever transient voltages may occur at the input and at the output. The converter shall have a voltage drooping characteristic on current overloads in excess of nominal rated current. The output shall maintain a steady state voltage setting of 37.5, ± 0.5 volts at the battery terminals over the entire range of 0% to 100% of available output current and over the entire range of third rail voltage in which the converter is required to operate.

The output voltage shall be continuously adjustable over a range of ± 2 volts from 37.5V. The voltage adjustment shall be unaffected by vibration and temperature effects and shall remain stable under the service conditions and ambient temperature ranges described in Section 2.4.

Output voltage variation due to temperature drift shall be zero, or minimally negative (increasing ambient temperature reduces output voltage). Any failure of the regulator circuit shall result in reduced or zero output.

The logic control shall be on printed circuit boards designed and manufactured in accordance with the requirements of Section 15.29.

The Contractor shall ensure that the converter is such that it cannot cause interference with the cab signal equipment of the new and existing fleet of cars under all conditions of converter load and train lengths having from one to four converters. To this end the Contractor shall insure that the power converter conforms to the vehicle ATC specifications identified in Section 11 and shall secure the approval of the ATC equipment manufacturer for the design and installation of the power converter. *(CDRL 902)*

The converter shall be adequately protected against snow and water spray under all operating or storage conditions.

Converter cooling shall be via adequate heat sinking and natural convection cooling.

The converter logic control circuitry shall have protective functions incorporated so that no abnormal condition of input voltage or output load will cause damage to the converter. These protective circuits shall not prevent the converter from automatically returning to normal operation when the abnormal condition is removed.

It is essential that maintenance personnel be protected from potential electrical shock hazard caused by stored energy devices such as the converter line capacitor bank. Therefore, adequate and approved means shall be provided for reducing the charge of all high potential capacitors for equipment servicing in accordance with the following guidelines:

A. Line voltage capacitor banks shall drain their charge to 15 volts or less, within 15 minutes after removal of line voltage, via permanently connected resistors.

B. There shall be a manually operated arrangement whereby maintenance personnel can disconnect the input power to the converter and connect supplemental discharge resistors which shall reduce the voltage on all high voltage capacitors to 15 volts or less within 15 seconds. The device used to disconnect the input power shall be designed to interrupt whatever current may be flowing through it. The arrangement shall include an interlock so that input power and the supplemental discharge resistors cannot both be connected at the same time. The overall arrangement shall be such that repeated manual short cycling of the disconnect and discharge switches neither damages the equipment nor causes the average power dissipated by any supplemental discharge resistor to exceed 50% of its rating.

Means shall be provided whereby maintenance personnel can easily, reliably, and safely verify that each high voltage capacitor has been discharged.

Converter control circuitry shall be accessible from the side of the car for maintenance.

The Contractor shall review the converter system interface design with the supplier of the propulsion equipment to assure that the energy storage characteristics of the converter do not interfere with propulsion system operation and protective devices such as potential relays.

9.4.3 Tests

Each static converter shall be subject to a routine commercial test, approved by the Authority, that includes insulation resistance tests, high potential tests, and operational testing at various input voltages and loads.

Within 18 months after Contract Award, one static converter, randomly selected by the Authority, shall be subjected by the manufacturer to a complete "Type" engineering test, as approved by the Authority, that will verify the adequacy of design and converter performance.

9.4.4 Capacity

The converter shall be able to deliver sufficient current at 37.5 VDC to supply all loads of a pair operating alone and of a pair operating as the lead pair of an eight-car train and shall be able in both cases to simultaneously provide 80 amps for charging of the battery. However, the converter output shall be at least 375 amps at 37.5 VDC. Under conditions such that the converter is not required to maintain 37.5 volts output, available output current shall rise with falling output voltage so as to prevent collapse of output voltage due to characteristics of battery system loads, some of which will draw substantially constant power.

9.4.5 Efficiency

The average power conversion efficiency of the converter shall be 80% or greater except for very light loads. No-load losses shall not exceed 200 watts at the 700 VDC line. Full-load losses shall not exceed 3 kW at the 700 VDC line.

9.4.6 Line Voltage and Control

The converter shall be supplied with nominal 700 VDC power from the auxiliary fuse through a protective circuit breaker and suitable line isolation system. This system shall be the normal means of energizing the converter. It shall be properly coordinated with the circuit breaker and auxiliary fuse to assure immediate interruption of any fault current with no damage to any equipment. Line isolation shall be achieved whenever the third rail shoes are not in contact with an energized third rail. The line isolation system shall be designed so that it does not interpret the presence of any on-car developed traction voltage as third rail voltage.

9.5 CONVENIENCE OUTLETS

Two duplex convenience outlets shall be provided in each car, located in the wall under the transverse seats, or in the base of the adjacent back-to-back seats, as shown on Contract Drawing 97936-001.

One of the outlets shall be supplied with nominally 37.5-volt battery voltage; the other outlet shall be supplied with 115-volt, 60 Hz, AC. The 37.5-volt outlet shall have a capacity of 50 amperes and shall be protected by a 50-ampere circuit breaker. It shall have the same plug interface as Hubbell Model 9367 used on the Authority's existing cars. The 115-volt outlet shall have a capacity of 20 amperes and shall be protected by a 20-ampere circuit breaker. It shall be a 20-ampere, 125-volt, 2-pole, 3-wire, grounding duplex receptacle.

9.6 BATTERY SYSTEM CIRCUIT GROUNDING

9.6.1 General

All systems, subsystems, and components connected to the nominal 37.5-volt system, including the battery and power converter, shall have their negative sides grounded through a common negative grounding pad.

9.6.2 Arrangement

The negative side connection between the battery and the power converter shall be through an insulated copper battery system main return bus plate grounded via the traction return bus on the “B” car. In order to control B(-) trainline current between pairs of cars due to voltage gradients along the running rails, the grounding path from the battery system return bus plate to the “B” car traction return bus plate shall include a fixed resistor suitably sized and ventilated and with a resistance value between 0.1 and 0.5 ohm. The negative return from all other 37.5 VDC systems or subsystems shall return to the negative side of the battery or converter through this battery return bus plate. Battery system current from the B(-) pole of the “A” and “B” car battery system circuit breakers of Section 9.2.4 shall be returned to the battery system return bus plate on the “B” car via the B(-) trainline cable described in Section 9.1.4 or via a separate B(-) return feeder. Return wires from negative poles of circuit breakers for individual battery system loads shall be terminated on a secondary bus plate connected to the negative pole of that car’s battery system circuit breaker.

Trainline currents which return to the controlling car via the B(-) trainline shall not go via the above paths but shall return to the B(-) trainline via separate wires and via a rotary switch as specified in Section 9.7.1.3. In addition to sizing negative return wires based on current carrying capacity, the Contractor shall consider voltage drop and noise sensitivity of the circuit involved in the final selection of wire size.

9.6.3 Grounding Bus Plates

The battery main and secondary return bus plates shall be housed in weatherproof and dust-proof enclosures complete with readily removable gasketed access covers for maintenance. The battery return bus plates shall be insulated from the carbody in such a manner that the insulation resistance between them and the carbody is a minimum of l00 megohms under all weather conditions.

The battery return bus plates shall be complete with means by which the car wiring can be attached thereto, preferably by means of copper posts or terminals, brazed or silver soldered to the bus plates and of adequate size to accommodate the wiring connected. No more than two wires may be connected to any one terminal. The battery return bus plates shall contain enough terminals to handle all return wires from the connected loads including the ATC and communications system, plus spare terminals numbering 5% (to the next higher integer) for each size terminal on each plate.

The battery main return bus plate shall be grounded to the carbody by means of removable cables, one connecting the battery main return bus plate to the 0.1 to 0.5 ohm grounding resistor and the other connecting the resistor to the traction return bus plate.

The return bus plates shall be the only locations where it will be permissible to ground the negative side of any system, subsystem, or component connected to the battery system. With the grounding straps between the battery system main return bus plate and the traction return plate removed, the 37.5-volt system wiring insulation resistance shall be as specified in Section 15.18.4.

9.7 CONTROL AND CIRCUIT BREAKER PANELS

9.7.1 General

Prior to acceptance of each car, all auxiliary circuits and equipment shall be checked for proper operation.

9.7.1.1 Panel Arrangements

Switch and circuit breaker panels shall be built into the cab and underfloor boxes as described herein. Enclosures within the carbody containing switches or breakers shall be lined with 3/16-inch to 1/4-inch thick “Insularc” insulating board or approved alternate nonflammable, insulating, structural material. Each panel shall have a “dead front” which shall, in the cab, be of black anodized aluminum. The “dead front” shall be designed to prevent personnel from coming in contact with energized parts when operating circuit breakers or switches. Wiring shall be accessible by removal of the “dead front.” All switches and circuit breakers shall be mounted so that the handle moves vertically, and the “Up” position shall indicate “On.”

Individual engraved nameplates shall be provided both above and below the breaker to permit identification from track level and when car is on jacks. The nameplates shall be mechanically fastened to the “dead front” and shall identify each switch or circuit breaker.

The lists of switches and circuit breakers given in Section 9.7.2, 9.7.3, and 9.7.4 are not necessarily complete; they are intended principally to identify the desired locations for the various items listed.

9.7.1.2 Switches

Switches shall be of the toggle action, indicating type unless otherwise specified.

9.7.1.3 Circuit Breakers

Circuit breakers shall be an approved type of high shock-resistant design suitable for railway service and bolted in place. They shall clearly indicate whether “On,” “Tripped,” or “Off.” Circuit beakers in nominal 700 volt circuits shall interrupt only the “Hot” side of the circuit and shall be mounted under the car. Unless otherwise specified, all 37.5-volt circuit breakers, except the propulsion system control breaker, shall be double-pole, and shall break both positive and negative feeds whenever either pole is tripped, in order to facilitate location of ground faults. The propulsion system control breaker shall be single-pole and shall break the positive side only. All circuitry shall be arranged to preclude “sneak circuits,” that is, energization via an abnormal path as a result of a breaker being open. Except in special cases, which may exist due to requirements elsewhere in the specification, separately protected circuits shall not be electrically connected on the load sides of their respective breakers. The most notable exceptions are those trainline circuits which share the B(-) trainline as a common return path. The currents which are drawn from those trainlines shall not pass through any negative side breakers but rather shall all be returned to the B(-) trainline via a rotary switch of the same type as the KAS2 trainline isolation switch used in the existing Authority cars. This rotary switch shall include 10% spare poles, and shall be arranged to facilitate location of ground faults of trainlines and of circuitry connected to them. The rotary switch shall have an additional pole which shall be used as an interlock in the feed to the emergency relay to insure that the switch is in the normal position prior to operation of the car. The arrangement shall be such as to preclude the possibility that the emergency interlock can be made up while some of the other poles are not fully closed.

MOD 2

Circuit breaker terminals shall not be used as junction points.

9.7.1.4 Fuses

Circuit breakers shall be used for circuit protection wherever possible. Fuses may, however, be used, with the Authority’s approval, where the use of circuit breakers is impractical or inappropriate provided that the fault isolation and anti-sneak circuit functions of the preceding paragraphs are maintained.

9.7.2 <u>Operator’s Control Console and Auxiliary Control and Indicator Panels</u>

A control console and auxiliary control and indicator panel shall be provided in each cab, as shown in the Contract Drawings. It shall contain the apparatus shown in the Contract Drawings and shall contain, in addition, any apparatus found, during the engineering, construction, and testing of the cars, to be necessary for the proper operation of the cars. A functional description of all of the cab controls is contained in Exhibit 9-1. Except as otherwise specified, the control console and auxiliary control and indicator panel shall be as identical to those of the Authority’s existing cars as possible in regard to appearance, form, feel, size, and function, except that lettering shall be engraved and filled with paint; silk-screened lettering is not acceptable. The console and control and indicator panel arrangement shall be submitted to the Authority for approval as part of the cab mock-up described in Section 1.3.4.1.

All push-buttons and indicators shall be uniform in style, and shall be arranged, sized and labeled as shown in the Contract Drawings. Insofar as possible, all push-buttons and indicator lamps shall be of the same manufacture.

All push-buttons indicated in Exhibit 9-1 as being normally lighted shall have their legends engraved on the top surface, so as to be visible by reflected light as well as by internal illumination. All push-buttons on the portion of the console angled 15 degrees from the horizontal shall be of the barrier type, to prevent undesired actuation.

All indicators, except combination push-button/indicators, shall display no wording unless illuminated from behind. When not illuminated, indicators shall appear black. All console indicators shall be of a design which provides good visibility even with bright sunlight conditions and minimizes glare under dark tunnel conditions.

The lights of the control console shall be illuminated as appropriate when that console is in control of its train but shall not be illuminated otherwise. Illumination of push-buttons and indicators shall be adjustable, under control of the four-position console light switch, and shall in the "High" position be easily visible under the highest ambient light conditions that can be expected. Conditioned power for all console lights shall be provided from the appropriate subsystem.

The console light power supply(s) shall adjust its output in response to the setting of the console brightness control switch so as to cause all console lights to produce suitable light intensities.

All lights in the console and auxiliary control and indicator panel shall be relamped from the front. Where lenses are removable for lamp replacement, the lenses shall be keyed or attached so that they can be returned only to the proper location.

Each push-button and indicator shall be illuminated by at least two lamps. The console light brightness switch shall include a spring return lamp test position for energizing all console indicators.

Small flood lamps shall be provided near the top of the console and shall illuminate the console when the console light brightness switch is set to "Low." The communications channel selector switch shall illuminate the number corresponding to the channel selected.

All push-button switches and combination push-button/indicators shall have silver-plated terminals and contacts. Contacts shall be so designed that they will not weld in service when used within their rating and will not bounce closed while the car is in motion. All indicators, push-button switches, and combinations of the two shall have an insulation resistance of at least 1,000 megohms to the case at 500 VDC. All contacts shall have a maximum resistance of 0.10 ohm at 3 VDC and 10 MA load. Minimum open contact resistance shall be 50 megohms.

All push-buttons or switches interfacing with the ATC system shall have double-break contacts unless otherwise indicated in the Contract Drawings.

The entire console shall be hinged at the rear or side and be able to be tilted upwards at least 45 degrees, for access to apparatus mounted underneath. The console may be divided into two separately hinged parts for this purpose. It shall not be necessary to disconnect wiring to raise the whole console or either of its parts separately. All indicators, switches, rheostats, push-buttons, gauges, master controller, audible alarms, and any other apparatus located in the control console or auxiliary control and indicator panel shall be furnished by the Contractor, which shall be responsible for interconnection of this apparatus with other car systems and the ATC system. Further details of the interface requirements may be found in Section 11 and the Contract Drawings

Exhibit 9-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
1.	Control Lock	Activates console for control of train. Sets up environmental control, door control, automatic train control, running lights, control and communications. Isolates all other master controllers in the train.	Control Lock; Off, On	(1)	--	--	Once activated, key cannot be moved to "Off" position unless Master Controller and Mode-Direction Switch are in "Auto/Store" position.
2.	Mode-Direction Switch	Selects mode of operation, either automatic or manual, and provides for direction reversal in manual operation only.	Mode-Direction Switch; Auto/Store, Man-Fwd, and Man-Rev.	(1)	--	--	In "Auto/Store" position with control key on, train is under control of the ATC system. In "Man-Rev" position or the Mode-Direction switch, operation is manual under control of the operator. Mode-Direction switch can not be moved between "Man-Fwd" and "Man-Rev" unless Master Controller handle is in "B5" or "Auto/Store" position. Switch cannot be moved between "Auto/Store" and "Man-Rev" positions except by way of "Man-Fwd" position. Switch cannot be moved to "Auto/Store" position unless MC handle is in "Auto/Store" position

*** Location Definition:**

Location:
- (1) Directly in front of the Operator on the control console.
- (2) Not used.
- (3) On the circuit breaker panel at the right side of the Operator below the cab side window.
- (4) Not used.
- (5) On a panel at the Operator's eye level to the right of the cab front window.
- (6) On a panel by side window on left side of cab.
- (7) On a panel below console on right wall of cab forward of breaker panels.
- (8) In a cabinet on left side of cab.
- (9) In the cab.

Item	Control	Function	Nomenclature	Location*	Normal	Color of	Remarks

Exhibit 9-1

Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
3.	Master Controller	Controls propulsion and braking in manual operation.	P5, P4, P3, P2, P1, Coast, B1, B2, B3, B4, B5, Emergency, and Auto/Store	(1)	White	--	Increasing power position numbers provide increasing positive tractive effort levels. Coast provides no tractive effort. Increasing brake positions provide increasing negative tractive effort levels. Emergency is electrically propagated through de-energization of trainline number 82 and pneumatically propagated. The Master Controller shall have an electric contact operating a magnet valve in the pneumatic trainline on each car. "Auto/Store" position is used for automatic train control operation and for handle storage on trailing and stored cars. Handle cannot be moved unless Mode-Direction switch is in "Man-Fwd" or "Man-Rev" position. Movement of handle from emergency to Auto/Store is prevented by a pawl unless the Over-Travel button has been pushed down.
4.	Over-Travel Push-button	Permits movement of master controller from emergency to Auto/Store. Prevents emergency application when Master Controller is moved from B5 through Emergency to Auto/Store. Permits recharging of brake pipe when MC is in Auto/Store.	Over-Travel	(1)	--	--	
5.	ATO Start Indicator/Push-button	Causes ATO operation to start if train is in ATO mode, but unstarted and non-zero code is being received. Also causes TWC to transmit train ready message.	ATO Start	(1)	--	Green	Lighted to indicate that train is in ATO mode, but that this button must be pushed in order to cause ATO operation to start.
6.	ATO Stop Push-button	Stops ATO operation; applies full-service (B4 rate) brake.	ATO Stop	(1)	Red	--	

Exhibit 9-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
7.	Horn Push-button	Blows horn.	Horn	(1)	--	--	
8.	Windshield Wiper Control	Turns wiper on; controls wiper speed.	Wiper; Low, Park, High	(1)	--	--	Provides full range of speed control plus parked position.
9.	Door and Environmental Control Key Switch	Activates door control panel for operation. (This duplicates existing function of Control Lock and is primarily for mid-train door control). It also allows turning environmental controls on for a timed interval and turning environmental control off when it would otherwise remain on for timed interval.	Door Control Key Switch; E.C. Off, Off, On	(5)	--	--	Environmental control is used for pre-cooling or pre-heating of train. Once environmental control is activated by turning key to "On" position, it remains so activated until timer expires or key is turned to "E.C. Off" position.
10.	Door Open Push-buttons (2 locations)	Opens side doors on entire train. Forestalls automatic closing.	Open Doors	(5) (6)	White White	-- --	
11.	Door Close Push-buttons (2 locations)	Closes side doors on entire train. Forestalls automatic opening.	Close Doors	(5) (6)	White White	-- --	
12.	Doors Closed Indicator	Indicates all side doors, both sides, are closed and locked.	All Doors Closed	(1) (6)	--	Green	
13.	Door Control Selector Switch	Selects mode of operation of doors; automatic, manual, or automatic/manual.	Door Mode Selector; Auto, Auto/Man, Man	(3)	--	--	In "Auto," doors are fully controlled by the ATC system, subject to manual override. In "Auto/Man," doors are opened by ATC input and closed manually by Operator from any active door control panel. In "Man," all ATC inputs are inhibited and doors are under full manual control by Operator from any active door control panel.
14.	Limiting Speed Indicator	Indicates maximum speed allowed by ATP.	Limiting Speed	(1)	Red	--	

Exhibit 9-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color	Color of Indication	Remarks
					Lighted		
15.	Regulated Speed Indicator	Indicates input to ATO speed regulator.	Regulated Speed	(1)	Yellow	--	Indicates either ATS or ATP speed command, whichever is lower.
16.	ATS Speed Error	Indicates invalid or lack of ATS speed input.	ATS Speed in Error	(1)	--	Red	ATO speed regulator will use ATP limiting speed value.
17.	Train Speed Indicator	Indicates actual train speed.	Train Speed	(1)	Yellow	--	
18.	Automatic Mode Indicator	Indicates changeover relays are in position for automatic mode.	Automatic	(1)	--	Green	
19.	Manual Mode Indicator	Indicates changeover relays are in position for manual operation.	Manual	(1)	--	Amber	
20.	ATP Cut-Out Indicator	Indicates ATP has been cut out by ATP cut-out switch.	ATP Cut Out	(1)	--	Red	
21.	Skip Stop Indicator	Indicates station stop marker has commanded skip stop instead of programmed station stop.	Station Stop Skip	(1)	--	Amber	
22.	Program Station Stop Indicator	Indicates initiation of a programmed station stop.	Program Station Stop	(1)	--	Blue	
23.	Brakes On Indicator	Indicates friction brakes applied on entire train.	Brakes On	(1)	--	Amber	
24.	Brakes Off Indicator	Indicates friction brakes and hand brakes released on entire train.	Brakes Off	(1)	--	Green	
25.	Motor Current	Needle indicates acceleration current by movement to right of center and braking current by movement to left of center.	Current, Acceleration and Braking	(1)	White	--	

Exhibit 9-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

					Lighted		
Item No.	**Control**	**Function**	**Nomenclature**	**Location***	**Normal Color**	**Color of Indication**	**Remarks**
26.	Motor Overload or Ground Fault Indicator and Reset Push-button	Indicates motor overload or ground fault has been tripped on one or more cars in train. Reset push-button resets tripped motor overload relays.	Motor Overload and Reset	(1)	--	Red	This is reset automatically at each station stop in automatic operation. Propulsion trip reset relay has counter and lockout to avoid excessive resetting.
27.	Doors By-Passed Indicator	Indicates door/traction interlock has been by-passed.	Doors By-Passed	(1)	--	Red	
28.	Headlight Dimming Switch	Controls intensity of headlights, bright or dim.	High Beam	(1)	--	Blue	
29.	Emergency Brake Push-button (2 locations)	Applies emergency brake pneumatically by opening air trainline and electrically by de-energization of TL82.	Emergency Stop	(1) (6)	--	--	Wheel slip-slide protection is nullified.
30.	Emergency Recharge Push-button	Recharges brake trainline after any emergency brake application.	Emergency Recharge	(1)	--	--	Operative if Master Controller is in Auto/Store with Over-Travel button depressed, or if in B5.
31.	Train Lights On, Off Switch	Energizes/de-energizes interior light control trainline.	Car Lights; On, Off	(5)	--	--	Self-centering switch with momentary On and Off positions.
32.	End Overhead Lights Switch On, Off	Permits cab fluorescent ceiling lights at center and left to be turned off locally when interior light trainline is energized.	Cab Fluorescent; On, Off	(5)	--	--	Two-position toggle switch.
33.	Cab Light Switch	Turns cab reading light on or off.	Cab Light	(1)	--	--	Push to turn on, push to turn off.
34.	Console Light Control	Controls brightness of console lights and has spring returned lamp test position.	Console Lights; Low, Medium, High, Test	(1)	--	--	Provides three levels of brightness for console lights and indicator lights. Small flood lights at top of console are turned on when medium or low level is selected.
35.	Brake Cylinder Pressure Gauge	Indicates brake cylinder pressure.	Brake Cylinder Pressure	(1)	White	--	Indicates brake cylinder pressure on lead truck.
36.	Brake Pipe Pressure Gauge	Indicates brake pipe pressure	Brake Pipe Pressure	(1)	White	--	Main reservoir pressure same as that of brake pipe when brake pipe charged.
37.	Accumulator Pressure Gauge	Indicates hydraulic accumulator pressure.	Stored Pressure Status	(1)	White	--	Applies only in case of hydraulic brakes.
38.	Yard Horn and Signal Buzzer Push-button	Actuates Yard Horn, and sounds buzzer in all cabs.	Yard Horn and Buzzer	(5)	--	--	

MOD 2

Item No.	Control	Function	Nomenclature	Location*	Lighted Normal Color	Color of Indication	Remarks
39.	Signal Buzzer	Permits others onboard to signal to operator and vice versa.	Intercar Buzzer	(1)	--	--	
40.	Snow Brake Push-Button/Indicator	Applies snow brake; indicates snow brake is applied.	Snow Brake	(1)	--	Blue	Push to apply, removal of control key releases.
41.	Trainline Circuit Breaker Tripped Indicator	Indicates trainline circuit breaker tripped on car in train.	T/L CB Tripped	(1)	--	Red	Lights and remains illuminated if trainline circuit breaker has tripped on any car in train. Also lights locally on any car on which trainline circuit breaker has tripped.
42.	Station Stop Cancel Push-button	Cancels programmed station stop.	Station Stop Cancel	(1)	--	--	
43.	Train Berthed Push-Button	Provide information to wayside that train is berthed and doors may be opened.	Train Berthed	(1)	--	--	Used to facilitate automatic operation of doors when in manual operation, with ATP.
44.	ATS Acceleration Limit Indicator	Indicates car is operating at reduced acceleration under control of ATS.	Power Limit	(1)	--	Amber	
45.	Cab Heater Control	Turns heater on and controls heat in two steps.	Cab Heat; Off, Medium, High	(1)	--	--	
46.	Overspeed Alarm	Gives audible warning when train speed exceeds limiting speed.	Overspeed Alarm	(1)	--	--	In manual operation with ATP.
47.	Car Wash Speed Push-button	Provides low speed for operation through car washer.	Car Wash Speed	(1)	--	--	Depressing button provides minimum level of tractive effort until train speed reaches 3 mph. Releasing button allows car to coast.
48.	Train Identity Readout	Indicates train number, train destination, and number of cars in train from ATS Input.	Train Identity	(1)	Red	--	
49.	Train Identity Error	Indicates possible error in train number.	Error	(1)	--	Red	
50.	Train Destination Error	Indicates possible error in train destination information.	Error	(1)	--	Red	
51.	Train Identity Switch	Provides for manual input of train destination, train number in the event of ATS breakdown.	Manual	(1)	--	--	

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
					Lighted		
52.	Train Identity Selector Switch	Isolates train identity switch output for automatic operation.	Selector Switch; Auto, Manual	(5)	--	--	Switch is sealed in "Auto" position. See 97936-011 of Contract Drawings.
53.	Door/Traction Interlock By-Pass Switch	By-passes door/traction interlock so that train can be moved in the event of failure of the circuitry.	Door Interlock; Normal, By-Pass	(3)	--	--	Operator must revert to manual operation when switch is in "By-Pass" position. Switch is normally in "Normal" position and sealed.
54.	ATP Cut-Out Switch	Cuts out ATP. Actuation of switch requires breaking of seal.	ATP Cut-Out	(8)	--	--	Cut-out status can be entered and will persist only while Mode-Direction Switch is in Man-Fwd or Man-Rev. Entering cut-out status requires Master Controller in B4 or B5 and momentary actuation of spring-return cut-out switch. ATP is restored whenever console is keyed out or Mode-Direction Switch is placed in Auto/Store. Cut-out switch is located behind window in door of its cabinet so that Operator coming aboard train can visually verify that seal on switch is not broken.
55.	Door Control Trainline Cut-Out	Disables trainline door control.	Door Control T/L C/O; Normal, Cut-Out	(3)	--	--	
56.	Propulsion Cut-Out	Cuts out propulsion in individual car.	Propulsion C/O; Normal, Cut-Out	(3)	--	--	
57.	Dynamic Brake Cut-Out	Cuts out dynamic brake on all cars.	Dynamic Brake C/O; Normal, Cut-Out	(3)	--	--	
58.	Power Knock-Out (Brake Release Interlock Bypass)	Permits train to take power even if Brakes Released trainline was not energized via the normal trainline circuit.	Power Knock-Out; Normal, By-Pass	(3)	--	--	Switch is to be sealed in normal position.
59.	Headlight Override	Permits turning on headlights of car whose controls are not keyed on.	Headlight By-pass; Normal, By-pass	(3)	--	--	Typically used on lead car when train is being controlled by some other car.
60.	Not Used						

Exhibit 9-1

Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
61.	Passenger Call Volume Control	Provides continuous variation from 10% to 100% of maximum volume at the passenger call cab speaker.	Intercom Volume	(1)	--	--	
62.	Passenger Call Chime	Alerts Operator to incoming call on passenger call system.		(9)	--	--	Activated by a push-button adjacent to each passenger call microphone.
63.	Passenger Call Talk Back Push-button	Allows Operator to reply to a passenger call.	Talk Intercom	(1)	--	--	When push-button is released, Operator will hear conversation from passenger.
64.	Passenger Call Reset Push-button	Disconnects activated passenger call station.	Reset Intercom	(1)	--	White	Annunciator lamp indication button is lighted when any push-button adjacent to a passenger call microphone is depressed. Remains illuminated until Reset push-button is depressed.
65.	Passenger Call Speaker	Allows Operator to hear a passenger call.		(9)	--	--	
66.	Radio Squelch Control	Provides manual adjustment of the radio squelch threshold.	Radio Squelch	(1)	--	--	
67.	Radio Volume Control	Provides continuous variation from 10% to 100% of maximum volume at the cab radio speaker.	Radio Volume	(1)	--	--	
68.	Radio Channel Selector Switch	Selects a specific operating channel on the two-way radio.	Channel	(1)	--	White	A four-position rotary stepper switch marked Channels 1 through 4 and 5 through 8. Indicator light adjacent to channel selected is illuminated.
69.	Local Public Address Push-button	Activates public address system.	Talk P.A.	(1)	--	--	Push-button must be held depressed while announcement is being made.
70.	Radio Public Address Push-button	Provides for train announcement over public address system from train radio input.	Radio P.A.	(1)	--	--	Push-button must be held depressed while announcement is being made.
71.	Central Call Push-button	Keys radio transmitter and modulates it with a 1,000 Hz tone for a period of 1/2-second.	Central Call	(1)	--	--	
72.	Band Select	Selects upper or lower range of radio frequencies.	Radio Channel; Blue 1-4 Amber 5-8	(1)	--	Blue (1-4) Amber (5-8)	Selects either channels 1-4 or 5-8 for radio.

73.	Radio Transmit Button	Keys radio transmitter for outgoing message on train radio.	Radio Transmit	(1)	--	Green (Left Side) Red (Right Side)	Green indicator denotes a received VHF signal. Red indicator denotes that transmitter is keyed.
74.	Radio Speaker			(9)			
75.	Destination Sign Control	Permits override of automatic control of destination sign.	Dest. Sign Input; Auto, Special, No Passengers	(5)	--	--	
76.	Uncoupling Actuator Switch	Actuates uncoupling.	Uncoupling Control; Actuator	(5)	--	--	
77.	Back End Code Present Indicator	Indicates that back end code is being received.	B.E.C. Indicator	(7)	--	Red	LED indicator.
78.	TWC Transmitting Indicator	Indicates that the Carborne TWC Encoder is Trans-mitting.	TWC Transmit	(7)	--	Red	LED indicator is activated when encoder is transmitting either a long or short message.
79.	TWC Receiving Indicator	Indicates that the Carborne TWC Decoder is Receiving.	TWC Receive	(7)	--	Red	LED indicator is activated when decoder is receiving either a long or short message.
80.	Trainline 82	Indicates that TL 82 is energized.	TL 82 Energized	(7)	--	Red	
81.	EMV Energized	Indicates that Emergency Magnet Valve is energized.	EMV Energized	(7)	--	Red	
82.	Regenerative Braking Cutout	Disconnects Regenerative Braking on all cars in train.	Regenerative Brake C/O; Normal, Cut-out	(3)	--	--	
83.	Heated Windshield Switch	Activates the heated windshield for defrosting.	Windshield Heater	(5)	--	Blue	
84.	Destination Sign Readout	Displays destination of train.	Destination Sign	(5)	-	Green	
85.	TCR Activated	Indicates that a TCR relay is activated within the train.	TCR	(5)	--	Amber	
86.	Brake Fault Detected	Indicates a blue light condi-tion exists within the train.	Brake Fault	(1)	--	Blue	
87.	Dead Car Indicator	Indicates a dead car within the train.	Dead Car	(5)	--	Red	MOD 2
88.	Battery Breaker Tripped Indicator	Indicates battery circuit breaker tripped within the train.	Battery Breaker Trip	(3)	--	Red	Lights and remains illuminated if battery circuit breaker has tripped on any car in train. Also, lights locally on any car on which battery circuit breaker has tripped.

9.7.3 Operator's Circuit Breaker Panel

A panel, containing circuit breakers listed in Exhibit 9-2, shall be located under the Operator's cab side window. There shall be no door on the panel but barriers shall be located between rows of switches and circuit breakers to prevent accidental movement of their handles. Items shall be located in accordance with the Contract drawings. A "roof" shall be provided over the top of this panel to prevent rain water from falling on the switches and circuit breakers whenever the window is open. This protection is required both in the side wall and above the operating face of the panel.

Exhibit 9-2 – Operator's Circuit Breaker Panel

Item No.	Circuit Breaker	Function—Protects Power Circuits to the Following
1	Headlights	Car headlights
2	Tail and Marker Lights	Car tail lights and running lights
3	Lighting Control	All lighting control relays on car
4	Emergency Lights	Emergency ceiling lights
5	Environmental Control	Control components of the air comfort subsystem; Cab heater fan
6	Left Door Operator	Car left side door operators
7	Right Door Operator	Car right side door operators
8	Conv. Outlet - 115 AC Conv. Outlet - 37.5 DC	Car convenience outlets (should normally be Off)
9	Protective Heaters	Undercar pneumatic drain valve protective heaters
10	Radio	Carborne radio communication equipment ("B" car only)
11	Bus Control	Cab control relays
12	Door Control	Door control circuits
13	ATC Power Supply	ATC power supply ("A" car only)
14	Master Control	Mode Direction Switch and to the Master Controller
15	Miscellaneous	Cab reading light; uncoupling control; snow brakes; crawl; reset; dynamic brake cut-out; emergency recharge; EM stop; dimmer control; slip-slide; and door bypass
16	Heated Windshield	Windshield heater element
17	ATC System	ATC system wiring ("A" car only)
18	Propulsion System	Propulsion system controls (single pole breaker)
19	Signs	Destination sign controls
20	Check Circuits	Door and brake check circuits
21	P.A. System	Public Address speaker amplifiers, cab amplifiers, and intercom units
22	Car Lights	Overhead lights in Circuit A
23	Car Lights	Overhead lights in Circuit B
24	Console Lights	Console lamp dimmer assembly ("A" car only)
25	37-Volt System	Operator's Circuit Breaker Panel
26	Miscellaneous Controls	Fault indicators in that car only
27	Friction Brake System	Friction brake system and to the horn

Means shall be provided to easily identify a tripped breaker during marginal lighting conditions without the aid of a flashlight.

In addition to the circuit breakers shown in the Exhibit 9-2 above, the Operator's Circuit Breaker Panel shall contain the following switches:

A. Door Control Selector Switch: Refer to item number 13 in Exhibit 9-1.
B. Door/Traction Interlock Bypass Switch (Door Interlock): Refer to item number 53 in Exhibit 9-1.
C. Door Control Trainline Cut-Out Switch: Refer to item number 55 in Exhibit 9-1.

D. Propulsion Cut-Out Switch: Refer to item number 56 in Exhibit 9-1
E. Dynamic Brake Cut-Out Switch: Refer to item number 57 in Exhibit 9-1.
F. Power Knockout (Brake Release Interlock Bypass Switch): Refer to item number 58 in Exhibit 9-1.
G. Headlight Override Switch: Refer to item number 59 in Exhibit 9-1.

9.7.4 Auxiliary Power Breaker Panel

An auxiliary power circuit breaker panel shall be located in a separate equipment box under each car. The circuit breakers shall be accessible from the side of the car. This panel shall contain, as a minimum, the circuit breakers listed in Exhibit 9-3.

Exhibit 9-3 – Auxiliary Power Breaker Panel

Item	Circuit Breaker	Function—Protects Power Circuits to Each of the Following
1	Battery Recharge	Converter Input (“B” car only)
2	Overhead Heat - F1	“F” End Evaporator - First Stage Heat
3	Overhead Heat - F2	“F” End Evaporator - Second Stage Heat
4	Overhead Heat - R1	“R” End Evaporator - First Stage Heat
5	Overhead Heat - R2	“R” End Evaporator - Second Stage Heat
6	Floor Heat 1 (Layover)	First Stage - Floor Heat
7	Floor Heat 2	Second Stage - Floor Heat
8	APS	Auxiliary Power System (230 VAC, 60 Hz)
9	Condenser Fans - “F” End	“F” End Condenser Fan Motors
10	Condenser Fans - “R” End	“R” End Condenser Fan Motors
11	Compressor - “F” End	“F” End Refrigerant Compressor Motor
12	Compressor - “R” End	“R” End Refrigerant Compressor Motor
13	Evaporator Fan - “F” End	“F” End Evaporator Fan Motor
14	Evaporator Fan - “R” End	“R” End Evaporator Fan Motor
15	Air Compressor	Air Compressor Motor (“A” car only)
16	Cab Heater	Cab Heater

In addition, a separate circuit breaker panel in a separate enclosure adjacent to the Auxiliary Power Circuit Breaker Panel accessible from the side of the car, or in the same enclosure if completely isolated from the 700 VDC circuits in accordance with the requirements of Section 15.18.3.2, shall be provided for the 37.5 VDC circuits listed in Exhibit 9-4.

Exhibit 9-4 – 37.5 VDC Circuits

Item	Circuit Breaker	Function—Protects Power Circuits From/To the Following
1	HPU	Circuit to the Hydraulic Power Unit (if used)
2	Converter-Output	Output Circuit from the Converter
3	Battery-Output	Output Directly from the Battery

MOD 3

All of the above circuit breakers shall be provided with name plates both above and below the breaker to permit identification from track level and when car is on jacks.

9.8 THIRD RAIL CONTACT SHOE ASSEMBLY

9.8.1 General

The car shall be provided with four contact rail power pickup devices, mounted one on each side of each truck.

The third rail shoes shall be designed to operate in contact with the third rail and to encounter third rail ramps and expansion joints as found on the Authority's tracks at car speeds up to 80 mph without damage to the shoes, shoe holders, ramps, or expansion joints. The third rail shoes and shoe holders shall be designed so that any longitudinal motion of the outer end of the shoe relative to the truck frame has an amplitude less than 1/16-inch peak-to-peak on smooth third rail while trains are slowing down or speeding up. The third rail shoes, shoe holders, and cabling shall be sized so that a single third rail shoe can operate indefinitely, without electrical or thermal distress, conducting whatever current the third rail shoe fuse will permit.

Prior to the acceptance of each car, each third rail shoe shall be set at the proper height and spring tension and functionally tested.

9.8.2 Third Rail Shoes

The third rail shoes shall be the overriding type, spring-loaded to permit adjustable shoe pressure between 10 lbs. and 50 lbs., and supported by a shoe and fuse holder assembly. The design shall ensure that the shoe pressure is maintained to within 2 lbs. of the set value for periods not less than 60 days. An adjustable positive mechanical stop shall be used to limit the downward movement of the third rail shoe. The stop shall be designed to prevent downward movement of more than 3/4-inch below the level operating position. The shoe holder shall provide for shoe height adjustment up or down to compensate for wheel wear. Third rail shoes shall be designed with a weak spot that will allow the shoe, in the event of fouling, to break off without damage to shoe holder or to third rail structure. The shoe material shall be compatible with the contact rail wearing surface and shall be sacrificial to the contact rail. Truck parts above and behind the third rail shoe and the shunt strap shall be guarded against arcs. Attachment of shoes to holders shall require only simple common tools and shall not require use of a torque wrench. The third rail shoe and the shunt strap shall be attached to the shoe holder by separate means. The third rail shoe shall be compatible with the third rail, ramps, and expansion joints used on existing and new construction. Refer to Contract Drawings 97936-029, 97936-035, and 97936-036 for details of the third rail and its expansion joints.

9.8.3 Third Rail Shoe Holder Assembly

The main body of the third rail shoe and fuse holder assembly shall be formed of high strength, non-flammable, dielectric material, impervious to moisture, highly resistant to electrical tracking, and fully adequate for the intended use.

The holder assemblies shall be mounted to bosses on the side of the truck frames.

Alternative methods of supporting the third rail shoe, made necessary or possible by unique features of the collector design, may be used if approved by the Authority.

9.8.4 Third Rail Shoe Fuses

Each car shall be provided with four third rail shoe fuses mounted one on each side of each truck and wired into the circuit of the third rail shoe on that side of the truck.

Fuses shall be of the current limiting and arc-confining type and shall be positioned so that metal and gas shall not be projected into the area between the third rail shoe and any metal portion of the truck. Fuse holders shall be arranged to permit adequate drainage of water and detergents. The fuse and fuse holder shall provide positive visual indication of whether or not the fuse is blown.

9.9 VEHICLE GROUNDS

MOD 2 All parts of the carbody and trucks shall be grounded to the rails. Unless otherwise approved ground cables shall be run as shown on Exhibit 9.5.

The traction return ground pad shall be electrically insulated from the carbody. The ground pad shall be electrically connected to the vehicle chassis through a shunt cable of adequate capacity.

Provisions shall be made on the vehicle chassis to connect the brushes of the truck apparatus safety ground brush holders to the carbody, if so desired, in the future.

No connection shall be made between the truck frame and any journal bearing housing. Electric current shall be prevented from flowing through any journal bearing.

The Contractor shall consider the possibility that with the above arrangement, some third rail current may flow from the motor frame through the motor bearings to the gears and thence to the axle or from the gear box through bearings to gears or to the axle. If such currents could be detrimental to the gears or bearings, then the Contractor shall provide alternate or additional approved arrangements to preclude such a problem.

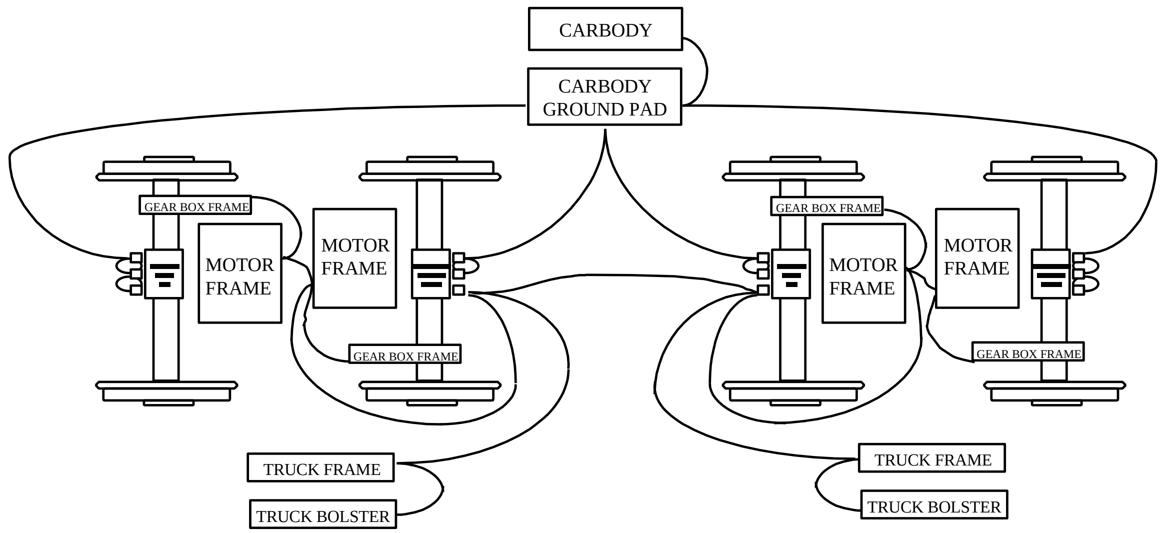
9.10 VEHICLE MONITORING SYSTEM (VMS) INTERFACE

The input and output signals from each critical auxiliary power supply system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

Exhibit 9-5 – Vehicle Grounds



SECTION 10
PROPULSION AND BRAKING SYSTEMS

TABLE OF CONTENTS

Section **Page**

Section **Page**

Section **Page**

Section **Page**

SECTION 10
PROPULSION AND BRAKING SYSTEMS

10.1 GENERAL

All cars to be furnished under this contract shall be equipped with variable-voltage, variable-frequency type propulsion control.

10.1.1 Responsibility

The Contractor shall be responsible for the coordination and proper installation of all components of the propulsion and braking systems and for their interrelation with other car systems in order to ensure the successful functioning and proper performance of the completed car in accordance with the requirements of the Specification.

10.1.2 Performance Standards

The cars to be supplied under this Specification shall perform in accordance with the following standards on the Authority's existing and planned rail rapid transit line, with its traction power supply system. The Contractor shall observe the voltage ranges established in Section 2.2 in the design and manufacture of the transit cars and their apparatus.

The following performance standards shall be met with third rail voltages as described in Section 2.2, with a six-car train, with new wheels, and on level, tangent track:

A. Cars with a passenger load of 24,000 lbs. (160 passengers) per car shall meet the following standards:

1.	Initial accelerating rate	2.8 mphps +0.2, -0

B. With a passenger load of 12,150 lbs. (81 passengers) per car, the following standards shall be met:

1.	Initial accelerating rate	2.8 mphps +0.2,-0
2.	Time to reach 50 mph	23 seconds or less
3.	Time to reach 75 mph	75 seconds or less
4.	Distance traveled in 50 seconds from a standing start	3,400 feet or more
5.	Distance traveled in 70 seconds from a standing start	5,500 feet or more
6.	Acceleration capability at 75 mph	0.25 mphps or more

In addition to the above minimum performance requirements a six-car train, with cars loaded to 12,150 lbs., shall have an acceleration vs. speed characteristic as shown on Exhibit 10-1, with a tolerance of +0, -10% at speeds above the constant acceleration zone.

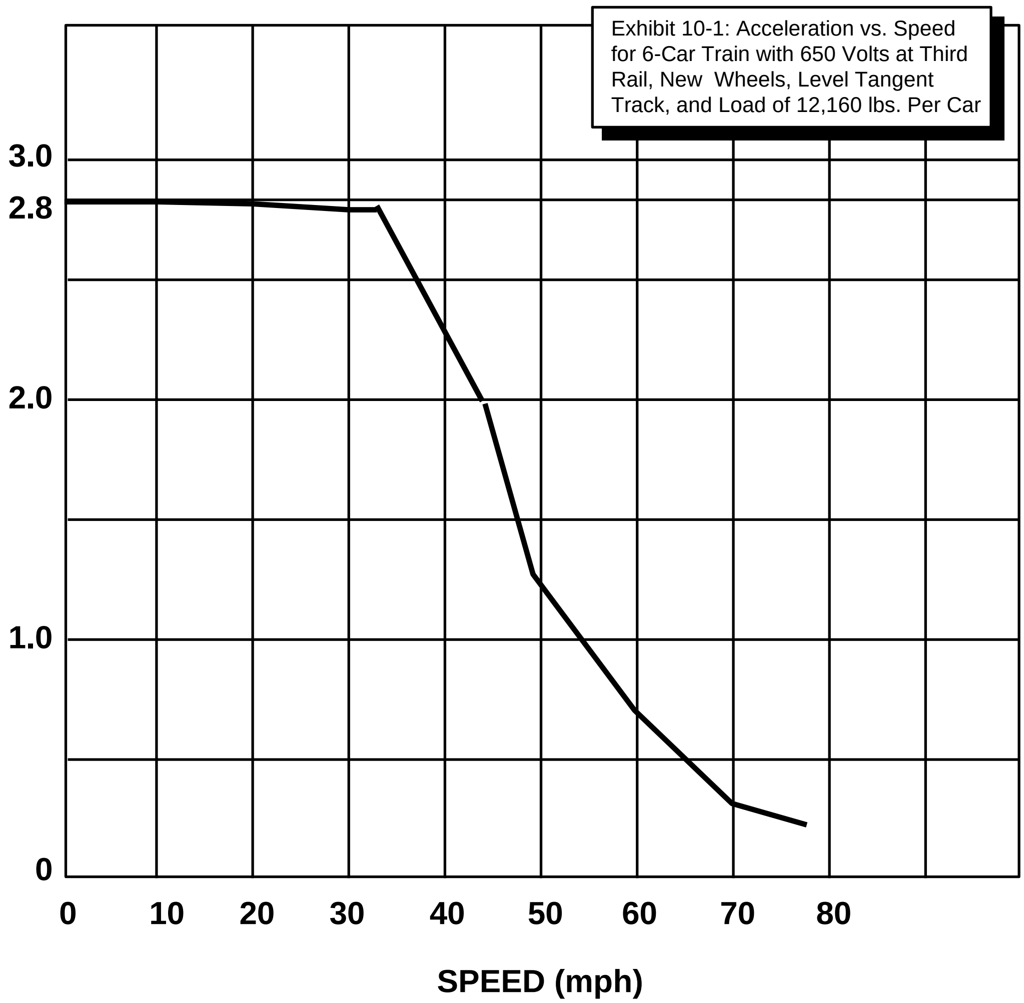
C. With fully worn wheels, all cars shall be capable of sustaining a speed of at least 75 mph without causing damage to or shortening of the service life of the car or any of its equipment.

D. The following maximum service brake rate (B-5) shall be available under control of the load weighing system:

Rate on level tangent track	Linear increase from
75 mph to 50 mph	2.25 to 3.0 mphps*
50 mph to 0 mph	3.0 mphps

* The intent of adjusting rate to vehicle speed is to provide maximum braking consistent with available adhesion. See Exhibit 10-2.

Exhibit 10-1 – Acceleration vs. Speed



E. Service friction braking shall be capable of developing the specified braking rate independently. Electrical braking need only be capable of developing the specified braking rate independently up to the absolute maximum load defined in Section 2.1.1.

F. The following emergency brake rates on all cars furnished shall be available for any passenger load up to 35,100 lbs., under control of the load weighing system, regardless of the initial temperature of the brake discs:

Emergency brake rate on level tangent track (friction brake only)	3.2 mphps at speeds below 50 mph with minimum instantaneous rate of 2.5 mphps at 75 mph.*

* All braking rates specified are instantaneous values, not including compensation for build-up or reaction time. These instantaneous rates shall be in accordance with the tolerances specified in Section 10.6.8. See Exhibit 10-2.

G. The friction brakes shall be capable of making any number of consecutive no-coast round trips between Metro terminals Addison Road and Huntington, Grosvenor and Silver Spring, and Ballston and New Carrollton, stopping at all stations and observing all speed restrictions, with a 30-second layover at each terminal, with a 100-passenger load for each inbound trip (Terminal to Central Business District) and a normal (81 passengers) load for each outbound trip (Central Business District to other Terminal), with dynamic brakes inoperative, without exceeding at any time a disc braking surface temperature of 800°F or alternate value if so allowed by the Authority, using the maximum rate for all accelerations and the B4 rate as defined herein for all braking.

H. The propulsion and electrical brake equipment shall be capable of making a no-coast round trip over the above defined routes with a normal (81 passengers) load, without exceeding the 1-hour ratings published by the manufacturer of the propulsion apparatus.

I. Traction equipment shall be designed to allow an eight-car train of operating cars (with a normal load), taking a full application of power, to move a train of eight dead cars (with a normal load, fully operating friction brakes, but inoperative propulsion and dynamic brakes) in the more unfavorable direction, making all stops between the two terminals creating the most unfavorable traction equipment RMS current condition on the Authority's rail rapid transit line without damaging the traction apparatus or shortening its service life. If necessary, electrical braking may be cut out on the operating equipment. Previously specified performance levels are not applicable to this situation. All accelerations shall be with P5 command and all braking shall be with B5 command. Station stops shall presume a dwell time of 15 seconds.

J. It shall not be possible under any circumstances for a failure of the traction power and friction brake system to result in violation of the Authority's Automatic Train Protection system Block Design.

10.1.3 Adjustments

For the purpose of calculations, including adjustment of performance data obtained under conditions other than as defined in Section 10.1.2, standard Davis train resistance formulae shall be used. Flange friction and air resistance coefficients may be modified to make allowance for truck wheelbase and car end configuration, respectively.

Where adjustment of performance data is required to determine compliance with the Specifications, it shall be the responsibility of the Contractor to carry out the calculations and to submit both the calculations and the results to the Authority in a form that will permit review and approval. *(CDRL 1001)*

Propulsion system operating parameters, including tractive effort and jerk rate, shall be programmable in order to set initial performance and for maintenance.

Except where specified otherwise, adjustments shall be made by modifying microprocessor non-volatile memory. Unless otherwise specifically approved by the Authority, non-volatile memory shall consist of ultraviolet-erasable Electrically Programmable Read Only Memory (EPROM) or Electrically Erasable Programmable Read Only Memory (EEPROM). The selected non-volatile memory shall be able to retain the control program for the life of the car. Maintenance staff shall be capable of making adjustments safely and knowledgeably utilizing the portable testers specified in Section 12.2.

The adjustment for wheel wear shall be implemented via the Portable Test Unit (PTU). At a minimum, adjustment for wheel wear shall be possible to 1/4-inch increments of diameter from new to fully worn wheels.

10.1.4 Performance Testing

10.1.4.1 Car Performance Testing

The Contractor shall make the necessary tests to prove compliance with the performance standards specified herein. As a minimum, the following tests are to be performed on the Authority's tracks:

A. Train resistance tests with one, two, three, and four married pairs.

B. Performance tests with one, two, and three married pairs.

For each test, the following values shall be recorded simultaneously for each car:

1. Acceleration (positive and negative)
2. Torque feedback (each truck)
3. Traction motor current (each truck)
4. Slip-Slide System Operation
5. Brake cylinder pressure (each truck)
6. Third Rail Voltage (B-car only, at collector shoe)
7. Total line current drawn by each car
8. Speed
9. Propulsion and braking trainline signals (rate and motor connection)
10. System controller operating mode
11. Inverter operating mode
12. Time intervals
13. Distance intervals using a digital odometer to record 100-foot increments
14. Two spare channels for additional tests that may be requested by the Authority

For these tests each car shall be equipped with Contractor-supplied multiple-channel recorders, which shall produce a permanent test record. The Contractor is to supply all recorders, sensors, pickups, wiring, and inverters to operate this instrumentation using the vehicle's 37.5 VDC supply. Accuracy and response to the instrumentation shall be sufficient to determine degree of compliance with the Specification and design data. The first two-car tests shall be run with empty cars and again with cars loaded to each weight specified for the performance standards. Each additional two-car unit to be used for the six-car tests shall be subjected to tests to confirm performance standards with the cars empty. The six-car test shall then be run with the cars empty and again with cars loaded to each weight specified for determination of the performance standards. Weights used for all test loading conditions shall be provided by the Contractor. The relationship between performance characteristics of empty and loaded cars shall be developed and used to evaluate the performance of all other two-car units, which may then be tested without load.

Should the cars fail to satisfy these requirements (or equivalents developed mutually by the Contractor and Authority to compensate for profile and voltage conditions), a program for correcting the deficiencies shall be submitted to the Authority within 30 working days, together with a proposed schedule for completing the suggested correction. If, in the opinion of the Authority the program and/or schedule is inadequate or unsatisfactory, an acceptable program and schedule shall be resubmitted within 15 working days.

Should the cars, after correction, still fail to meet the performance requirements specified, the Authority shall have the option of requiring the Contractor to make further modifications to bring performance up to the required standards or, in accordance with the Inspection Clause of the General Provisions, of requiring delivery of the cars at a reduction in price which is equitable under the circumstances.

Any modifications contemplated to bring performance to the level required shall be submitted to the Authority for approval. If, in the opinion of the Authority, the proposed modifications will increase maintenance costs or otherwise affect the serviceability of the cars, the modifications will not be approved.

10.1.4.2 Drift Tests

To verify the coefficients used in performance calculations (see Section 10.1.3), the Contractor shall perform drift tests using trains of one, two, three and four married pairs. A sufficient number of tests shall be made to secure dependable data. Coefficients shall be calculated from these data by the Contractor, and the data and calculations shall be submitted to, and become the property of, the Authority.

10.1.5 <u>Control</u>

The traction apparatus and controls shall be designed for multiple-unit operation of from two to eight cars. The controls shall permit operation of the train from any one Operator's cab.

10.1.6 <u>Electrical Protection</u>

All electrical protective apparatus and systems shall be subject to approval by the Authority and shall include the following:

A. Motor overcurrent protection

B. Protection against propulsion system ground faults (i.e., return of nominal 700-volt propulsion system current via improper paths)

C. Any other protective apparatus deemed necessary by the Contractor.

Protection against return of propulsion current through paths other than the normal paths from the traction equipment to the traction return bus shall be provided by verifying that nominal 700-volt traction feed and return currents sum to zero.

This shall be done by comparing the propulsion feed current from the knife switch with the propulsion return current to the traction return bus and detecting any difference. The arrangement used to accomplish this shall be subject to the approval of the Authority.

Means shall be provided to immediately remove power by opening the line switch and also to cut out propulsion and dynamic brake when current imbalance is detected. The detection shall be as sensitive as is consistent with avoidance of nuisance trips due to normal transient effects. The Contractor shall measure current imbalance behavior on completed cars and shall adjust the sensitivity accordingly.

For purposes of calibration and diagnosis, a means shall be provided for test of the calibration when the car is dead.

Actuation of propulsion system protective apparatus on any car in a train shall cause a local indicating light to be illuminated on the exterior rear bulkhead of the responsible car on the Operator's control console of the responsible car, and also on the Operator's control console of the controlling car of the train. Protective apparatus shall be reset through a reset push-button in the control cab or from the ATC. It shall only be possible to reset while the train is stopped. Protective apparatus reset relay shall be equipped with a device to indicate the number of operations of the relay and to disconnect (lock out) the relay from the reset request trainline after three (3) resets. The operations indicator shall be so arranged that it may be viewed from underfloor without removing covers. After lock-out, the relay shall require direct manual resetting, which shall not be trainlined, at which time the counting device shall return to zero, and any tripped protective devices shall also be reset.

All contactors which can interrupt traction current shall be provided with arc chutes adequate to insure arc extinction under the most adverse conditions which can occur in service. These arc chutes shall be vented outside the control boxes if the build up of ionized gas is possible. Control contacts and other elements operating at battery system voltage shall be separated by insulating barriers from traction current contactors and switches.

To insure compatibility with certain Authority cars which are equipped with temperature control relays (TCRs), a trainlined TCR annunciation capability with an amber indication on the active cable auxiliary control panel shall be provided. Trainline 67 shall be utilized as the signal line to indicate an activated TCR relay by illuminating an amber "TCR" indicator in the keyed-up cab via the ACCCHR relay.

10.2 VARIABLE-VOLTAGE, VARIABLE-FREQUENCY PROPULSION SYSTEM

10.2.1 General

Traction motor temperature shall be continuously sensed, either directly through thermal probes embedded in the motors, or indirectly by means of instantaneous winding resistance calculations based on winding voltage and current measurements or other approved method. The microprocessor shall also monitor the status of the propulsion system and shall store certain diagnostic information to be utilized for performance monitoring and maintenance purposes. Data from the propulsion system microprocessor shall be provided to, and stored in, a data acquisition module (DAM) as specified in Section 10.2.10.

Convection or forced air cooling may be used. Air intakes, if required, shall be located so as to preclude the ingestion of water, snow or debris and shall be provided with service-proven filtering arrangements. Equipment and traction motor ventilation blowers, if provided, shall be of a service-proven design. The blowers shall be directly driven by motors that are powered by the vehicle's Auxiliary Power Supply. The motors shall be of a type currently in railroad or rail transit service. The blower and motor shall have permanently lubricated bearings with rolling elements. Detection of apparatus overtemperature shall shut down the equipment and illuminate a Propulsion Fault indicator in the cabs of the leading car and the car on which the failure has occurred.

Traction motor temperature shall be continuously sensed, either directly through thermal probes embedded in the motors or indirectly by means of instantaneous winding resistance calculations based on winding voltage and current measurements. Motor temperature measurements shall be used to indicate overtemperature conditions to the propulsion control logic to remove power and to activate the Propulsion Fault indicator in the cabs of the leading car and the car on which the overtemperature exists. Traction motors must be self-ventilated.

10.2.2 Configuration

The propulsion system shall be configured to provide control on a per truck basis.

The control electronics and power switchgear may be located in a single package or, if control is provided on an individual truck basis, may be packaged for location near their respective trucks. The control electronics shall preferably be located within the carbody in a seat enclosure; however, a location within the power control unit is acceptable provided the electronic control unit is effectively sealed from the environment. Any separated functions shall be logically grouped, identified, and provided with diagnostics to simplify maintenance.

There shall be a separate motor for each and every axle. All motors and couplings shall be interchangeable from axle to axle.

10.2.3 Duty Cycle Rating

Traction motor temperature rise for the worst-case continuous duty cycle shall be limited to that allowed by IEC Publication 349 for one class lower (lower temperature) than the actual insulation class provided. The continuous thermal, current, and mechanical ratings of all propulsion system equipment shall be based on the duty cycle described in Section 10.1.2.

The Contractor shall submit current and temperature calculations for the worst-case duty cycle and compare them to the ratings of the proposed equipment to illustrate compliance with the above requirements.

10.2.4 Interference Limits

Line transients normally generated by the propulsion system shall be suppressed so that they do not exceed ±10% of no-load voltage. Transients generated by fault-clearing devices may exceed this limit. If the monitor detects greater than 1.1 amperes RMS of conductive emissions at 60 Hz, per Section 1.4.5, being generated by the propulsion system, then the propulsion system will take corrective action to reduce or eliminate this level of emissions.

Electromagnetic interference limits of Section 1.4.5 are applicable to the AC inverter control system, and shall not be exceeded by the propulsion system during any mode of operation. The propulsion system shall be able to operate properly in an environment of high ambient electrical noise.

The Contractor shall provide an independent method of monitoring on-board 60 Hz conductive emissions from the propulsion system. The monitor shall be designed and constructed using fail-safe principles. The Authority shall review and approve the 60 Hz monitoring system and its emission limits.

10.2.5 Performance Characteristics

The propulsion system shall provide vehicle acceleration and deceleration as required by Section 10.1.2 within the specified tolerances, including:

A. Commanded acceleration and deceleration rates

B. Jerk limit

C. Mode change dead time

D. Sufficient time response to result in maintaining vehicle deceleration within the specified accuracy during blending of friction and dynamic braking

E. Sufficient time response to meet wheel spin-slide efficiency requirements

F. Sufficient resolution to allow the required speed regulation.

Accuracy and time response shall be independent of ambient temperatures within the limits given in Section 2.4 and variation of the low voltage supply within the limits given in Section 9.1.3.

10.2.6 Electric Brake Capabilities

MOD 2 | Braking effort shall be load compensated in order to maximize use of the available adhesion. The characteristics of the load compensation signal are given in Section 10.6.8. The level of electric braking effort shall be provided to the friction braking system in the form described in Section 10.6.5.

Electric braking shall be continuously available from maximum car speed down to 5 mph, and shall be both rheostatic and regenerative. In electric braking, the control system shall continuously monitor line voltage on each inverter cycle and shall supply to the third rail the maximum amount of energy possible within the line voltage limits prescribed in Section 2.2, diverting to the braking resistors only the generated energy in excess of that accepted by the line.

A means shall be provided to quantitatively measure and store the amount of regenerative braking achieved.

10.2.7 Direction Change

Direction change shall be provided by traction motor rotation reversal. A change of rotation shall be possible only when the car is motionless and the traction motor power circuits are de-energized. Failure of the reversing equipment to correspond to the direction trainline signal shall disable the propulsion and electric brake.

10.2.8 Wheel Spin-Slide Correction

The propulsion system shall control tractive effort in both propulsion and electric braking as required, to correct wheel spin and slide. A signal indicating the existence of wheel spin or slide shall also be provided by a contact closure in the friction brake system. Wheel spin-slide correction shall be available exclusively from the friction brake system in the event the propulsion system is inoperative.

10.2.9 Routine Switching

Switching for propulsion-brake mode changes and for direction changes, if required, shall be accomplished by suitably rated solid state devices. The line breaker shall not be operated during routine power-to-brake and brake-to-power transitions.

10.2.10 Vehicle Monitoring System (VMS) Interface

The input and output signals from each critical propulsion system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

10.3 TRACTION MOTORS

10.3.1 General

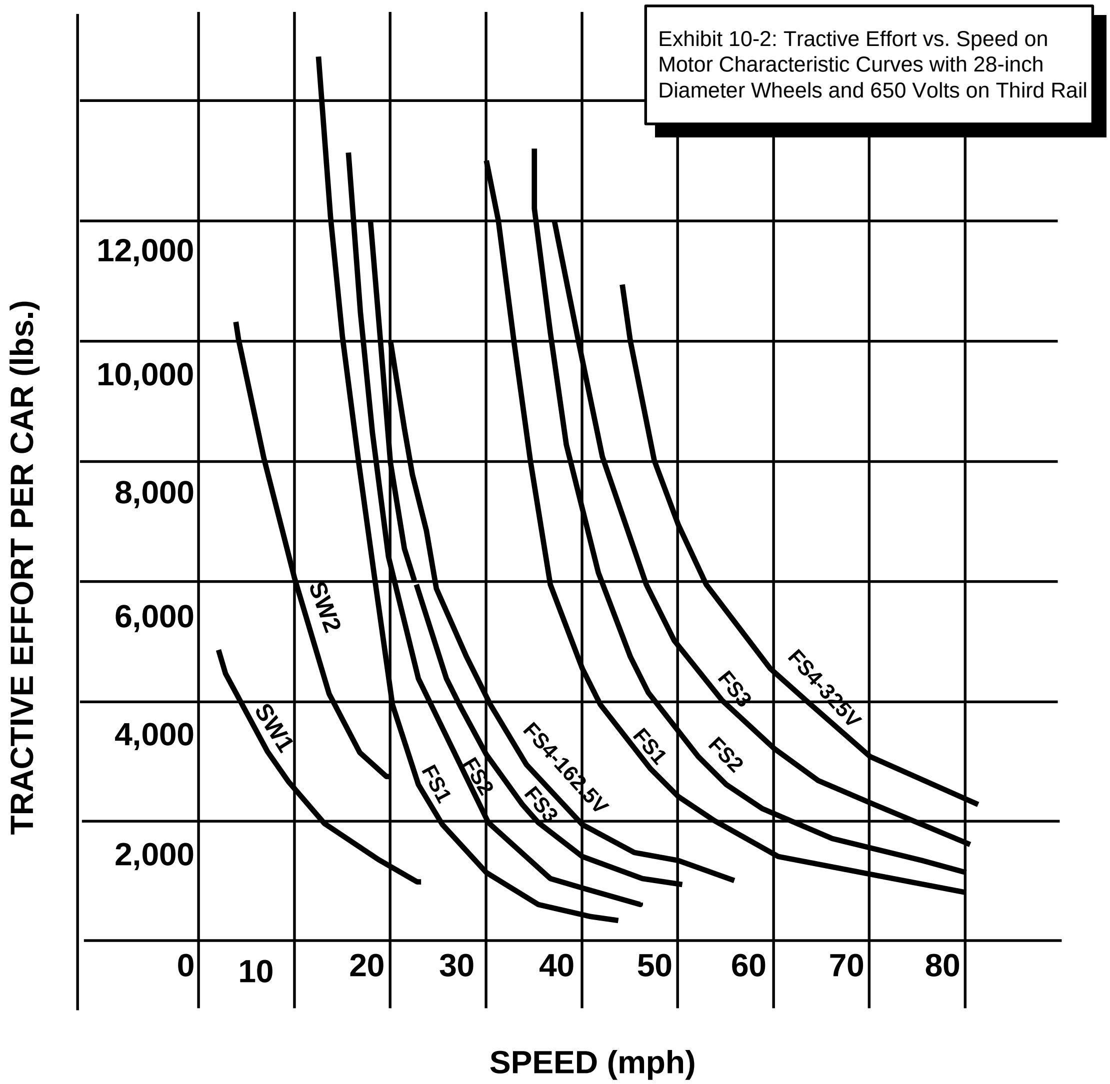
Each axle shall be driven by a 3-phase, squirrel cage induction traction motor which is self-ventilated with a copper rotor cage. The motor shall have characteristics such as to produce accelerations equal (+0%, -10%) to those developed by the existing cars whose motor characteristics are shown in Exhibit 10-2. The traction motor shall also develop tractive effort necessary to obtain the performance required in Section 10.1.2. The tractive effort levels shown in Exhibit 10-2, together with the assumptions stated thereon, shall be transmitted to the ATC subcontractor for use in establishing tractive effort requirements for maintaining the various speeds commanded. The traction motor shall be a service-proven design and shall have a record of successful transit or electrified railway service of no less than 100,000 individual motor miles.

All traction motors shall be physically and electrically interchangeable between cars, as described in Section 2.7.

10.3.2 Mounting

Each motor shall be resiliently mounted in the truck and, unless otherwise approved by the Authority, shall drive through a suitable direct coupled gear drive as specified in Section 10.4.

Exhibit 10-2 – Tractive Effort Vs. Speed



10.3.3 Duty Rating

The traction motors shall be rated in accordance with the duty cycles defined in Section 10.1.2 and shall be capable of meeting all the requirements of that section.

10.3.4 Load Sharing

The motor's characteristics shall allow all performance characteristics to be met with wheel diameter differences which vary up to 1/4-inch between axles on a truck and up to 1/2-inch between trucks on a car.

10.3.5 Design Standards

The motors shall comply with EN 60349-2: 1994, except as specified herein. Within 18 months after Contract Award, two traction motors, randomly selected by the Authority, shall be subjected by the Contractor to a complete "Type" engineering test. Additionally, one in every one hundred production motors shall also be "type" tested. MOD 1

10.3.6 Insulation

The motor insulation system shall be unaffected by airborne foreign material including, but not limited to, dust, water, and snow. Motor insulation shall be IEEE Standard 11, Class H insulation system or better. However, allowable temperature rise shall conform to Class F. Motor stator coils shall be vacuum pressure impregnated (VPI). The proposed vacuum pressure impregnation process shall be submitted for approval by the Authority. Impregnation processes other than VPI, thoroughly proven in traction service, may be offered as alternatives, subject to the approval of the Authority. The Contractor shall manufacture two simulated sections of the stator and winding assemblies to verify the VPI process. These simulated stator assemblies shall undergo the VPI process simultaneously with production stators. The Contractor shall section these assemblies to establish freedom from insulation voids and to verify that there is good bonding. This VPI verification test shall be conducted with the first two stators and one additional stator selected at random by the Authority. If voids are found, then the sample size shall increase.

10.3.7 Ventilation Filter

An effective and efficient filtration system shall be provided to remove dirt, snow and water from the self-ventilated traction motor cooling air. The air inlet openings shall include a protective screen designed in such a way as to preclude the accumulation of leaves and debris. If installed, filters shall require cleaning no more frequently than once every 30 days. The traction motor ventilation system shall be subject to the approval of the Authority.

10.3.8 Shaft Coupling

The traction motor shall be connected to the gear unit through a splined or keyed, taper fit, flexible coupling. The coupling design and the motor-to-gear unit mounting arrangement shall minimize coupling dynamic angular displacement.

10.3.9 Design Speed

Motor design maximum speed shall be that corresponding to a vehicle speed of at least 75 mph with fully worn wheels. IEC 349 definitions of "maximum speed" and "overspeed" shall be used.

10.3.10 Overspeed Protection

Motor overspeed protection, if used, shall operate at a motor speed corresponding to fully worn wheels at not less than 105% of maximum car speed, as specified in Section 10.1.2.

10.3.11 Bearings

Anti-friction bearings enclosed in a sealed grease cavity shall be provided. Grease cavities shall be large enough to hold a three-year supply of lubricant. Bearing housings shall be provided with grease fittings or tapped lubricant openings fitted with pipe plugs. Lubricant openings shall be accessible from a maintenance pit with the motor installed in the truck. The addition of lubricant shall not be required more often than once per year. Arrangements which use gear lubricant for the traction motor bearing at the pinion end are acceptable. Bearings shall have an ANSI/AFBMA L_{10} rating life equivalent to at least 1,000,000 miles of service.

10.3.12 Motor and Rotor Balance

Motors shall be dynamically balanced to meet the requirements of NEMA MG 1-12.06 and IEEE Standard 11-13.2.2. The rotors shall be dynamically balanced to within a maximum imbalance of 1.0 inch-ounce, even if a greater imbalance will satisfy the NEMA MG 1-12.06 requirements. Balancing methods shall be as approved by the Authority.

10.3.13 Marking

Terminals, leads, and motor frame shall be clearly marked for positive identification.

10.3.14 Electrical Connections

The motor leads shall be provided with compression type terminals which shall be bolted to the terminals of the disconnect plug cables. This connection shall be insulated using neoprene sleeves, or shrink tubing, and shall be held against the outside of the motor frame by a motor terminal clamping bridge using an insulating filler block of phenolic or polyester-glass.

Ground brush cables shall be arranged as described in Section 10.4.10.

The traction motor cables and ground cable from each axle shall connect at the carbody in a plug arrangement, similar in style to the “clam shell” type used on the Authority’s existing cars. Preferably, the plug arrangement shall be completely watertight under all conditions. If not watertight, the plug arrangement shall be provided with drain holes. No on-truck direct connections between traction motors or between ground brushes, other than grounds, shall be used. See Section 3.15.1 for traction motor lead connector watertightness test requirements.

Traction motor cables shall employ stranding and construction in accordance with AAR Specification S-501. Cable insulation shall be extra flexible, irradiated cross-linked polyolefin, 2,000V Class.

10.4 GEAR UNITS

10.4.1 General

Gear units shall be directly connected to the traction motors. Parallel drives shall be provided.

10.4.2 Mounting

Gear units shall be arranged to provide resilient attachment either to the axle or to the traction motor.

10.4.3 Specification

Gear units shall be capable of satisfactory operation with the proposed traction motors while conforming with the performance levels required in Section 10.1.2.

10.4.4 Bearings

The gear unit shall be equipped with anti-friction bearings throughout. Bearings shall be designed and applied to require inspection and adjustment to coincide with wheel replacement but no more frequently than once every 500,000 miles. Bearings shall have an ANSI/AFBMA L_{10} rating life equivalent to 1,000,000 miles, or more of service.

Bearing adjustments in the gear housing shall be by shims. Bearing end play clearance or preload shall be set using shims to achieve the required setting. Machining of housings to attain bearing end play is not acceptable.

10.4.5 Gears

Helical gears designed for the duty required shall be provided throughout the gear unit. Gears shall be designed and applied to require inspection and adjustment to coincide with wheel replacement but no more frequently than once in every 500,000 miles. Gears shall have not more than a 10% failure rate at the end of 1,000,000 miles of service.

10.4.6 Lubrication

The gear box shall be oil lubricated and provided with sufficient baffles, dams, passages, etc., to ensure an adequate flow of lubricant to all bearings and gears under all conditions of speed, load, temperature and weather including continuous operation in either direction at maximum speed. Gear unit shall be designed to prevent infiltration of moisture into lubricant from any and all sources. Gear unit shall not consume or lose oil at a rate in excess of one quart for every 100,000 miles.

10.4.7 Seals

All seals on rotating parts shall be of the labyrinth type. The gear manufacturer may also elect to supply an elastomer lip seal for the output shaft in addition to the specified labyrinth seal.

10.4.8 Inspection Openings

Inspection openings shall be provided. Covers shall be attached with bolts, gasketed, and designed to prevent loss of lubricant.

10.4.9 Plugs

Direct access, via a conveniently located oil fill plug, shall be provided for servicing the gear units. The fill plug opening shall be arranged to provide an indication of oil level and to prevent overfilling.

Drain and filler plugs shall be of the magnetic type, except that the filler plug may be non-magnetic if a magnetic inspection cover is provided. Drain and filler plugs shall be of a type or so located to prevent damage by obstacles on the track and the resultant loss of lubricant. Drain and filler plugs shall be lock-wired, or incorporate other approved device, to prevent their working loose in operation.

10.4.10 Ground Brush and Cover

The gear unit shall carry three ground brushes and a brushholder to conduct ground current to the axles via a press-fit ground ring. If required by the gear unit design, the ground brushholder may be mounted on the journal bearing assembly. The brushes and the cabling and shunts shall be sized so that the brushes on only one truck can carry the maximum total current flowing from the car to the running rails without overheating.

Each brush and its holder shall be protected from mechanical injury, dirt and oil by a housing having a cover easily removed for access. See Section 9.9 for grounding arrangement.

The brush assembly shall be designed so that the ground cable terminal can be attached thereto conveniently.

10.4.11 Speed Sensing

These cars will be equipped with systems requiring accurate speed intelligence, with the basic speed information coming from sensing devices mounted to the traction motor gear unit. In addition to the sensors inherent to the propulsion system, e.g., wheel slip-slide system and brake speed taper, provisions shall also be made on the gear unit for the application of speed sensing devices to be used by the ATC system. The ATC system will require two speed sensing devices, each mounted on separate gear units on one truck of the "A" car. Truck wiring, gears used for speed detection, and speed sensor mounting provisions shall be identical on "F" and "R" end trucks to permit truck interchangeability by adding or removing speed sensors. Dummy plugs or receptacles shall be provided for securing unused connectors at both ends of the speed sensor wiring if the truck is installed at a location where the speed sensor and speed sensor wiring is not required. Speed sensors and companion carbody wiring shall be coded or indexed in such a way as to prevent miswiring when trucks are removed and replaced.

Speed sensors shall be Airpax Electronics Model 101-0001 or equivalent as approved by the Authority. The number of teeth on the gear monitored and the gear ratio shall be such that 325 ± 1.5 teeth pass the sensor per wheel revolution.

All speed sensors shall be mounted in such a manner as to provide an adjustment in gap setting over a range of 0.005-inch to 0.0625-inch. The final setting required for ATC speed sensors shall be chosen to satisfy the requirements of the subcontractor supplying the ATC equipment and shall not include a tolerance of more than ± 20%. The electrical interface of the ATC speed sensors with the ATC apparatus shall be as shown in the Contract Drawings 97936-21 and 97936-22.

Alternate speed sensors and speed sensor locations, are subject to approval by the Authority. Speed sensor mounting provisions shall be identical on all gear units in order to effect complete interchangeability between units. The mounting of speed sensors shall be such as to avoid loss of gear lubricant.

All speed sensors shall be easily accessible for inspection, adjustment, and replacement with trucks attached to cars over the pits or on jacks and with trucks sitting by themselves on the floor. Mechanical teeth whose motion is used for speed information shall be designed and arranged so that it is impossible for them to be rotating at any speed other than the speed corresponding to the speed of the axle unless the propulsion gear train has suffered massive damage. The active face of each speed sensor shall be provided with a protective cover.

10.5 WHEEL SLIP-SLIDE PROTECTION SYSTEM

10.5.1 General

The cars shall be equipped with wheel slip-slide protection. The slip-slide system shall detect all slips and slides whether they are random or synchronous. It shall correct for tractive effort in excess of that which available adhesion will support during acceleration and deceleration of the car, and shall prevent flat-spotting and other damage to wheel treads under all adhesion conditions at all speeds in propulsion; and at all speeds above 5 mph in braking, provided that the coefficient of sliding friction exceeds 5%. The design shall also seek to minimize damage to wheel treads during braking below 5 mph.

The preferred failure mode of the system shall be such as to render the wheel slip-slide system ineffective and allow the brake to remain applied during a wheel slip-slide sequence. Failure modes which produce invalid indications of a wheel slip or slide will be tolerated, provided that apparatus is included to detect such invalid signals and restore braking effort within 4.5 seconds of recognizing the invalid signal and the method of achieving the timing is inherently fail safe. Once activated, the time-out feature shall not reset until traction power has been reapplied to the car. Slip correction shall be removed on a per truck basis if correction cannot be achieved in 4.5 seconds or the average deceleration of the affected truck, taking into account wheel slip, is less than 80% of the requested rate.

The efficiency of the Wheel Slip-Slide Protection System must be designed to operate in a manner such that it can pass the requirements of the following test procedure:

A. A married pair of test vehicles will be tested on a designated dry section of track which is reasonably straight and within ±1% of level. This pair will make four, 75 mph stops, two with blended brake and two with friction only braking at a B1, B2, B3, B4, and B5 brake rate requests. The stop distances and/or average deceleration rates will be measured for each stop. The data from the stops at each rate will be averaged. These averages will define the baseline stop performance at each rate.

B. The test vehicles will be outfitted with a track sprayer system that can spray the rails in front of each truck on the test pair. The sprayer will use a mixture of water, windshield washer solution, and soap if necessary. The mixture will be varied until the test pair begins to experience wheel slippage during 75 mph stops at a B2 blended brake request. This mixture will become the test mixture.

C. Slippery rail stops from 75 mph will be run using the test mixture for B1, B2, B3, B4, B5, and Emergency Brake Levels. Four runs (i.e., two blended and two friction only) will be made at each brake request. All slippery rail stops must be no more than 110% of the baseline stop performance.

D. The slip-slide equipment must effectively protect against wheel flats during the above test.

Efficiency shall be tested both for electrical and for friction brake, and available adhesion shall be estimated respectively from motor current or brake cylinder pressure just prior to the beginning of each slip.

10.5.2 Function

The slip-slide protection system shall function properly with differences of up to 1/4-inch in diameter among wheels on a truck and differences of up to 1/2-inch in diameter among wheels on a car. Detection of slips and slides shall be by means of evaluations of axle accelerations, axle speeds, or a combination of the two. Alternate means of detection with successful transit service experience may be offered for consideration.

Detection of a slip during acceleration shall initiate reduction of the traction motor torques from the propulsion system at a controlled rate. Once slip has been corrected, the reapplication of traction power shall then occur at a jerk-limited rate.

Upon detection of a slide by the friction brake control system during electric or blended braking, electric brake will have a certain amount of time (adjustable) to correct the slide. If the slide is not corrected during this period of time, electric brake shall be removed and friction brake take responsibility for braking until the slide is corrected. After the slip or slide has been corrected, braking shall be reapplied automatically at a rate consistent with obtaining maximum performance without exceeding the specified jerk limit. To ensure re-establishment of static wheel-rail adhesion, cancellation of the slip-slide signal to the electrical brake control system shall occur two seconds after detection that the slip or slide has been corrected. Electrical brake reapplication shall occur at a jerk-limited rate. The 2-second delay in reapplication of traction power or electrical brake shall be capable of adjustment over a range of 1 to 3 seconds.

The wheel slide protection system shall be functional under all braking commands, except an emergency brake application initiated by the Operator's Emergency Brake Push-button. The system shall be so arranged that failure of any component of this system shall not prevent development of a full emergency brake application. All components of the slip-slide protection system contained within the brake controller, shall receive 37.5-volt power from the friction brake system circuit breaker.

10.5.3 Slip-Slide Test

A test is to be performed using one married pair to demonstrate that the slip-slide system functions in accordance with the specification requirements of Section 10.5.1. This test is to be performed using a wetting agent which will, when sprayed on the rails during tests, result in a reasonably accurate simulation of conditions which would be produced by dew or a light rain and result in approximately 5% adhesion. A controlled spray is to be introduced on the rail immediately in front of the lead wheels on each truck in the direction of travel. This spray is to be regulated in a manner which permits flow rate to be controlled and turned on or off to individual trucks from within the car. These tests shall be sufficient to demonstrate that the slip-slide system efficiency is attained.

During this test a multiple channel recorder is to be used to record the following parameters as a minimum:

A. Third rail voltage: each car
B. Motor current: each truck
C. Brake cylinder pressure: each truck
D. Axle speed: each axle
E. Slip-slide command signals: each axle
F. Rate trainline event markers
G. Distance marks: 100-foot increments
H. Time markers
I. Car acceleration and deceleration rates
J. Torque feedback: each truck

A report which includes all data, data reduction, and analysis of results is to be prepared by the Contractor for approval by the Authority. *(CDRL 1002)*

10.6 ACCELERATION AND BRAKING CONTROLS

10.6.1 General

All acceleration and braking controls shall be designed to operate successfully in train. The maximum allowable variation in acceleration rate shall be 0.6 mphps absolute in a 0.25-second period. The average rate of change of acceleration or deceleration (jerk rate) shall be not more than 2.2 mphps/second under all normal conditions and this shall be inherent in the propulsion and braking systems. Emergency braking and wheel slip-slide correction shall be considered abnormal conditions and jerk limiting shall be nullified during these times except as required by Section 10.5.2. A free-running coast position shall be provided. If required for responsive control, an electrical brake rate of not more than 0.1 mphps may be used in lieu of free running coast.

Command intelligence for control of propulsion and braking shall come from either of the two following sources.

10.6.1.1 Automatic Train Control (ATC)

The ATC system is specified in Section 11 of this specification. The ATC system shall interface with the propulsion and braking apparatus furnished as part of the car in a manner as specified in Section 11 and as indicated in the Contract Drawings. The ATC system shall provide inputs to the propulsion and braking control systems to:

A. Initiate movement of the train and direct acceleration of the train to the speed commanded

B. Maintain proper car speed as commanded by the Automatic Train Protective System (ATP) or Automatic Train Supervisory System (ATS) both of which are subsystems of ATC

C. Adjust performance of the propulsion system (rate control) as commanded by ATS

D. Command and execute programmed station stopping.

One ATC system shall be provided for each pair of cars. In addition, the ATC system will accept certain inputs from other car systems. These inputs are outlined hereinafter and in the Contract Drawings 97936-21 and 97936-22.

10.6.1.2 Manual Train Control (MTC)

In MTC operation, movement of the train will be under direct control of the Operator through a master controller with enforcement of command speeds carried out by the ATP system in a manner similar to conventional cab signal-train speed control systems. In addition, it shall be possible to operate the train in MTC without ATP by activation of a sealed ATP cutout switch located in the Operator's cab.

10.6.2 Manual Master Controller

A single handle, all-electric type, manual master controller shall be provided in each cab. This controller shall operate to call for various steps of propulsion and braking and shall also be provided with interlocks dedicated solely to the ATC system as shown in the Contract Drawings 97936-21 and 97936-22.

The positions of the manual master controller shall be:

	Function		
Position Identification	Motor Connection Simulation	Field Shunting	Nominal Rate (mphps)
P5	Parallel	Fully Shunted	+2.8
P4	Parallel	Min. Shunted	+2.8
P3	Parallel	Full Field	+1.5
P2	Series	Fully Shunted	+1.5
P1	Series	Full Field	+0.075
Coast	Free running or minimum coasting current		
B1	–	–	-0.75
B2	–	–	-1.65
B3	–	–	-1.9
B4	–	–	-2.2
B5	–	–	-3.0
Emergency	Electrically and Pneumatically propagated		-3.2
Auto-Store	For ATC operation and handle storage on trailing cars		

The master controller handle shall move forward and rearward in a longitudinal vertical plane on the console. Power positions shall be obtained by forward movement of the controller handle. Progressively increasing values of braking shall be obtained by moving the handle rearward with the "Auto/Store" position located at the extreme end of the rearward movement. The "Coast" position shall be between the power and braking sector. A mechanical pawl shall be provided to prevent overtravel of the master controller handle into the "Auto/Store" position during frenzied movement of the handle to the "Emergency" position. The master controller handle shall also be complete with a rotary "deadman" emergency brake control arranged as on the Authority' existing cars.

An "overtravel" button shall be provided adjacent to the master controller. Depression of the overtravel button shall cause the pawl to retract, thus allowing the master controller to be moved from emergency to auto/store, and also allowing the master controller to be moved from B5 through emergency to auto/store without causing the train to go into emergency.

In the "Auto/Store" position of the master controller handle, full service brake (B4) shall be applied when the Mode-Direction switch is in either manual position. With the Mode-Direction switch in the "Auto/Store" position brake application will be determined by the ATC system in conjunction with the state of other console control switches. Recharging of the emergency brake when operating manually shall be accomplished by placing the master controller handle in the "B4," "B5," or "Auto/Store" positions and pressing the emergency recharge push-button. When operating under automatic train control with the handle in the "Auto/Store" position it shall be possible to recharge by pushing the emergency recharge push-button with the "overtravel" button also depressed.

10.6.3 Mode Direction Switch

A mode-direction switch shall be provided on the control console. The switch shall have three positions - "Auto/Store," "Man-Fwd," and "Man-Rev." The switch shall be arranged as shown in the Contract Drawings and shall be constructed so that a permanent stop will prevent its being moved between "Auto/Store" and "Man-Rev" positions except by way of the "Man-Fwd" position. The switch shall be interlocked with the master controller so that it cannot be moved between the "Man-Fwd" and "Man-Rev" positions unless the master controller is in the "B-5" or "Auto/Store" position and the switch cannot be moved to the "Auto/Store" position unless the master controller is in the "Auto/Store" position. Conversely, interlocking shall prevent movement of the master controller unless the mode-direction switch is in either of the manual positions. This interlocking shall be of such strength that the master controller handle and the mode-direction switch handle are sacrificial to the interlocking in the event either handle is subject to excessive force.

In the “Auto/Store” position of the mode-direction switch, the train shall be under control of the ATC system. The switch shall be interfaced with the ATC system as shown in the Contract Drawings. In this position of the switch, the propulsion system directional circuitry shall be set up for forward motion. In the “Man-Fwd” position of the mode-direction switch, the train shall be under manual control and the directional circuitry arranged for motion in a forward direction. In the “Man-Rev” position of the mode-direction switch, the train shall be under manual control and the directional circuitry arranged for motion in a rearward direction. Whenever a mode-direction switch is in the “Man-Rev” position, the yard horn at that end of the train shall sound continuously.

10.6.4 Control Lock

A control lock shall be provided in each control console which lock shall be operated by the control key (See Section 5.9.1). The lock shall have two positions—”Off” and “On.” The control lock shall be of a fail-safe design such that removal of the control key shall be impossible if any electrical contact of the lock has welded and shall be so interlocked with the Mode-Direction switch that the lock cannot be moved to the “Off” position unless the Mode-Direction switch is in the “Auto/Store” position, and the Mode-Direction switch cannot be moved with the control lock in the “Off” position. All control lock electrical contacts shall use silver and graphite contact elements or else shall incorporate approved alternate features to ensure that contacts cannot possibly remain closed when lock or switch positions indicate that they should be open.

This interlocking shall be of such strength that the mode-direction switch handle and the control key are sacrificial to the interlocking in the event either is subject to excessive force.

In the “On” position of the control lock, that control console shall be established as the control position for operation under either MTC or ATC and shall isolate all other control consoles, including control lock outputs, in the train. The “On” position shall also energize the appropriate main and auxiliary car circuits, the appropriate ATC circuits as shown in the Contract Drawings and the ATC power supply on each pair of cars in the train. In the “Off” position of the control lock, the appropriate main and auxiliary car circuits and the appropriate ATC circuits shall be de-energized.

In addition to those functions previously mentioned, the “On” position of the control console lock shall energize any auxiliary control circuits that should be de-energized when the cab in question is not in control of the train; including, but not limited to, the following:

Item	See Section
Destination sign trainline control	5.4
Door trainline control	6.1
Console door indication lamp	6.4.3
Headlight, taillight and marker light selection	8.2.4
Control console lights	9.7.2
Snow brake setup	10.6.8
Cab brake test lights	10.8.17
Communication system power	13.7

The control key shall be removable from the control lock in the “Off” position only. The “Off” position shall set the brakes at Negative Level 4 (2.2 mphps) and shall not of itself effect an emergency application.

In the “Off” position of the control key, and with the battery system power converter inoperative, all control circuits except layover heat, door control, and ATC control (as shown on the Contract Drawings 97936-21 and 97936-22) shall be disconnected from the battery.

10.6.5 <u>Acceleration and Braking Control Trainline Interfaces</u>

The trainline interfaces for control of acceleration and braking, whether such control is initiated by either manual or automatic control, shall be in accordance with the energization patterns shown in Exhibit 10-3.

10.6.5.1 Train Direction

A forward wire and a reverse wire, each of which may be energized by battery voltage, shall select train direction. Energization of the forward wire while the reverse wire is de-energized shall result in motion in the forward direction; energization of the reverse wire while the forward wire is de-energized shall cause motion in the reverse direction. Direction control apparatus shall be protected against the possibility of simultaneous energization of both direction trainlines.

10.6.5.2 Power-Brake Trainline

This wire shall be energized by battery voltage when calling for power or coast and having brakes released, and shall be de-energized when calling for brake. The energization and de-energization of this wire shall not defeat jerk limiting and shall not have any effect on the inhibition of the friction brake when a rate wire energization pattern calling for any level of braking is present on any car in a train.

10.6.5.3 Rate Selection

Five wires shall be selectively energized with battery voltage to provide rate selection intelligence to the local car propulsion and braking systems as shown in Exhibit 10-3.

Energization patterns other than those listed specifically in Exhibit 10-3 shall remove power and result in friction braking at Negative Level 4. Electrical braking shall be initiated only in the case of a negative level energization pattern, and de-energization of all motor connection trainlines.

The rates as stated are those to be achieved on level tangent track.

Exhibit 10-3 – Trainline Energization Patterns

MTC** Command	NOMENCLATURE/ FIELD CONFIGURATION	RATE	15 FWD*	16 REV*	17 COM	18 R1	19 R2	20 R3	21 R4	22 PB	30 SW1	24 SW2	25 SF S1	26 PF S1	27 FS2	28 FS3	29 FS4	76 CR	31	32	33	5	55
			TRAINLINES																				
P5	Parallel Maximum Shunt	+2.8	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	O					
	Parallel Intermediate Shunt	+2.8	X	O	X	X	X	X	X	X	X	X	X	X	X	X	O	O					
P4	Parallel Minimum Shunt	+2.8	X	O	X	X	X	X	X	X	X	X	X	X	X	O	O	O					
P3	Parallel Full Field	+1.5	X	O	X	X	X	X	O	X	X	X	X	X	O	O	O	O					
P2	Series Maximum Shunt	+1.5	X	O	X	X	X	X	O	X	X	X	X	O	X	X	X	O					
	Series Intermediate Shunt	+1.5	X	O	X	X	X	X	O	X	X	X	X	O	X	X	O	O					
	Series Minimum Shunt	+1.5	X	O	X	X	X	X	O	X	X	X	X	O	X	O	O	O					
P1	Series Full Field	+0.75	X	O	X	O	X	X	O	X	X	X	X	O	O	O	O	O					
	Switching 2***	+0.75	X	O	X	O	X	X	O	X	X	X	O	O	O	O	O	O					
	Switching 1***	+0.75	X	O	X	O	X	X	O	X	X	O	O	O	O	O	O	O					
CWL	Crawl (Car Wash)		X	O	X	O	X	X	O	X	O	O	O	O	O	O	O	X					
CST	Coast	0	X	O	X	O	X	X	O	X	O	O	O	O	O	O	O	O					
B1	Level 1	-0.75	X	O	X	O	O	X	O	O	O	O	O	O	O	O	O	O					
B2	Level 2	-1.65	X	O	X	O	O	X	X	O	O	O	O	O	O	O	O	O					
B3	Level 3	-1.90	X	O	X	O	O	O	X	O	O	O	O	O	O	O	O	O					
B4	Full Service Braking	-2.2	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O					
B5	MAXIMUM SERVICE BRAKING	-3.0	X	O	X	O	X	O	O	O	O	O	O	O	O	O	O	O					
EMR	Emergency Braking (Pneumatic)	-3.2	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O					
	Motor Overload Indication																		O	X	O	O	O
	Motor Overload Reset																		O	O	O	X	O
	T/L C/B Tripped Indication																		O	O	X	O	O
	Control Lock Interlock																		X	O	O	O	O
	Dynamic Brake Cut Out																		O	O	O	O	X

* Either 15 or 16 is energized, but not both. With Mode Direction Switch in Auto/Store or Man-Fwd position, 15 is energized.

** ATC can command all held configurations, but MTC can command only the configurations identified.

*** With these energization patters, Series Full Field shall be provided.

X = Energized

O = Not Energized

The energization of rate selection trainline wires representing a negative level of tractive effort shall cause retardation at that particular level irrespective of the energization pattern of other trainline wires. It shall be possible to achieve tractive effort modulation at any time by altering the energization pattern of the rate wires.

10.6.5.4 Motor Connections

The following final pseudo-motor connections shall be established by the energization of a trainline wire or wires with battery voltage whenever the rate wires are calling for any value of positive tractive effort. The propulsion system shall supply tractive effort as shown in Exhibit 10-2, based on the following motor connection trainline configuration.

10.6.5.4.1 *Crawl*

Energization of this wire shall produce sufficient tractive effort to produce a very slow speed for operation through a car washer. See Section 10.6.9. Response to the energization of this wire shall be predicated on the energization of the power-brake and direction trainline wires.

10.6.5.4.2 *Switching 1*

Energization of this wire shall cause the propulsion system to simulate a single fixed resistance step of motor tractive effort versus speed. This step shall not be made available to MTC. Response to the energization of this wire shall be predicated on the energization of the power-brake and direction trainline wires.

The values of the “fixed resistance” steps of tractive effort shall be such as to produce minimum cycling of the propulsion and braking systems for command speeds of 15, 22 and 28 mph. The ATC will not produce an energization pattern calling for either of these modes until a minimum speed of 12 mph has been reached. The cars shall be capable of continuous operation in either switching position above this minimum speed.

10.6.5.4.3 *Switching 2*

Energization of this wire shall cause the propulsion system to simulate a single fixed resistance step of motor tractive effort versus speed. This step shall not be made available to MTC. Response to the energization of this wire shall be predicated on the energization of the power-brake, direction, and Switching 1 trainline wires.

The values of the “fixed resistance” steps of tractive effort shall be such as to produce minimum cycling of the propulsion and braking systems for command speeds of 15, 22 and 28 mph. The ATC will not produce an energization pattern calling for either of these modes until a minimum speed of 12 mph has been reached. The cars shall be capable of continuous operation in either switching position above this minimum speed.

10.6.5.4.4 *Series Field Strength 1*

Energization of this wire shall cause the train to accelerate at the selected rate until voltage applied to the motors equals half the third rail voltage and thereafter to accelerate along the motor curve for the particular voltage applied. Field shunting shall also be available in this position. Response to the energization of the series wire shall be predicated on the energization of the power brake, direction, and Switching 1 and 2 trainline wires.

10.6.5.4.5 *Parallel Field Strength 1*

Energization of this wire shall cause the train to accelerate at the selected rate until full third rail voltage is applied to the motors. Field shunting shall be available in this position. Response to energization of the parallel wire shall be predicated on the energization of the power-brake, direction, Switching 1 and 2, and series trainline wires.

10.6.5.4.6 *Field Strength 2*

Energization of this wire in either series or parallel operation shall cause the traction control equipment to advance to the minimum field shunting position and produce tractive effort in conformance with the motor curves labeled FS-2 on Exhibit 10-2. Response to the energization of this wire shall be predicated on having satisfied the control conditions for either series or parallel operation.

10.6.5.4.7 *Field Strength 3*

Energization of this wire in either series or parallel operation shall cause the traction control equipment to advance to the intermediate field shunting position and produce tractive effort in conformance with the motor curves labeled FS-3 on Exhibit 10-2. Response to the energization of this wire shall be predicated on having satisfied the control conditions for either series or parallel operation and energization of the FS-2 wire.

10.6.5.4.8 *Field Strength 4*

Energization of this wire in either series or parallel operation shall cause the traction control equipment to advance to the maximum field shunting position and produce tractive effort in conformance with the motor curves labeled FS-4 on Exhibit 10-2. Response to the energization of this wire shall be predicated on having satisfied the control conditions for either series or parallel operation and energization of both the FS-2 and FS-3 wires.

10.6.5.5 Coast Position

Coast position shall be commanded by energization of the power-brake trainline and de-energization of the motor connection wires while the rate selection wires are calling for any positive level of tractive effort.

All of the previously outlined trainline control wires shall be interfaced with the ATC system as shown in the Contract Drawings. The total load on any trainline wire interfaced with the ATC system shall not exceed 4 amps at 32 volts with an eight-car train.

The sensitivity of apparatus connected to trainline wires shall be such as to not respond to voltage levels less than 12 volts.

10.6.6 Acceleration and Braking Control Circuit Protection

Acceleration and braking control circuitry shall be protected by a control circuit breaker. Trainlines used for control of acceleration and braking and fed from the control cab shall be protected by the control circuit breaker in that car.

Local car circuitry accepting inputs from each of the acceleration and braking control trainline wires shall be protected by an individual circuit breaker with one of the two poles used to actuate the indicating light. These breakers shall be arranged in a single panel and located in the Operator’s cab. A single indicating light on the end sheet of the car shall be provided, visible from both sides of the car, to indicate when any of the circuit breakers are tripped. Circuit breakers shall be sized based on the current carrying capacity of the wiring that they protect.

In addition, an indicating light shall also be provided on the console which will indicate when any of the circuit breakers has tripped on that car, and, when the car is a lead car, when one or more circuit breakers have tripped on the train.

10.6.7 Acceleration Control

The Contractor shall provide cars with solid state variable-voltage, variable-frequency (VVVF) control. The propulsion system shall use either gate turn off type thyristors (GTO) or insulated gate bipolar transistors (IGBT) for control of acceleration and braking current. The cars are required to be able to operate satisfactorily in trains with the Authority's existing cars. The propulsion control system must duplicate or mimic the behavior of the switched resistor controls with which the Authority's cam-controlled cars are equipped except where acceleration of those cars changes abruptly due to stepped movement of the cam shaft. In such a case the propulsion controls shall produce a steady acceleration. The propulsion control system shall have maximum regenerative and full rheostatic braking capability.

The acceleration controller shall be automatic, maintaining the selected initial rate up to "commanded" speed. Acceleration shall be compensated by adjusting tractive effort for passenger loads up to 24,000 lbs. (160 passengers at 150 lbs.), until the motors are operating on the characteristic curve called for by the particular MTC or ATC command. Suspension pressure information shall be obtained as specified in Section 10.6.8. During acceleration, compensation for load shall be based on the average of the loads measured at the front and rear trucks. This averaging shall be performed electrically. The actual tractive effort characteristic curves of the equipment furnished shall conform to Exhibit 10-2 values of tractive effort (+0%, -10%) through the entire speed range for the voltage specified.

It shall be possible to modulate the tractive effort by selective energization of the trainline wires controlling rate and motor connections, including control of field strength. The energization pattern of the trainlines may be changed at any time without following any particular sequence and without going through any intermediate energization pattern. The traction control system will reflect the change by altering the torque demand to simulate change in armature and field control connections of the switched resistance scheme within jerk limit restrictions. Traction control system cycling by the ATC system under all possible grade conditions shall be held to no more than four undesirable changes in tractive effort per minute averaged over the duration of the test runs between Silver Spring and Dupont Circle, which are described in Section 11.4.6. Although traction control cycling may be held to no more than four undesirable changes in tractive effort per minute when a car furnished under this contract is in control of the train, cycling will be at a rate of up to 12 undesirable changes per minute (averaged over a 10-minute period) when an existing Authority car is in control of the train. By definition, an undesirable change is any demand for a decrease in positive or negative tractive effort. The propulsion system shall also be designed to operate in conjunction with the ATC system on the existing Rohr-built cars.

The maximum jerk rate specified in Section 10.6.1 shall be adhered to at all times; however, in order to avoid extremely low jerk rates at high speeds and the corresponding loss in power-to-brake transition time, the traction control apparatus shall be arranged to have power removal time speed-dependent.

Maximum power removal time shall be as follows:

A. Above 70 mph: 0.35 second
B. 70 mph to 4l mph: 1.06 second
C. 40 mph to 0 mph: 1.5 second

Power removal, whenever called for, shall be ensured by fail-safe back-up circuitry.

Related equipment shall be furnished to the following functions.

10.6.7.1 Input Filter

A propulsion input filter shall be provided to prevent damage to the solid state equipment due to the very large voltage transients that are likely to be present on the third rail due to causes such as lightning strikes and interruption of maximum fault currents by vehicles and by wayside breakers. A surge arrestor shall be included at the input of the filter. Means shall be provided to limit input filter inrush current following closure of the line switch.

Each string of capacitors connected in series in the propulsion input filter shall be separately fused, and an indication shall be provided to detect the opening of each such fuse. The strings shall be sized so that the chopper can function satisfactorily in all respects with two fuses open in the filter capacitors. The propulsion overload light under the car and at the controlling console of the train shall be illuminated and if any of the fuses are open, propulsion in the car in question shall be cut out. Alternate means to protect the capacitors and to ensure the continued effectiveness of the filter may be provided.

10.6.7.2 Line Switch

A propulsion line switch designed to interrupt full fault current and located between the main fuse and the propulsion input filter shall be provided. The opening speed of the line switch shall be coordinated with the characteristics of the propulsion input filter of Section 10.6.7.1 above and the relaying of rate of rise of inrush current so as to satisfy the inrush energy limitation of Section 10.6.7.1.

10.6.7.3 Filter Discharge Switch

A manually operated switch shall be provided to give maintenance personnel a simple means of discharging all high voltage capacitors prior to maintenance work. This switch shall be interlocked with the line breaker so that the line breaker can be closed or remain closed only when the switch is in the full open position. Closure of switch shall connect each high voltage capacitor or parallel group of capacitors to its own discharging resistor rated to discharge the capacitor from a fully charged state to less than 15 volts within 15 seconds. As an alternative, an automatic means of discharging the high voltage capacitors is acceptable.

All doors and covers of boxes containing high voltage capacitors shall be labeled both inside and outside with decals providing warnings of danger from charged capacitors and instructions to operate the discharge switch and wait 15 seconds and then verify that the capacitors are discharged prior to working near them.

10.6.7.4 Third Rail Sensing

Means shall be provided for sensing third rail potential independent of the voltage on the capacitor of the input filter whenever the car is neither returning power to nor drawing power from the third rail. Means shall also be provided to detect the absence of flow of current between the third rail and the car.

The propulsion line switch and the power converter input contactor and any other line breaker that connects the third rail shoes to filters, which could keep the shoes energized shall open whenever third rail current ceases as a result of encountering a third rail gap or de-energized third rail and whenever third rail voltage below the minimum of Section 2.2 is sensed. Opening of these contactors in response to zero current shall occur within 200 milliseconds after detection of zero current. The line switch and auxiliary converter contactor are not to be opened while one of the control consoles in the train is activated as long as the equipment are all functioning normally, current is flowing between the car and the third rail, and the third rail is energized to normal voltage levels.

In addition to sensing third rail voltage and current conditions, there shall be sensing of rate of rise of outrush current such as would occur if there were a resistance fault somewhere on the third rail side of the propulsion input filter. The propulsion line switch shall be opened whenever current outrush that is indicative of such a fault is sensed. The arrangement shall be coordinated with the characteristics of the line switch and the propulsion input filter to provide outrush rate-of-rise protection that does not degrade the rate of rise protection previously provided by the Authority’s traction substation protective controls by more than 20%.

10.6.7.5 Electronic Monitoring

Electronic monitoring shall be provided to detect abnormal conditions. It shall include fault current interrupting breakers or alternative reliable means arranged to insure that control or component malfunctions do not cause secondary damage due to continued current flow, such as from dissipation of energy stored in the propulsion input filter, or due to energy generated by braking.

10.6.7.6 Cooling System

While convection cooling is preferred, forced air cooling will be considered. However, external air shall not be used to cool live electrical components in the power modules.

10.6.7.7 High Voltage Clearance and Creepage Distances

10.6.7.7.1 *Normal Class Apparatus*

All apparatus that may reasonably be expected to remain clean and dry will be classified as "Normal Class." This classification makes allowances for the effects of moisture, brake and rail dust, and the residual gases produced by unsealed or unvented switchgear and brush-type motors. The majority of undercar control apparatus falls into this category.

A. Location and Enclosure Requirements

1. Equipment housed in sealed enclosures
2. Convection-cooled electronic control apparatus located inside the vehicle, protected against dirt, moisture, and the intrusions of contamination incidental to interior vehicle cleaning
3. Undercar control apparatus housed in well-gasketed enclosures and cooled by well filtered air or by convection
4. External terminal posts well protected by tape or tight-fitting boots.

B. The clearance and creepage distance requirements for the Normal Classification of apparatus are the following:

1. Clearance: Between (3.00 + 0.01V) mm and 10 mm, ±0.05 mm
2. Creepage: Between (3.00 + 0.045V) mm and 10 mm, ±0.05 mm

   Where V is defined in Section 2.2 as the nominal system voltage.

C. For Printed Circuit Boards where circuitry is exposed to line potential 2.5 mm

10.6.7.7.2 *Dirty Class Apparatus*

All apparatus that is exposed essentially unenclosed, or subject to build-up of ionized gases will be classified as "Dirty Class." For example:

A. Components that are considered Dirty Class include:

1. Brake resistors
2. Open fuse holders
3. Unvented line switches, circuit breakers, or frequently switched contactors.

B. For exposed apparatus, the given creepage distances are intended to apply to ceramic insulators or to other insulators, ribbed or with approximately vertical surfaces that exhibit a high degree of resistance to tracking. The clearance and creepage distance requirements for Dirty Class apparatus are:

1. Clearance: Between (5.00 + 0.05V) mm and 10 mm, ± 0.05 mm; where V is less than or equal to 500 volts.
   (20.0 + 0.02V) mm, where V is greater than 500 volts.

2. Creepage: (25.0 + 0.045V) mm
Where V is defined in Section 2.2 as the nominal system voltage.

C. For Printed Circuit Boards where circuitry is exposed to line potential 2.5 mm

10.6.7.8 Electro-magnetic Interference

The propulsion system shall be designed and installed so as to preclude the possibility of electromagnetic interference with the functioning of the carborne and wayside signal equipment including equipment on the Authority's existing cars. To this end, the propulsion system equipment design frequency, installation, and test data shall be fully coordinated with the Automatic Train Control supplier, the Contractor, and with the Authority. Changes to the supplied propulsion equipment or Automatic Train Control equipment shall be provided as may be necessary to ensure operational and safety compatibility with existing Authority wayside train control and communications equipment. Information about the existing wayside and Automatic Train Control equipment will be made available to the Contractor.

10.6.7.9 Switch 1, Switch 2, and Series

The propulsion system shall provide a "pseudo series" mode in order to cause the series/parallel connected traction motors to exhibit the tractive effort versus vehicle speed behavior that would occur if third rail voltages were applied to the motors connected four in series. In this mode, the inverter output shall vary as required to maintain requested current until average output voltage reaches one-half of third rail voltage or 350 volts, whichever is lower, and shall remain at the lower of those two values as long as the series mode is commanded.

Similarly the propulsion system shall incorporate control modes that mimic the tractive effort-speed characteristics of the Switch 1 and Switch 2 modes of the Authority's existing cars. However, motor current shall be clamped at a value corresponding to third rail potential of 700 volts whenever third rail voltage is above that value.

10.6.7.10 Undercar Equipment

The Contractor shall install and wire all undercar equipment, especially traction equipment, in a manner that will cancel the magnetic field conducted, induced or radiated by such equipment.

10.6.8 <u>Braking Control</u>

Dynamic regenerative/rheostatic braking shall be provided. On all cars the braking resistors shall be sized to dissipate all dynamic braking energy. The propulsion system shall be able to control regenerative braking energy flow, the rheostatic braking energy flow, and the total dynamic braking effort to maximize the return of braking energy to the third rail within adjustable line voltage limits established in the propulsion system control. In connection with regenerative braking the following functions shall be included:

A. A switch on the control cab circuit breaker panel and an accompanying trainline cutout, to cut out regeneration on all cars in train and cause all electrical braking energy to be dissipated in the carborne resistors. (This switch and trainline are to be separate from the ones for dynamic brake cutout, which serve to prevent electrical braking altogether.)

B. Control, whereby when regeneration is enabled, each car shall automatically blend from full available regeneration to full rheostatic braking and zero regeneration as third rail voltage rises to 780 volts. The control shall be such that regenerated current does not oscillate and third rail voltage is not raised above 780 VDC in response to abrupt changes in receptivity of the third rail. The equipment shall include provision for moving the maximum voltage anywhere in the range from 780 VDC to 860 VDC.

C. Control, whereby electrical braking power is rapidly switched to the rheostatic brake whenever return of regenerated current to the third rail is abruptly terminated. Fluctuation in electrical braking effort due to such switching shall not cause introduction of friction braking.

D. Regenerated current shall pass through the line switch (Section 10.6.7.2) and shall thereby be prevented from energizing a previously de-energized section of third rail.

E. The rheostatic brake portion of the electric braking system shall be capable of operating continuously in the absence of regenerative braking and shall provide the full braking effort required.

Braking shall be automatic at all speeds, maintaining the rates commanded whether the braking commands originate in the MTC or the ATC system. All of the braking rates shall be available to MTC and these shall be as selected by the master controller through the selective energization of the rate trainline wires. The selected rate shall be carried downward to a stop through the electrical brake fadeout point unless the rate wire energization pattern is changed either by the MTC or the ATC system. The braking rates specified are instantaneous rates, not including build-up or reaction time. Brake build-up time from receipt of a command shall not exceed that required to comply with jerk limit requirements plus a maximum of 200 milliseconds dead time (friction brakes). In no case shall electrical brake buildup time exceed 5 seconds from receipt of a command. During any one stop, 95% of all instantaneous rates shall not exceed the prescribed tolerances, the remaining 5% may exceed the specified tolerance band by no more than 3% of the nominal rate, unless otherwise noted herein. Braking and braking control system shall have the capability to maintain net rates with new wheels for each level of service braking as described in Section 10.6.2 and in following table.

Tolerance

Braking Levels	Instantaneous Rate	All Electrical Brake Except Inshot*	All Friction Brake
B1	-0.75 mphps**	±0.1 mphps	See ranges of tolerance vs. speed shown on Exhibit 10-4
B2	-1.65 mphps**	±0.1 mphps	
B3	-1.90 mphps**	±0.1 mphps	
B4***	-2.2 mphps**	±0.1 mphps	
B5	-3.0 mphps	±0.2 mphps	
Emergency	-3.2 mphps	N/A	

* To electrical brake fadeout point only

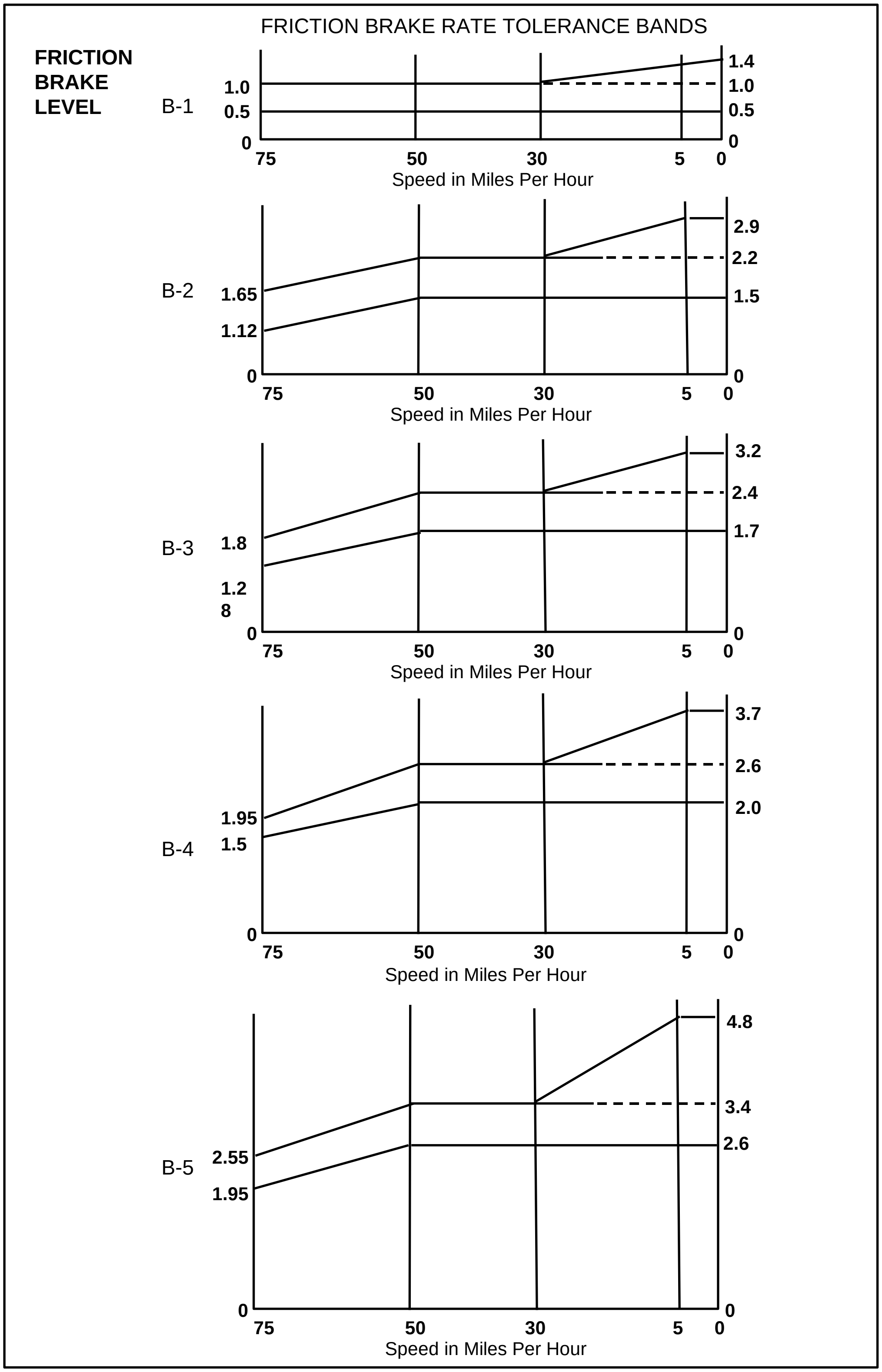
** Without including contribution from train resistance

*** In Braking Level 4, no instantaneous value of deceleration shall exceed the upper limit shown in Exhibit 10-4 when blending electrical and friction brakes.

Coordination between the electrical and friction braking shall be of the constant blending arrangement. A signal, proportional to the electrical brake effort, shall control brake cylinder pressure supplementation to achieve the rate commanded. The apparatus supplying the electrical braking effort shall be fail-safe in design and no possible failure mode shall cause the signal to indicate a level of braking higher than actually being developed.

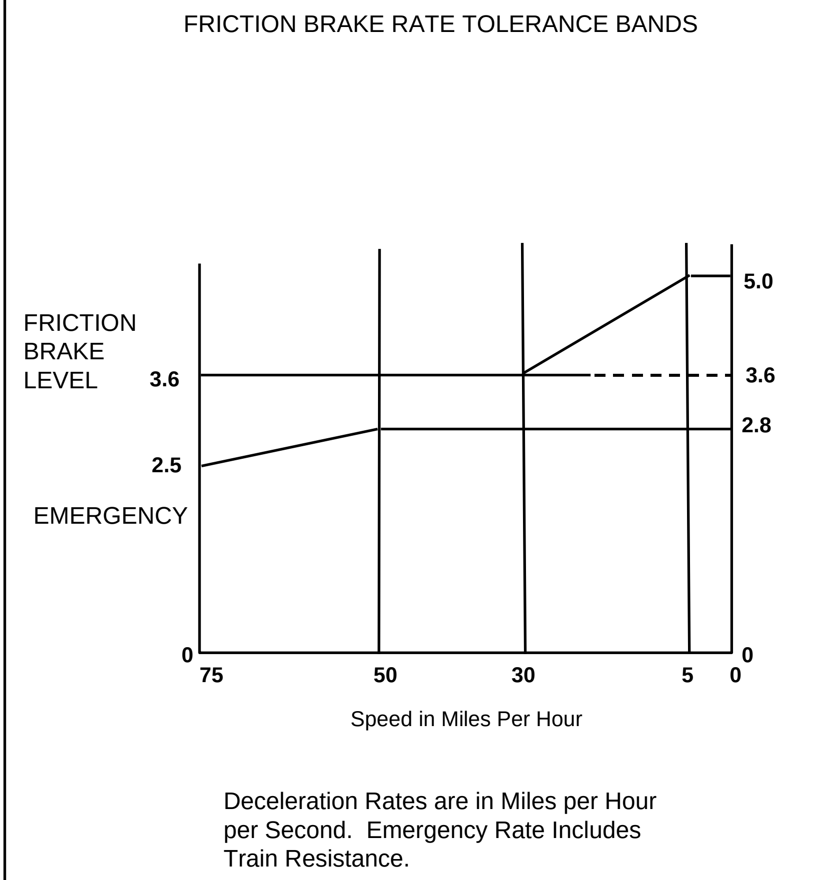
Jerk rate control shall be applicable to braking as well as propulsion. Jerk limiting for the friction braking system shall be fail-safe in design to ensure that the failure mode of the jerk limiting shall not reduce the braking rate during a brake application.

Exhibit 10-4 - Friction Brake Rate Tolerance Bands (Sheet 1 of 2)



Deceleration Rates are in Miles per Hour per Second. B-1, B-2, B-3 and B-4 DO NOT INCLUDE Train Resistance. B-5 INCLUDES Train Resistance.

Exhibit 10-4 – Friction Brake Rate Tolerance Bands (Sheet 2 of 2)



The braking control apparatus shall be arranged for fast release of the service brake when the car is stopped. Under this condition, the maximum release time, with any level of service brake applied, shall not exceed 1.0 second.

All braking effort, including friction and electrical service and friction emergency, shall be compensated for passenger load by a load weighing system in order to produce a constant decelerating rate within the limits specified in Section 10.1.2. The load weighing system shall be so coordinated that friction brake supplementation of electrical brake will be implemented if the passenger load requires more braking effort than can be supplied by electrical brake alone. The load weighing system shall be fail-safe in design to ensure that any failure of the system or any loss of air spring pressure shall not result in a braking effort less than 75% of that required on the married pair and shall result in a white light condition as defined in Section 10.8.1.A.

The air suspension pressures at the two ends of the car shall be sensed by pneumatic-to-electric transducers. If at a given end of the car, the pressures in the left and right side air suspension bags are not inherently equal, each shall be sensed by a separate transducer and electric circuitry shall be used to average the two. For load compensation of braking, a circuit shall compare the resultant front and rear truck signals and select the larger of the two.

The electrical and friction brake systems shall be so arranged that each level of braking outlined in Sections l0.6.2 and 10.6.5, except Level 5, can be individually adjusted in the field to produce any rate within ±10% of that specified for that level, but shall not permit adjustment outside the range of ±15% relative to that specified.

Both friction and electric braking in levels B-2, B-3, B-4, and B5 shall be speed tapered to produce, at 75 mph, 75% of the rate called for with the brake rate increasing linearly to 100% of the rate called for at 50 mph. The friction brake speed taper circuitry shall be inherently fail-safe in design and no failure mode of the system shall result in any reduction of braking beyond that called for by the taper.

If, because of the nature of the trainline command signals, translation is required, such translators for the acceleration and electrical brake control system shall be part of that system. Translation required for control of the friction brake system shall be part of that system. Under no circumstances shall both the friction brake and electrical brake systems use the same translation apparatus.

A trainlined snow brake switch shall be provided and be located in the Operator’s auxiliary control and indicator panel. This switch shall be a push-button and shall apply sufficient brake cylinder pressure to prevent icing of the brake shoes. The system, once set up, shall remain so set up until the control key is removed from the control lock, when the brakes shall return to normal operation.

A rotary modified shovel “deadman” emergency brake control shall be provided on the master controller handle with the arrangement like that of the Authority’s existing cars. An electrically and pneumatically propagated emergency brake application shall occur whenever the handle is released, unless:

A. Master controller handle is in the “Auto/Store” position

B. Master controller handle is in the “B4” or “B5” position and brake cylinders have at least 75% of B4 pressure level

C. Master controller handle is in the “B4” or “B5” position and train speed is less than 2 mph.

10.6.9 <u>Car Wash Speed Control</u>

A “crawl” speed control push-button shall be provided in the Operator’s auxiliary control and indicator panel. When this button is pushed with the master controller in “Coast” position the traction motors shall be energized so as to accelerate to and maintain speed between 2.5 and 3.0 mph for operation of trains through the car wash and for other similar purposes.

Circuiting shall be arranged so that the button must be held down to continue application of power. When button is released, power shall be cut off. Car wash speed control shall be functional only when the mode-direction switch is in either of the MTC positions. This "crawl" speed control shall be trainlined. It is anticipated that trains of up to 8 cars may be operated through the car washer. Design shall provide for at least 4 minutes sustained operation in this position with propulsion inoperative on half of the cars in the train.

10.6.10 Door/Traction Interlock

Intelligence relative to the position (open or closed) of the side doors on the entire train shall be trainlined to the control cab of the train. Circuitry shall be of a fail-safe design using double-break principles with pole changing based on the direction of travel. All relays used in the circuitry shall be the vital signal type of inherent fail-safe design in accordance with the requirements of Section 15.31, or alternatively, of a fail-safe design as approved by the Authority.

In the absence of intelligence indicating that doors are closed, the traction interlock circuitry shall act to (1) remove and prevent the application of traction power on the train and (2) set the train braking system at Braking Level 4 (2.2 mphps rate). The traction interlock circuitry shall also interface with the ATC system as shown on the Contract Drawing 97936-21. This interface shall take the form of two contacts each rated at 15 watts, both of which shall be closed when the doors are closed and locked.

A sealed door/traction interlock bypass switch shall be provided on the Operator's switch and circuit breaker panel which will allow for movement of the train in the event of failure of the traction interlock circuitry. This switch, in addition to nullifying the power removal and brake application feature, shall also interface with the ATC system as shown on the Contract Drawing 97936-21. This interface shall take the form of two contacts on the switch, each rated at 15 watts, which shall be closed in the "Off" position and open in the "Bypass" position.

MOD 2

10.6.11 Arrangement of Control Components

Motor and electrical braking control shall be combined as far as practicable, into a single integral control package unit and shall be constructed to include all the parts essential for control of accelerating and electrical braking, except the main resistors, control cut-out switches and electronic controls. Harness wiring shall be used to the maximum extent practicable for wiring these control items together. Mechanical indexing shall be provided on all static control cards in order to prevent inadvertent insertion of a control card in the wrong receptacle. The devices shall be mounted on a metal framework enclosed in a sheet metal box with hinged, gasketed covers. This apparatus shall be coordinated in design, giving due consideration to insulation and arcing distances and accessibility for maintenance. The box shall be provided with watertight strain relief bushings for cables that extend from the box for main car wiring. The control devices mounted in the box shall be insulated from it so that the box shall not require mounting insulation. The box shall be grounded to the underframe. All openings in the box shall be sealed sufficiently to exclude dust, rain and snow. If openings are required for ventilation, they shall exclude dust, rain and snow. The control package shall be fully assembled and tested prior to installation in the car and connection to other car systems. Control boxes containing apparatus normally requiring attention at 10,000 mile intervals shall be mounted at or near the longitudinal centerline of the car and shall be arranged to give full accessibility for pit maintenance. Control boxes containing apparatus requiring more frequent attention shall be arranged to give full accessibility or maintenance from the side of the car. Doors on boxes, when hinged, shall be easily removable without requiring the removal of other apparatus.

All propulsion and braking electronic control cards shall be interchangeable between cars without adjustment.

Where it is necessary to introduce compensation for car-to-car variations in parameters of traction motors, power capacitors, power inductors, etc., such compensation shall be provided via potentiometer on a circuit board which is semi-permanently attached to the car.

The first control group of each type shall precede the remaining control groups in each stage of the construction and assembly, and the Authority reserves the right to examine and approve each assembled and completed part of the work before similar work is undertaken on those remaining. This procedure shall be continued until the first control group of each type is completed. The remaining groups shall be constructed and assembled in accordance with the sample, and no changes shall be made unless authorized in writing by the Authority, who will examine each assembled and completed part when notified by the Contractor and will promptly approve or reject the item to avoid any delay in completion.

All control components or systems requiring periodic calibration or testing, such as accelerating and electrical brake current regulation, wheel slip protection system, load weighing system, electrical brake feedback, friction brake system, and pressure switches, shall be arranged with test points or test fittings so it is not necessary to remove any wires or break any pipes to perform said testing or calibration. In addition, test points and test fittings shall be so located and so arranged that calibration can be performed by one man unassisted.

A main-circuit current indicator shall be provided in the cab. The indicator shall have a zero position in the center and shall indicate amount of individual car propulsion current to the right and braking current to the left. Graduations are not required on this indicator. The signal for this indicator shall come from a transductor energized by battery system power and measuring armature current in one of the traction motors. Full-scale deflection of the indicator shall correspond to maximum accelerating current.

10.6.12 <u>Braking Resistors</u>

Dynamic brake resistors shall be of edge-wound ribbon, expanded metal, or stamped metal and shall be of sufficient capacity to handle full-service braking in operation over the specified profile with a vehicle weight up to and including crush-loaded. Other propulsion system power resistors shall have a power dissipation capability 20% greater than the maximum load to which they can be exposed under any specified operating condition.

Resistors shall be insulated from their support frames, and the support frames from the carbody, with high temperature insulators. Provision shall be made for resistor grid movement resulting from expansion and contraction. All resistor hardware shall be stainless steel. Expanded metal resistors shall be stainless steel.

The braking resistors shall be mounted under the floor and shall be arranged for natural ventilation by convection and car movement. The resistors shall be connected in order to minimize external magnetic fields. Alternate means to provide reduced values of magnetic fields external produced to the resistors may be submitted for approval by the Authority. Resistors and resistor groups shall be protected from wheel splash and flying missiles. Safety guards shall be provided as described in Section 3.1.2. The resistors shall have sufficient capacity to allow all braking to be done rheostatically with regeneration permanently cut out under all operating conditions in the Authority's system without exceeding an operating temperature specified in IEEE Standard Number 16, assuming a rating for continuous duty, without permanent distortion due to this heating effect, and without shortening the service life of the resistors and associated mounting hardware.

Adequate space shall be provided around resistors to allow for heat dissipation, or heat shields must be provided to protect adjacent wiring and apparatus.

10.6.13 Contactors

All propulsion system contactors shall conform to the requirements of Section 15.31 and be capable of safely interrupting the maximum possible load current in the event of a control malfunction (not fault current). The arrangement of arc chutes, blow-out coils, and venting, along with the contactor tip size, shall allow safe, continued operation upon reset after a malfunction. Contactors shall be installed for free air ventilation and easy accessibility for routine inspection and maintenance. Access to the contactors shall only require opening a box cover. Access to the contact tips shall only require snap-off removal of the arc chute.

10.6.14 Control Logic

Propulsion system control logic shall consist of 16- or 32-bit microcomputers with all the peripherals necessary to meet the required functions and performance criteria. Control programs shall be stored in non-volatile memory.

Sufficient non-volatile memory shall be included for the purposes of storing, by manual command, all significant parameters that occurred over a period of at least 2 seconds before a fault event, as indicated by any of the propulsion fault indicators when the propulsion system is last turned off. These data shall be held until normal car operation is resumed, a reset command is received from a portable test device, or a reset push-button on the control logic monitoring panel is pushed. These data shall be addressable by the portable test device for troubleshooting purposes and by the set of built-in troubleshooting displays.

Control logic cabinet(s) on each car shall include LED for indicating system states and faults.

Control logic and signals from the propulsion system shall be easily accessed from a portable test device per Section 12.2. Both analog and digital data must be readily accessible, and have the ability to address all logic signals significant to analysis and diagnosis, including signals to and from contactors and all external inputs and outputs. Unless otherwise specifically approved, the portable test device will have the capability of supplying a minimum of eight channels available as analog outputs to a high impedance chart recorder for real time recording of propulsion data. There shall also be an addressable output that is RS232 compatible.

Logic shall be arranged for the connection of a portable test unit to permit static testing, and running monitoring of propulsion system operation, accessing fault or other memory, and access to analog signals.

10.6.15 Current Measurement

Each traction motor circuit shall also contain an ammeter test shunt and isolation amplifier, or calibrated Hall Effect transducer, to which a standard high impedance meter or recorder can be attached. The sensors may also be used to supply the current feedback signal for the power control circuit, provided that appropriate buffer amplifiers are included to provide isolation between the functions. This apparatus shall be connected to the ammeter connection panel which shall be located inside the carbody.

Alternatively, motor current data may be provided via a port in the microprocessor control system to which the PTU can be connected and by configuring one of the analog outputs to provide this information. A signal shall be provided in the DAM, in accordance with the requirements of Section 10.2.10, to monitor regenerated current/power that is fed back to the third rail.

10.6.16 Undervoltage Protection

Undervoltage protection shall be provided on an individual car basis to remove propulsion power when the contact rail voltage drops to a level which would be harmful to the equipment. When contact rail voltage rises above 430 volts, propulsion power shall be automatically restored.

10.6.17 Main Switch (Knife Switch)

A main knife switch shall be installed, in a box, under the floor of each car. It shall be accessible from the side of the car and shall be located within five feet of the transverse centerline on the left-hand side of the car. The main switch shall have four positions with connections as follows: MOD 2

Position	Items Connected	Items Isolated
Run	a) Third rail shoes b) Auxiliaries c) Propulsion	a) Shop power stud
Rail Test	a) Third rail shoes b Auxiliaries	a) Shop power stud b) Propulsion
Off	a) None	a) All four items
Shop Test	a) Shop power stud b) Auxiliaries	a) Third rail shoes b) Propulsion

The shop power stud shall be designed to break away without damage to its mounting plate in case a car is moved with a shop power cable still attached. Attachment of the stud to its mounting plate shall be by means that:

A. Permits easy replacement of a broken stud

B. Precludes any need for disassembly or special repair of other components due to overtightening of any screw threads used in mounting the stud.

The shop power stud shall be compatible with the Authority's existing design of shop power connector.

Means shall be provided within the control system to permit exercising the propulsion control equipment when the knife switch is in the "Shop Test" and "Rail Test" positions.

The feed from the knife switch to the 700-volt auxiliary circuits shall proceed immediately to a fuse protecting the auxiliary circuits. This fuse shall be located either in the knife switch box or in an immediately adjacent vented box. The cable from the auxiliary fuse to the 700-volt auxiliary breakers shall be located and supported in such a way that in case of arcing from a failed fuse to the cable, the cable cannot fall into contact with the knife switch or any other conductor at third rail voltage, and the arc will be vented but contained in an area away from grounded conductors until the cable has been eroded far enough to extinguish the arc. However, the auxiliary fuse shall be chosen so as to insure so far as possible that when one blows, it will clear and not set up an arc. MOD 2

Unless otherwise approved, the feed from the main knife switch to the propulsion line switch shall be via a main propulsion fuse located adjacent to the knife switch. MOD 2

10.6.18 Test Panel

A test panel shall be provided adjacent to the propulsion logic unit containing banana-type motor current and brake cylinder feedback connections. The ammeter wires shall be from the main circuit current transductor for each pair of motors and shall be fused in the propulsion group. The brake cylinder wires shall be from the brake cylinder feedback transducers and shall be fused in the brake package. All wires shall be run underfloor. In lieu of fusing, current limit may be used to protect the test point wiring.

Quick-disconnect connections for a brake cylinder test gauge for both front and rear trucks shall be provided in the left rear seatwell as specified in Section 3.5.

10.6.19 Propulsion Cut-Out Switch

A Propulsion Cut-out Switch shall be provided in the Operator's cab, located as specified in Section 9.7.3 and Contract Drawing 97936-12, to permit total de-energization of the propulsion and electrical brake system on that car. This switch, when operated, shall completely isolate the propulsion system from all trainline control wires and shall prevent electrical brake operation. It shall not affect operation of the friction brake system or slip-slide system, or prevent normal control of the train by the master controller or the ATC system. Additionally, each truck motor depending on the propulsion control shall be individually isolated by the propulsion cut-out switch.

10.6.20 Dead Car Indication and Annunciation

A red annunciator, located in the cab to indicate when one or more cars in a train is not providing the requested level of tractive effort, shall be provided. The annunciator shall function in the control cab and also provide local indication in the car(s) not providing the requested level of propulsion effort.

10.7 PROPULSION ACCESSORIES AND WIRING

10.7.1 General

Wiring harnesses within control boxes shall be secured to tape rails with high temperature plastic tie wraps or approved equivalent at least every 8 inches. Wiring harnesses within control boxes shall be run, whenever possible, at the top of the box, however, harness runs at the bottom of the box will be allowed providing the closest point on the harness is at least 1-inch above the floor of the box. Strain relief bushings shall be used at the points where wiring harnesses enter or exit control boxes and electrical components. Interconnecting wiring harnesses under car and not in raceways shall be taped with at least two layers of PVC tape, half lapped, and secured with insulated clamps at no more than 18-inch intervals to prevent movement. No plastic tie wraps will be allowed to secure harnesses outside of control boxes.

The same wiring arrangement shall be used on all cars and all wiring identification shall be visible.

All resistors, particularly braking resistors, shall be installed so as to prevent overheating of adjacent apparatus, wiring, or carbody. In addition to the resistor assembly heat shield, a supplementary stainless steel heat shield shall be provided between the resistor assembly heat shield and the carbody.

10.7.2 Propulsion Prototype Tests

One set of prototype propulsion equipment shall be laboratory tested for electromagnetic emissions, conductive and inductive, according to the methods referenced in Section 1.4.5.

Laboratory tests shall be conducted on a set of prototype propulsion equipment prior to beginning production of that equipment, using a dynamometer that simulates vehicle inertia and train resistance. This test is for the purpose of demonstrating that this equipment functions properly and meets all Specification requirements in Section 10.

10.7.3 Propulsion System Tests

The first complete set of propulsion equipment, i.e., the first four motors and the first motor control unit, shall be set up at the Supplier's facility for performance of a complete systems test on the dynamometer. The dynamometer shall be capable of simulating all service conditions. The dynamometer test setup shall be able to provide for propulsion and braking loads under varying passenger loading conditions and the full range of specified third rail voltages both during acceleration and dynamic and regenerative braking.

The Contractor shall provide the Authority with complete reports of all tests upon completion of tests.

10.8 AUTOMATIC FRICTION BRAKE SYSTEM

10.8.1 General

A friction brake system shall be provided as a supplementary brake and as a fail-safe back-up to the electrical brake system. This brake system shall function properly in coordination with the electrical braking system. The friction brake system shall be inherently fail-safe in design, construction, and operation to the degree defined hereinafter.

Following a stop imposed by the brake pipe pressure switch as described in Sections 10.8.4 (pneumatic brakes) or by the second of the hydraulic accumulator pressure switches as described in Section 10.8.23 (hydraulic brakes), the brake actuation energy storage accumulators shall have sufficient energy and fluid stored so that if a train is left with the trainlines calling for B4, B5, or Emergency, the commanded brake cylinder pressure will remain present for at least 90 minutes in the absence of third rail power, based (pneumatic brakes) on the cut-in pressure of the air compressor.

While it is highly desirable to have the entire friction brake system designed on completely fail-safe principles, it is absolutely essential that the train protection braking, namely, Braking Level 4 (2.2 mphps) and Braking Level 5 (3.0 mphps), be absolutely fail-safe. These levels shall be considered to meet the fail-safe criteria required if no failure or series of related failures can occur which will cause the resultant brake force applied to be less than 75% of the braking force commanded by Level 4.

In regard to fail-safe design criteria for the friction brake system, the criteria specified in Section 1.11.4 and the following are established as guidelines:

A. Self-detecting component failures shall cause a white light condition.

B. Non-self-detecting component failures will not cause unsafe consequences and will not, when added to other failures, cause unsafe consequences.

C. Any number of simultaneous component failures attributable to the same cause or related causes will not cause unsafe consequences.

D. Broken wires, damaged or dirty contacts, relays failing to respond when energized, or loss of power will not result in an unsafe condition.

E. All relays used shall be vital relays. As an alternative, the use of non-vital relays or electronic circuits will be acceptable for any application that would call for vital relays, provided that sufficient checks are incorporated to detect welded relay contacts and stuck or welded relay armatures, or if the electronic circuiting meets fail-safe criteria.

F. In establishing fail-safe criteria for electronic circuiting, components shall be considered to be able to fail in either the open or shorted position. It shall be assumed that multi-terminal devices can fail with any combination of opens, shorts, or partial shorts between terminals. It shall also be assumed that any amplifier can break into spurious oscillation at any frequency.

A sufficient degree of redundancy without adversely affecting system reliability may be used to achieve the degree of fail-safe operation required. Since only Braking Levels 4 and 5 are required to be absolutely fail-safe, the redundancy need be applied to these levels only. Furthermore, Level 5 need only be fail-safe to the extent that it will produce the same braking effort as Braking Level 4.

Note that fail-safe techniques shall be applied to the component level, as well as being incorporated in the basic system design. Systems that process amplitude-or frequency-modulated AC signals; or that employ purely electro-mechanical, electro-hydraulic, electro-pneumatic, or pneumatic-hydraulic devices; or that combine such devices and control circuits, and that are inherently fail-safe, are preferred to purely DC analog systems, which cannot readily be designed to meet the specified fail-safe criteria. The use of control circuits that are not fail-safe at the component level, that do not use vital relays, or that in some other manner do not meet the specified fail-safe criteria are acceptable only when furnished on a per-truck basis. The use of monitoring and checking circuits, within each per-truck brake system is, due to their added complexity, an undesirable approach. Brake systems supplied on a per-truck basis shall, however, compare performance of the two subsystems and detect failures in either of them. Detection of subsystem failure shall prevent the release of brakes and application of power at the next station. Monitoring and checking circuits shall meet the specified fail-safe criteria at the component level. The microprocessor shall also monitor status of the friction brake system and shall store selected diagnostic information to be utilized by the vehicle monitoring system via a data acquisition module (DAM) as specified in Section 10.8.37.

Whenever Braking Level 4 is commanded, the braking effort produced shall never be less than 75% of that required to produce the commanded rate on level, tangent track. A system, which has a failure mode that can result in less than full commanded pressure being supplied to brake cylinders, shall be provided on a per-truck basis.

10.8.2 Service Brake Control

Trainline control of service braking shall be entirely through electrical trainline circuits, which shall be of the fail-safe type, protected against trainline circuit faults. The levels of service braking outlined in Section 10.6.2 shall be made available to either MTC or ATC by the selective energization of the rate trainlines. The trainline rate wires shall use a common return trainline wire isolated from the ground in each car and connected to ground at the control cab only. The call for Braking Level 4 (B4 master controller position) shall, in addition to de-energizing the rate wires, open the rate return trainline.

A single trainlined air line shall be provided, which shall function as a main reservoir equalizing pipe, and shall also function to provide pneumatic initiation of an emergency brake application.

10.8.3 Arrangement of Control Components

The entire service friction brake control system shall be packaged in a single integral control package and located under the left rear back-to-back seat in a manner so as to provide accessibility for maintenance. All of the electrical test points necessary for periodic routine calibration and adjustment shall be brought out to a convenient test receptacle where a testing device can be plugged in. A test fitting for brake cylinder pressure shall also be made available at the unit.

MOD 2

The fluid control portion of the brake control apparatus may be located underfloor with the permission of the Authority.

10.8.4 Emergency

Emergency braking shall be all-friction braking and shall be obtainable from the master controller, from the deadman’s handle of the controlling cab, from any Operator’s emergency stop push-button in the train, and by “accidental uncoupling” anywhere in the train.

When emergency braking is initiated via the master controller or deadman’s handle in the controlling cab, it shall normally be propagated through the train by de-energization of TL82. When TL82 is de-energized, an electrically-controlled, air-operated brake pipe dump valve shall be opened on each car of the train. When this occurs, brake pipe pressure on each car of a train of any length shall, within 1 second following de-energization of TL82, drop below the level at which the brake system goes into emergency.

Depressing an emergency stop button shall cause the de-energization of TL72 and TL82 and shall provide the normal means for an Operator to initiate an emergency stop while operating in Automatic mode.

Each emergency stop push-button shall also have a pneumatic portion that shall pilot a pneumatically controlled brake pipe dump valve separate from the electrically-controlled dump valve. Each pneumatically-controlled dump valve shall be located under the cab and shall open in response to abrupt pressure drop or to outrush of air due to prior dumping by the adjacent pair of cars. It shall also open due to uncoupling as well as in response to pneumatic piloting from either of the emergency push-buttons in the cab above it. The push-buttons, air lines, pneumatically-controlled dump valves, and brake pipe sizing and routing shall be such that brake pipe pressure at the last car of an eight-car train drops below the pressure at which the brake controls go into emergency, within 3 seconds following depression of an emergency stop push-button in the first car of the train, with TL82 kept energized artificially.

Each car shall be equipped with an air trainline (i.e., brake pipe) pressure switch which shall open when the pressure drops to the drop out pressure of the Authority's existing cars. Opening of this switch shall cause the drop out of the emergency relay on the car. De-energization of TL82 shall also cause the emergency relay to drop. Conversely, dropping of the emergency relay shall cause the car's electrically controlled dump valve to vent the brake pipe.

Dropping of the emergency relay shall ensure that propulsion power is removed by immediate opening of the line switch.

LED indicators shall be provided in each cab to indicate the presence of B+ from TL82; and the presence of current in the coil that keeps the electrically controlled dump valve from venting the brake pipe. These indicators shall be arranged so that an Operator can tell which car must have its brakes cut out in order to move a train in which some cars cannot be released from an emergency application due to an electrical malfunction.

If the cars are equipped with couplers that produce only momentary pressure drop in the pneumatic trainline when cars are uncoupled, the cars shall be equipped with an emergency valve that is sensitive to rate-of-change of air pressure, to ensure emergency applications when cars are uncoupled, whether intentionally or accidentally. Devices that are used to interface the pneumatic trainline with hydraulic braking systems shall be constructed such that leakage of hydraulic fluid into the pneumatic system is impossible under all possible conditions of wear or malfunction. Control of the brake cylinder pressure by the pneumatic trainline shall not make use of electricity in any way. Any emergency application from any car of a train shall promptly operate the emergency brakes on all cars in the train and shall be so arranged as to shut off the power on all cars and open the rate return wire on the control car simultaneously. The brake cylinder pressure shall be determined by the variable load control as governed by the passenger load. Electrical brakes shall not operate in emergency. It shall be possible to obtain a full emergency brake application at any time or at any stage of brake application or release regardless of the degree of service application. Each auxiliary control and indicator panel shall contain an emergency brake recharge push-button which, together with an emergency brake charging magnet valve, shall be used to recharge the brake system after an emergency application of the brakes.

Brake pipe arrangement and valuing shall permit one pair of cars to charge and supply an adjacent pair whose air compressor is inoperative and whose main reservoir is initially empty. Following charging, the first pair shall be able to supply the adjacent pair with all the air that it can consume in normal functioning (including air suspension load compensation and friction braking under conditions of poor adhesion) via the brake pipe without the train being put into emergency by reduction in brake pipe pressure.

10.8.5 Initial Application

An initial predetermined amount of brake cylinder pressure shall be admitted to the brake cylinder when the electrical brake is operating to assist in synchronizing the blending of friction with electrical brake when the latter fades at the end of the normal service stop. This requirement shall not apply to brake systems in which slack adjuster design holds brake shoe clearance to 1/4-inch or less at the point of maximum gap.

10.8.6 Pressure

Brake cylinder pressure for a commanded level of friction braking shall be consistent, repetitive, and independent of ambient temperature.

Allowable maximum pressures shall be as follows depending upon the friction brake system selected:

A. Pneumatic System: The maximum pressure in the system shall be 160 lbs. psi (main reservoir safety valve setting) with the governor set at 130-150 lbs. psi. Pressure in the brake cylinder shall be regulated through the variable load devices between the empty and fully loaded car. Maximum brake cylinder pressure shall be no more than 100 lbs. psi.

B. Hydraulic Brake System: Maximum brake cylinder pressure shall be no more than 1,450 lbs. psi.

C. Pneumatic-over-Hydraulic System: The respective portions shall conform to the corresponding requirements as stated in Paragraphs A and B above.

10.8.7 Friction Brake

Individually actuated disc brakes shall be installed outboard of each wheel of the trucks. The disc hubs shall be fastened to the wheels, using lock-wired Grade 5 bolts. The discs shall be located so as to be concentric to, and parallel with, the wheel.

A means shall be provided to maintain optimum brake pad clearance throughout the full service life of the pads and disks and, in the case of pneumatically energized brakes, to minimize brake air cylinder volume for rapid control response under poor adhesion conditions.

10.8.8 Coordinated Application

The friction brake shall cut in automatically when the electric brakes are inoperative without further operation of the controller.

10.8.9 Main and Supply Reservoir Arrangement

A main air reservoir shall be furnished on each car. If a pneumatic friction brake system is employed, a supply reservoir shall also be furnished for each car. A non-return check valve shall be installed between the main reservoir and the supply reservoir. Air shall be taken from the supply reservoir for braking only. If brake safety is based on independence of the front and rear brake systems, then separate front and rear brake supply reservoirs and check valves shall be furnished on each car. The main air reservoir shall be provided with a manual drain cock. The drain cock shall be constructed of noncorroding materials. The main reservoir shall be mounted in such a manner as to provide a 1-inch slope from end to end with the drain cock located at the lowest point. The supply reservoirs shall be mounted without slope. A sump reservoir fed from the compressor and supplying the main reservoir shall be provided as a part of the compressor unit as described in Section 10.10.

Except in the case of reservoirs made of aluminum or stainless steel, each air reservoir shall be drilled over its entire surface with telltale holes, made by a standard 3/16-inch drill. These holes shall be spaced not more than 12 inches apart, measured both longitudinally and circumferentially, and drilled from the outer surface to an extreme depth determined by the formula:

$$D = \frac{0.6\,PR}{(S-0.6P)}$$

where: D = extreme depth of telltale holes in inches but in no case less than 1/16-inch
P = certified working pressure in pounds per square inch
S = 1/5 of the minimum specified tensile strength of the material in pounds per square inch
R = inside radius of the reservoir in inches.

One row of holes shall be drilled lengthwise of the reservoir on a line intersecting the drain opening. Each main reservoir and supply reservoir shall also be subjected to a hydrostatic test before being put in service.

Air reservoirs shall meet requirements of ASME Pressure Vessel Code and shall be stamped with ASME certification. If a hydraulic friction braking system is employed, the supply reservoir and its associated apparatus may be eliminated.

10.8.10 Pressure Gauges

Two or three pressure gauges at least 3 inches in diameter shall be provided in each Operator's cab. Each shall have an evenly-illuminated black dial and 270-degree pointer movement. One electric gauge shall indicate brake pipe pressure. The second gauge shall be an electric gauge indicating brake cylinder pressure of the front truck as measured by a pressure transducer incorporated into the brake control unit. The third gauge shall be provided if hydraulic braking is used and shall be an electric gauge indicating hydraulic accumulator pressure. Regardless of type, gauge faces shall make use of color bands to indicate the range of normal working pressures.

10.8.11 Pressure Test Fittings

Pressure test fittings shall be provided in air or hydraulic lines to gauges and other apparatus, such as pressure switches and pressure-to-electric transducers, requiring periodic routine calibration.

The fittings shall allow for simple and effective accuracy and calibration testing without removing the item being tested from the car. 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. This valve will, upon insertion of the test apparatus, close off the normal supply line to the component being tested. Fittings shall be installed close to the device that they serve and shall be mounted in an accessible location.

10.8.12 Brake Cylinder Pressure Control Valves

Any electronic components incorporated into the brake control valves shall be located so as to be accessible without removal or disassembly of the fluid containing portions of the valves. Any adjustments required shall be possible without removal of the valve from the car. Design of brake cylinder pressure control valves shall be such that fluid flow through the valves ceases when fluid is not flowing in or out of the brake cylinder.

10.8.13 Brake Cylinder and Friction Brake Cut-Out Provisions

A means shall be provided for cutting out brake cylinders on each truck in such a manner that brakes on that particular truck will be released automatically. The cut-out device shall be located on the supply side of the pressure sensing devices for the brake status lights. The brake cylinder cut-out provisions for the rear truck shall be located in the right rear back-to-back seat well. The cut-out device for the front truck shall be located in the left front back-to-back seat well. The cut-out provisions shall be arranged for operation both from above and below the floor.

Friction brake cut-outs shall be provided for the purpose of cutting out friction brake on the entire car, on a per-truck basis, in the event of a malfunction. The cut-out controls shall be arranged in such a manner as to automatically release brakes on the car when moved to the cut-out position. The cut-out provisions shall be arranged for operation both from above and below the floor. Cut-out controls shall be located in the same back-to-back seat wells as the brake cylinder cut-outs.

10.8.14 Trainline Cut-Out Cock

Cut-out cocks shall be provided in all air lines between cars.

10.8.15 Handle Position

All cut-out cock handles shall be arranged so that in the open position they shall be parallel to the flow of fluid, and in the closed position, perpendicular to the flow of fluid. Cut-out cocks shall be turned to a position that will not allow the valve handle to vibrate to the opposite position in service. An adequately supported handle or rod shall be provided to drain the main reservoirs from the side of the car. This handle or rod shall be so located as to be well clear of contact rail.

10.8.16 Flexible Connections

Vibration-eliminating flexible connections shall be provided on all piping between braking system components not rigidly mounted to the carbody. Quick-disconnect self-sealing connections shall be provided on hydraulic connections between trucks and carbody. Standard AAR swivel fittings shall be provided on pneumatic connections between trucks and carbody. Connections shall not provide a path for return current between carbody and truck.

10.8.17 Brake Status Lights and Checks

10.8.17.1 Green and Amber Status Lights

Trainlined brake status indicator lights shall be provided in each cab, which shall be activated by the operation of the control console key at the Operator's cab. There shall be a green "release" status indicating light, which shall be illuminated when all friction brakes and handbrakes in the train are fully released. With the snowbrake applied, and the brakes released, the green "Brakes-Released" indication shall be displayed. There shall also be an amber "Applied" indication light, which shall be arranged to be illuminated only when all friction brakes in the train are applied to at least 75% of Braking Level 4 and no "white light" condition exists in any car in the train.

Exterior amber and green indication lights shall be provided on the "R" end of the car, which shall indicate the condition of the brakes, including handbrake, on that car only in the same manner. These lights shall be located so as to be readily visible from the ground on both sides, and from the end doorway.

The information for these indications shall be obtained from individual sensors, one of which shall be provided for each independent brake system located on the brake cylinder side of the brake cylinder cut-out device. Trainline circuitry shall be such that in the event of any circuit failure no indication shall be given. The relay corresponding to KABAR on the existing cars shall be a vital signal relay.

An interlock shall be provided such that if the above brakes-applied indication and the summary door-closed indication are both absent at the same time then the Operator will not subsequently be able to release brakes or take power until either the brakes-applied indication is recovered or the Operator keys out (and keys in) after the doors-closed indication is again present. (The ATC equipment is to provide a similar interlock to prevent operation in automatic mode following simultaneous absence of the brakes-applied and doors-closed indications but restoration of the brakes-applied indication is to be the only means of releasing that interlock.)

10.8.17.2 White Indicator Light

An exterior white brake system fault indicating light shall be provided on each side at the "R" end of each car, and shall be lighted to indicate each of the following faults (as applicable):

A. If friction brakes are hydraulically-powered, and the hydraulic pump is not fully functional.

If friction brakes are pneumatically-powered, and an apparent failure of the air compressor is detected as described in Section 10.11. MOD 3

B. If redundancy of front and rear truck brakes is used as the basis for brake safety, and the front and rear truck brake cylinder pressures differ by more than an 25%.

C. Upon failure of the load weighing system or any loss of air spring pressure to the system.

10.8.17.3 Blue Indicator Light

If brake safety is based in part on use of redundant brake systems for the front and rear trucks, then two exterior blue brake fault indicator lights shall be provided on each side at the "R" end of each car, one located above the white light and representing the front truck and the other located below the white light and representing the rear truck. If brake safety does not depend on redundancy, then there shall be just a single blue light located beside the white light. Each blue light shall indicate faults in the brake equipment that it represents under the following conditions, as applicable:

A. If hydraulic brakes are used, then wherever there is an abnormally low condition of fluid level or pressure in the hydraulic accumulator.

B. For any type of brake system, from the beginning of any period of service friction braking either not requested or no longer requested by trainline.

A blue light condition due to low hydraulic accumulator fluid level or pressure shall cause venting of the brake pipe until the condition has been corrected or the faulty brake system has been cut out.

Any activation of the blue brake fault indicator shall cause the indicator to latch in, regardless of any subsequent change in the condition that caused it, until the circuit is reset by opening and closing the friction brake system control breaker on the car with the fault. Design of the system shall preclude nuisance latching of the indicator caused by transient conditions within the brake system.

10.8.18 <u>Brake Test Rack</u>

The Contractor shall furnish to the Authority a brake test rack designed for use with the system installed on the cars built under the Contract in accordance with the requirements of Section 12. The test rack shall be arranged to permit all shop tests necessary on this apparatus to be made quickly and conveniently. The rack shall be delivered to a point to be determined by the Authority prior to the delivery of the first cars.

10.8.19 <u>Emergency Stop Valve</u>

Two emergency stop valves shall be provided on each car, one on the Operator's console, and the other on the door control panel on the left side of the car each being part of the emergency stop button as specified in Section 10.8.4. Pneumatic emergency application of the train brakes shall be made when either of the Operator's emergency stop push-buttons is depressed. Communication between the emergency stop push-button and the valve shall be pneumatic. The emergency stop valve when actuated shall, in addition to applying the emergency brake, cause the wheel slip-slide protective system to be nullified for the duration of the stop.

10.8.20 Power Knockout

The brake system shall be arranged to remove traction power on all cars in a train simultaneously whenever the friction brake or the handbrake is applied on any car in a train. This function may be a part of, or receive its intelligence from, the Brake Status Light System previously described in Section 10.8.17. A sealed bypass switch shall be provided in the Operator's cab (Section 9.7.3) to permit moving the train in the event of a circuit malfunction.

10.8.21 Slip-Slide Valves

Valving shall be provided for each truck to be used to modulate brake cylinder pressure at the request of the wheel slip-slide detection system. If necessary to meet the fail-safe requirements of Section 10.5, valving shall be so arranged that upon receipt of a wheel slide indication that persists uninterrupted for a maximum period of 4.5 seconds, the valves will automatically restore brake cylinder pressure for the duration of the brake application. Timing of the valves shall be accomplished electrically and shall be independent of brake cylinder applied pressure. Valves shall be arranged so that they will function regardless of the amount of brake cylinder pressure at the time the wheel slip relay is actuated. Methods of combining these valves and pressure control valves may be used subject to approval by the Authority.

10.8.22 Truck-Mounted Brake System Components

Each brake caliper shall be supplied through a separate hose from the carbody. Hydraulic connections shall utilize self-sealing fittings, which shall permit quick disconnection and facilitate truck removal. No hydraulic or pneumatic service brake apparatus other than the brake cylinders shall be mounted on the truck.

All carbody-to-truck hoses shall have sufficient slack to accommodate the maximum rotation permitted by the truck design.

10.8.23 Accumulators

If a hydraulic brake system is furnished, separate accumulators shall be supplied for each truck. A pressure relief valve shall protect accumulators from pressure in excess of 2,500 psi. Each accumulator shall store enough fluid to produce, with the hydraulic pump shut down, five maximum service pressure station stops from 75 mph in normal revenue service including 20-second station dwells before the low pressure warning prevents restarting of the train. The five stops shall start with an accumulator pressure just above the cut-in point of the hydraulic pump. These five stops shall be made with slip control functioning and electrical brakes inoperative.

The system shall have the ability to monitor and annunciate loss of hydraulic pressure from the fluid system and loss of gas from the accumulator.

The loss of pressure shall be annunciated via white light conditions (see Section 10.8.17) in a manner analogous to that in which the main air reservoir pressure switch is used (see Section 10.10).

If the function of this first pressure switch can be adequately performed by a single pressure switch associated with the hydraulic pump, that arrangement is also acceptable.

When the second of these pressure switches opens it shall interrupt the feed from TL82 to the coil of the emergency relay and thereby initiate an emergency stop. Opening of the second switch shall also illuminate a blue light as described in Section 10.8.17.

The fluid and energy remaining in the hydraulic accumulators when the second switch transitions shall meet the same requirements as would be imposed by Section 10.10 relative to opening of the brake pipe pressure switch if pneumatically powered brakes were used.

Hydraulic accumulators shall meet the requirements of the ASME pressure vessel code and shall be tested in accordance with these requirements.

10.8.24 Hydraulic Pump

If a hydraulic brake system is furnished, a hydraulic pump shall supply hydraulic fluid under pressure to the accumulators on the car. The pump shall have sufficient capacity to meet all normal needs of the brake system, including full service pressure stops from 75 mph with friction brakes only and with continuous operation of the slip-slide system on rail providing an adhesion level of 5%. Cooling shall be supplied for the hydraulic fluid if the fluid temperature exceeds 190°F under any conditions.

10.8.25 Hydraulic System Filters

Hydraulic power units shall include adequate filtration to maintain a constant or decreasing system contamination level. System design must be compatible with level of filtration selected. All filters must be easily accessible and be of the disposable element type and have a service life compatible with other car equipment service intervals.

10.8.26 Hydraulic Fluid Requirements

If a hydraulic brake system is furnished, the hydraulic fluid supplied shall be of approved non-aqueous, fire-resistant composition that shall not be injurious to any of the elastomeric or other synthetic materials used on the car, to natural rubber or to any of the electrical insulation material used, or to any gaskets, seals, piping, materials or components within the hydraulic system.

10.8.27 Line Supports

All pipes, hoses and tubes shall be supported in such a manner as to minimize vibration and prevent rubbing and chafing, either between brake system components themselves or between such components and any part of the car.

Where pipes or tubes are required to run in close proximity to conductors carrying third rail, propulsion or braking currents, they shall be shielded from possible electric arc damage by being carried within metal conduit or by other means approved by the Authority.

10.8.28 Code Requirements for Hydraulic Brake System

The design and installation of all hydraulic brake system components shall conform with the latest revision of the Joint Industry Conference (JIC) Hydraulic Standards for Industrial Equipment, with the following specific modifications:

A. Mounting of pumps and relief valves inside accumulators will be permitted only when the pump assembly is readily removable for repair, inspection and replacement.

B. Return fluid shall not be required to have peripheral flow along the reservoir side wall unless such flow is absolutely necessary for adequate cooling of the fluid.

C. Filters shall be of the bypass type, and shall not restrict the return flow from the brake cylinders.

D. Couplings between hydraulic tubing and flexible hose shall be of the self-sealing type to prevent escape of fluid when disconnected.

10.8.29 <u>Friction Brake Tests</u>

The Contractor shall perform all tests required by Sections 10.8.29 to 10.8.32, using the first prototype production units.

10.8.29.1 Brake Rate Characteristics Test

A dynamometer test shall be performed at the facilities of the Contractor or its Subcontractor to evaluate the characteristics of the friction brake materials proposed for use on the cars. These tests shall demonstrate that the friction materials are capable of developing the friction brake rate characteristics under all operating conditions. Tests shall include but not be limited to combinations of new, seated, and fully worn brake pads, new and worn-in discs, hot and cold disc tests, and tests under wet and dry conditions. Evaluation of the materials shall be based on attaining consistent results under all of the preceding conditions and demonstration that the materials selected will provide or exceed the service life required under these conditions. Dynamometer tests shall also confirm that the maximum allowable disc temperature during simulated operation with the passenger loadings as described in Section 10.1.2 on the Silver Spring to Dupont Circle portion of the Red Line will not be exceeded when making the test using B4 all friction brake rates for all braking.

10.8.29.2 Brake System Performance Test

After delivery of the first production cars to the Authority by the Contractor, the friction brake system shall be subjected to the performance tests required to demonstrate that the system complies with all of the requirements of Sections 10. Performance testing is to be run in conjunction with the tests required in Sections 1.8. Successful completion of all of the preceding tests and acceptance of the test results by the Authority will be required for final approval of the friction brake system by the Authority.

10.8.29.3 Brake System Functional Test

The Contractor shall perform a complete functional test of the friction brake system prior to shipment of each pair of cars from its plant. Tests shall include, as a minimum, check of command and load weigh signals, brake cylinder pressure settings, control and indicator checks, and leakage tests.

10.8.29.4 Handbrake Test

The handbrake on each car shall be tested. On the first car, a test of the adequacy of the design shall be made (using first new, and then fully worn, brake shoes) by measuring, with a scale, the force needed to move the car with the handbrake applied. On the remaining cars a functional test shall be performed with new shoes.

10.8.30 <u>Brake Unit Fatigue Test</u>

A test set-up shall be arranged such that a brake unit (one disc and caliper assembly) is exposed as nearly as possible to the same conditions it would encounter in service, particularly with regard to shoe force and force developed by braking torque in each direction. It shall be subjected to one million cycles of the working loads predicted, which shall have the approval of the Authority. This test shall be performed on both air and hydraulic brake units as applicable, prior to installation on the car.

10.8.31 <u>Brake System Endurance Test</u>

Prior to delivery of the sixth married pair of cars, a complete production friction brake system shall be assembled before mounting on the car and shall be subjected to an endurance test of one-half million cycles of normal applications and releases to demonstrate that the control apparatus has the endurance required for rail transit service. The system will not be considered acceptable until the test has been performed without component failure of any kind. Testing will not be required on components that can be shown to have had satisfactory service experience of comparable severity and duration.

10.8.32 Braking System Capacity Test

The first production brake disc and caliper assembly shall be dynamometer or flywheel tested to verify that the design can perform the specified operation over the Authority profile. The production brake shoe material shall be used and temperature limits specified in Section 10.1.2 shall not be exceeded. The test program shall be submitted to the Authority and their approval shall be required before the test is begun.

10.8.33 System Test

The first production system shall be completely assembled prior to installation on the car and pressure tested to verify the strength and quality of all pressure parts. If a hydraulic system is used, the system shall successfully pass a test applying 300% of maximum system pressure for 5 minutes in the presence of the Authority or their authorized representative. If a pneumatic system is used, the test pressure to be used for this test shall be 225 psi. After assembly on the car, a hydraulic system shall test successfully at 150% of normal working pressure and a pneumatic system at maximum normal working pressure. Neither damage to equipment nor creation of leaks shall result from either test.

10.8.34 Submission of Test Data

Copies of all test data shall be submitted to the Authority and shall include copies of all original records for each test. Recordings of brake cylinder pressure, braking effort and input signals shall clearly show zero and one hundred percent of the recorded traces, and those values shall be defined. Recordings from the braking disc capacity test shall include braking torque, temperature at braking surface, speed and brake cylinder pressure. Recorded values shall be coordinated to permit correlation of instantaneous values and shall show clearly run and dwell times for the total test.

10.8.35 Friction Disc and Pad Service Lives

Brake discs and pads containing no asbestos materials shall have service lives equal to or exceeding the following values:

A. With all braking by friction brakes: brake discs 30,000 miles; brake pads 1,500 miles.

B. With normal electrical plus friction braking: brake discs 150,000 miles; brake pads 25,000 miles.

These service lives shall be demonstrated by dynamometer test based on no-coast round trips between Metro terminal pairs, Addison Road and Huntington, Grosvenor and Silver Spring, and Ballston and New Carrollton, stopping at all stations and observing all speed restrictions with a full (100 passengers) load for each inbound trip (terminal to CBD) and a normal (81 passengers) load for each outbound trip (CBD to other terminal), with dynamic brakes inoperative, with accelerations at P5, and all braking at B4.

10.8.36 Maintenance Interval

All brake system pneumatic or hydraulic equipment shall be designed such that overhaul is required no more frequently than at 5-year intervals.

10.8.37 Vehicle Monitoring System (VMS) Interface

The input and output signals from each critical friction brake system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

10.9 HANDBRAKE

10.9.1 Performance

A mechanical handbrake shall be provided which, when operated together with its associated apparatus including connecting rods, chains, cables, sheaves, levers, brake shoes and wheels, or discs and pads (depending on the configuration used) will be able to hold a crush-loaded car on a 5% grade when an actuating force of 50 pounds is applied 3 inches from the end of the hand lever. The arrangement of the mechanical handbrake and associated apparatus shall permit the specified effect to be attained under the condition of fully worn brake shoes or brake pads and fully worn wheels or discs with reserve travel remaining in the apparatus.

10.9.2 Mounting

The handbrake shall be mounted in the equipment locker at the “F” end of the car. All connecting linkages and operating parts above car floor shall be housed in the locker. It shall be recessed to prevent passenger and mechanical interference and shall provide a minimum of 4 inches of hand clearance in all positions of the lever except at the stored position where a minimum of 2 inches of hand clearance shall be provided.

10.9.3 Design

The handbrake shall apply brakes to both axles on the front truck.

A friction catch shall be provided to hold the handbrake lever in the stored position. A stainless steel or aluminum guard shall be provided over exposed connecting linkages and operating parts above the car floor. An electrical signal shall be provided to indicate positively when the handbrake is applied and released. An electrical interlock shall be provided to prevent the application of traction power if the handbrake is not fully released. Provisions shall be made to positively prevent force beyond design limits from being applied to the brake connecting linkage.

10.10 AIR COMPRESSOR

10.10.1 Compressor

The air compressor shall be located on the “A” Car and shall be direct driven by a totally enclosed, fan-cooled, 230 VAC 3-phase motor of approved design, furnished complete with suspension frame. The suspension frame shall pass under the compressor and motor and shall be so designed as to remain safely supported in the event of failure of suspension bolts or resilient mounting. All parts of the compressor shall be designed to produce a minimum noise level. The compressor shall be capable of quiet and safe operation at all third rail voltages specified in Section 2.2, and shall be designed to be capable of operating continuously at maximum capacity or under short cycle conditions. The compressor shall use an approved lubricating oil as specified by the compressor manufacturer. The compressor unit shall be arranged for suitable mounting under the carbody, and in such a manner as not to conduct noise or vibration into the car, and to permit interchangeability between cars.

With either a pneumatic or hydraulic friction braking system, the compressor shall produce compressed air for operation of the braking system, propulsion system (if required), suspension system, couplers, and horns and similar accessories. The capacity of the compressor shall be sufficient to supply all compressed air requirements on a train composed of two pairs of cars with the compressor on the other pair inoperative. In no case shall the delivery be less than 22 cubic feet per minute at a pressure of 150 lbs. psi.

If not fully enclosed, the compressor motor shall be equipped with an impingement-type filter that will prevent entrance of dirt and snow.

10.10.2 Bearings

Compressor and compressor motor shafts shall be equipped with anti-friction bearings of the sealed lubrication type. Grease cavities shall contain sufficient lubricant to allow operation for three years without re-lubrication. The compressor may be designed to use crankcase oil for lubrication of crank shaft bearings.

10.10.3 Cooling and Drying System

The cooling system shall consist of a fin-pipe cooling unit included in the compressor unit and arranged to drain by gravity into the sump reservoir, which shall be included in the compressor unit. Temperature of air at the exit from the compressor shall not be more than 10°F above ambient. The sump reservoir shall be equipped with a heated, automatically timed, electrically piloted drain valve, which shall operate at the end of each period of air compressor operation. The drain valve shall not incorporate any materials subject to corrosion.

Heaters shall be provided in the automatic drain valves specified herein; these heaters shall operate from the 37.5 VDC supply. Protective heaters shall be controlled by an outside thermostat set at 40°F. Protection for the 37.5 VDC and high-voltage heaters shall be provided by circuit breakers in the Operator's circuit breaker panel and the auxiliary power breaker panel, respectively.

10.10.4 Filter Dryer

Air for all systems shall be filtered by means of a high-efficiency, self-purging desiccant filter dryer with a thermostatically controlled, heated, automatically timed, electrically piloted, solenoid drain valve. The desiccant shall not require replacement more often than once a year. To ensure that air system moisture levels are tolerable, the proposed filter dryer system shall be demonstrated to the Authority by an approved test procedure.

The efficiency of the air dryer system in eliminating moisture in air piping, reservoirs, and pneumatic components shall be demonstrated by a procedure which must be submitted to the Authority for approval.

10.11 LOW PRESSURE CUT-OUT

MOD 3 A pressure switch shall be provided on the main air reservoir and shall be used together with an indication of the presence of auxiliary power voltage to detect apparent failure of the air supply. When such failure is detected, the white light of Section 10.8.17 shall be illuminated and the trainline brakes-applied indication shall not be given, thus forcing key-out prior to release of brakes following the next station stop as also described in Section 10.8.17). This is not intended to require key-out of a train composed of more than one pair of cars if compressors on other cars are able to supply air to the afflicted pair through the brake pipe.

In the event of a further drop in pressure, the brake pipe pressure switch will cause power to be removed and brakes to be applied immediately, even if a station stop has not been made.

In the case of a car with pneumatically energized brakes, the air stored in the supply reservoir(s) when the supply pressure is the same as the pressure at which the brake pipe pressure switch opens shall be adequate for five complete all-friction brake station stops from 75 mph with poor adhesion and slide control functioning and shall satisfy the brake holding time requirement of Section 10.8.1.

SECTION 11
AUTOMATIC TRAIN CONTROL

TABLE OF CONTENTS

Section **Page**

Section **Page**

SECTION 11
AUTOMATIC TRAIN CONTROL

11.1 GENERAL REQUIREMENTS

The Contractor shall provide or procure from a single supplier, as an integrated system, all of the ATC equipment required by this Contract. All of the requirements of this section (Section 11) as well as the applicable requirements of the rest of the Contract shall be passed on to any such supplier. The ATC will be fully compatible with the Authority's existing infrastructure, system interfaces, and operational and maintenance practices. The Contractor shall provide for the monitoring of certain system signals and storing them in a data acquisition module (DAM) as specified in Section 11.2.8.

11.1.1 Design

The design of vital circuits shall be in accordance with accepted signal system design practices and applicable sections of the AAR Signal Manual recommendations or approved equivalent, and shall comply with the fail-safe design requirements specified in Section 1.11.4.

Synchronous logic shall be used for all digital logic circuits. Where unsynchronized signals are applied to digital logic circuits, they shall be synchronized with the logic clock at the point of entry.

All inputs and outputs of the ATC system which connect to digital logic and other low energy level circuits, shall be isolated with noise rejection circuitry.

11.1.2 Design Reporting

The Contractor shall submit a conceptual design description for approval, per Section 1.4.2.1. This design description shall describe the concepts to be used for all functions of the ATC equipment and all interfaces to the Authority's existing system and the rest of the car subsystems.

Preliminary design descriptions for each of the ATC subsystems and for the complete system shall be included in the conceptual design description and shall be submitted for approval. These design descriptions shall identify the source of all pertinent design information, assumptions made, and tests planned to verify the adequacy of the design as well as providing a clear understanding of the design.

Final design reports shall be submitted for approval after design verification tests are concluded and any required design changes are incorporated. The final design reports shall be full and complete reports of the design including all development, verification and safety test reports and the results of all final analyses conducted such as reliability, safety and maintainability. The final design reports shall also include sufficient manufacturing drawings to identify the configuration to the component level. The approved final design reports shall serve as a production baseline.

11.1.3 Testing

The Contractor shall perform all tests in accordance with the requirements of Section 11.4.

11.1.4 Manufacturing

The ATC system shall be manufactured in accordance with the schedule required by the car manufacturing plan.

Quality assurance during the manufacturing process shall be in accordance with the requirements of Section 1.7.

Materials and workmanship used in the manufacturing process shall be in accordance with the applicable requirements of Section 15.

The ATC system shall be manufactured in accordance with the approved drawings and procedures which serve as the production baseline. Changes from the production baseline shall not be made without prior approval of the Authority.

11.1.5 Packaging of Equipment

A modular design, oriented to maintenance efficiency, shall be used throughout the ATC system. Electrical and mechanical components shall be organized in plug-in assemblies and shall be rack-mounted. Rack-mounted equipment shall be hinged on one side (or otherwise constructed) so as to facilitate access to the rack wiring. The mixing of equipment associated with two subsystems in one plug-in assembly will not be acceptable.

11.1.6 Component Protection

Components shall be protected from damage in the event a plug connector or plug-in unit is removed while equipment is energized. As an alternative, a power disconnect switch with warning decal may be located in plain view in close proximity to the plug-in unit.

11.1.7 Adjustments

Adjustable components shall be avoided wherever possible by the use of appropriate circuitry, stable components, and high-tolerance circuits. Adjustable components, useful during design development to determine experimentally the correct operation settings, shall be eliminated in the final design. Adjustable components, where required, shall have locking devices or shall be self-locking to prevent inadvertent operation and/or drift. Whenever practical, two or more points of adjustment which are required during the same tune-up operation, shall be located within 12 inches of each other and in such a way that they can be operated by one man. Interacting adjustments shall be avoided. The replacement of a component or PC card with a spare shall not require compensating adjustments to the associated components or modules. If the compensating adjustments are required, they shall be limited to the device to be replaced or repaired.

11.1.8 Test Points

Test points for checking essential voltages and wave forms and for injecting test signals shall be provided for troubleshooting and routine maintenance. Selected test points shall be provided to detect defective PC boards and equipment modules without the disconnection of wires. All test points shall be readily accessible when the equipment is in the normal operating position or, in the case of printed circuit boards, when the board is on an extender board provided by the Contractor. All test points shall be clearly labeled. Test points shall be capable of accepting probes and connectors used with standard test equipment such as voltmeters and oscilloscopes, except where only special test equipment and connectors supplied by the Contractor will serve.

11.2 DESIGN REQUIREMENTS

Each pair of cars shall be equipped with an Automatic Train Control (ATC) system as specified herein and as shown on the Contract Drawings. The ATC system shall be compatible with the existing Authority ATC system and shall permit satisfactory ATC operation at all revenue service operating speeds. The ATC system shall consist of three major subsystems as follows:

A. Automatic Train Protection (ATP)
B. Automatic Train Operation (ATO)
C. Automatic Train Supervision (ATS)

The ATC system shall also contain built-in monitoring and test facilities as specified herein and all other appurtenances required to produce a complete, safe, reliable and operational system.

11.2.1 Automatic Train Protection (ATP)

The ATP equipment shall be organized to perform the following functions:

A. Receive and decode the speed limit and door control commands
B. Measure train speed and compare it to the speed limit
C. Control the door operations and check door position
D. Apply full service braking in the event of overspeed or system failures that affect safety.

The ATP system shall be fail-safe and shall meet the reliability and fail-safe requirements set forth in Sections 1.9 and 1.11.4, respectively.

The ATP system shall have the capacity to receive and decode 12 commands from the front of the train and two commands from the back of the train.

Command	Carrier Frequency*	Code Rate	Frequency (Hz)**
15 mph	4,550 Hz (F1)	Code Rate 2	4.5 Hz
22 mph	4,550 Hz (F1)	Code Rate 3	6.8 Hz
28 mph	4,550 Hz (F1)	Code Rate 4	10.1 Hz
35 mph	4,550 Hz (F1)	Code Rate 5	15.3 Hz
40 mph	4,550 Hz (F1)	Code Rate 6	21.5 Hz
45 mph	5,525 Hz (F2)	Code Rate 2	4.5 Hz
50 mph	5,525 Hz (F2)	Code Rate 3	6.8 Hz
55 mph	5,525 Hz (F2)	Code Rate 4	10.1 Hz
65 mph	5,525 Hz (F2)	Code Rate 5	15.3 Hz
75 mph	5,525 Hz (F2)	Code Rate 6	21.5 Hz
Open Right Side Doors	5,525 Hz (F2)	Code Rate 1	3.0 Hz
Open Left Side Doors	4,550 Hz (F1)	Code Rate 1	3.0 Hz

* The tolerance of these carrier frequencies will be ± 0.5%.
** The tolerance of these code rate frequencies will be ± 5%.

Absence of an ATP command shall be interpreted by the equipment to mean “STOP” when operating in the Automatic mode, and “STOP AND PROCEED AT 15 MPH” when operating in the Manual mode.

A block diagram of the ATP system is presented on Contract Drawing 97936-021.

11.2.1.1 Reception and Decoding

ATP command reception shall be accomplished through two coils mounted on the cab end of each car. The Contractor shall rigidly mount the coils to the carbody located as shown on Contract Drawing 97936-025.

The coils on both the “A” car and the “B” car shall be monitored by the ATC equipment on the “A” car. Fail-safe transfer relays shall be included to switch the coil inputs to the reception circuits, as shown on Contract Drawings 97936-024 and 97936-021. The coils shall not be connected to the speed command reception circuits during backup moves.

11.2.1.1.1 *Receivers*

Two receivers shall be provided on each “A” car. One receiver, hereafter referred to as the front-end receiver, shall receive and demodulate the ATP signals presented to the front of the train while the second receiver, hereafter referred to as the back-end receiver, shall receive and demodulate the ATP signals presented to the back of the train.

A. The front-end receiver shall meet the following specifications:

1. Dynamic range of input: 30 dB minimum

2. Sensitivity: 90 mA rail current minimum
6.0 A rail current maximum

3. Selectivity: Selectivity at 4,550 Hz:
a) at -25 dB, +90 Hz through 160 Hz from carrier frequency
b) at -60 dB, +325 Hz through 350 Hz from carrier frequency

Selectivity at 5,225 Hz:
a) at -25 dB, +115 Hz through 190 Hz from carrier frequency
b) at -60 dB, +395 Hz through 425 Hz from carrier frequency

4. Outputs: a) Fail-safe drive to vital relay when coded carrier frequency F1 is received
b) Fail-safe drive to vital relay when coded carrier frequency F2 is received
c) Pole-changed energy drive to the code rate detectors at the code rate carried by F1 and F2

B. The back-end receiver shall meet the following specifications:

1. Dynamic range of input: 20 dB minimum

2. Sensitivity: 90 mA rail current minimum
6.0 A rail current maximum

3. Selectivity: Selectivity at 4,550 Hz:
a) at -25 dB, +90 Hz through 160 Hz from carrier frequency
b) at -60 dB, +325 Hz through 350 Hz from carrier frequency

Selectivity at 5,225 Hz:
a) at -25 dB, +115 Hz through 190 Hz from carrier frequency
b) at -60 dB, +395 Hz through 425 Hz from carrier frequency

4. Outputs: Pole-changed energy drive to the code rate detectors at the code rate carried by F1 and F2

Refer to Section 11.2.1.3 for the use of the signals from the back of the train.

The code output of the front-end receiver shall be monitored by six code-rate detectors, each of which shall drive a vital relay when its associated code rate is present.

11.2.1.1.2 ***Timing Coordination***

Timing shall be such that a change to a more restrictive speed command is detected in less than 2 seconds under any condition, including failure conditions of a more restrictive speed command generator or decoder. The timing of the output drive to the F1 and F2 relays shall be coordinated between F1 and F2 and between the F1 and F2 drives and the output of the code rate detectors such that transition from any speed command to any other speed command will not result in a false or unrecognized speed command for more than 0.6 seconds. Further, false speed commands occurring during transition from one command to another shall not be more permissive than the more permissive of the commands causing the transition, e.g., a change from 50 mph to 35 mph shall not result in a temporary false command higher than 50 mph. The time required to detect an overspeed condition and open the front contacts of the vital relay shall be less than 0.75 second under any condition.

In the case of transitions between door-open commands and speed commands, temporary false commands shall never be door-open commands. To assist in this coordination, the wayside circuitry will always remove the speed commands a minimum of 2 seconds prior to applying the door-open commands. The change from a door-open command to a speed command can be instantaneous.

Timing coordination shall not compromise the safety of any portion of the reception and decoding equipment.

11.2.1.1.3 *Code-Rate Detectors*

Code-rate detectors shall be inherently fail-safe and shall not require the use of check circuits to ensure their integrity. The design shall be such that under normal or failure mode conditions the output relay current shall not exceed 75% of the minimum release (drop-away) value with no signal applied or with a more restrictive signal applied at its maximum level.

Code-rate detectors shall require at least two complete cycles of the designated code rate to produce sufficient output current to energize the output relay.

11.2.1.1.4 *Decoding Requirements*

The contacts of the six code-rate relays and the two carrier relays driven from the front-end receiver shall be fanned to decode the command. The decoding fans shall be such that the most restrictive command has priority. The command decoding fans shall output to the following:

A. Speed selection circuits for overspeed protection
B. Speed selection circuits for automatic speed regulation
C. Automatic door control (not a full fan)
D. Limiting speed indicators on the control consoles (need not be direct)
E. Brake interface.

11.2.1.2 Overspeed Protection

Overspeed protection shall be provided by a self-checking measurement unit that compares the speed selected by the command decoding fan, in connection with the automatic-manual circuits to the actual train speed. Actual train speed shall be derived from a speed sensor monitoring the rotation of a gear in a gear unit. Wheel-wear compensation shall be provided in discrete steps to correct for variations in wheel diameter on the axle monitored by the ATP sensor. Overspeed protection shall be verified by comparing a second speed sensor signal with the ATP speed sensor signal.

11.2.1.2.1 *Speed Sensors*

Speed sensors as specified in Section 10.4.11 shall monitor the rotation of a gear in the traction motor gear unit. The shape of the gear teeth monitored, the gear material, the gap setting between the sensor and the gear, and the ATC circuitry shall be such that continuous speed detection exists between 3 mph and 80 mph.

The sensor used for overspeed protection shall not be used for any purpose other than ATP. The self-checking feature of the speed measurement system shall also ensure that the speed sensor is both electrically and mechanically intact. Protection shall also be provided against sensing errors due to gear rotation that is not in conformance with actual car speed.

11.2.1.2.2 *Speed Measurement and Safety Precautions*

A motion-detection circuit shall be provided to energize a motion-detection relay when gear rotation is sensed by the speed sensor.

The motion-detection relay shall be used in conjunction with the necessary logic to provide rollback detection and to continuously prove the speed sensor dynamic response and the mechanical adjustment. Rollback detection shall function to detect rollback and brake the train to a stop without the train moving more than 50 feet, in Automatic mode only.

The speed measurement unit shall energize a vital relay to indicate that the actual train speed is less than the limiting speed and that the unit is operating properly. In the event of a failure, or if the actual train speed exceeds the speed limit, this vital relay shall become de-energized.

11.2.1.2.3 *Speed Enforcement*

When the train is in the Automatic Train Operation mode, an overspeed condition detected by the Overspeed Protection system shall result in the removal of all calls for positive tractive effort and shall initiate a Full Service brake application. The Full Service brake application shall be enforced until the overspeed condition no longer exists.

When the train is in the Manual-Operation-With-Protection mode, an overspeed condition detected by the Overspeed Protection system shall result in the removal of all calls for positive tractive effort and shall initiate a Full Service brake application. An overspeed warning in the cab shall also be sounded and shall persist until the Operator places the Master Controller into the Full Service brake position. The Full Service brake application shall be enforced until the overspeed condition no longer exists and the Operator has placed the Master Controller in the Full Service brake position. When the train is in the Manual-Operation-With-ATP-Cutout mode, no action shall be taken by the ATC system as a result of an overspeed condition.

The Overspeed Protection System shall also include “Zero” Speed detection circuitry. The train shall be indicated as being at Zero Speed when the speed is being detected, in a fail-safe manner, to be below 1 mph.

The overspeed alarm shall be functionally compatible with existing Authority cars.

11.2.1.2.4 *Daily Safety Test Provisions*

Equipment and circuitry shall be included to facilitate testing of the Overspeed Protection system during the daily test required with the integrated “on-board” Daily Safety Test (DST) circuitry.

A separate test winding shall be incorporated in the ATP receiving coils to facilitate injection of the ATP signals generated by the DST circuitry. As an alternate, separate coils may be permanently mounted such that the test signals are inductively coupled to both ATP receiving coils on each car. In either case, the test windings or test coils shall not be energized through the same cable used by the operating system.

The ATP signal level produced by the test unit and the coupling to the ATP receiving coils shall be such that the signal presented to the ATP reception and decoding equipment, with both ATP receiving coils functioning properly, simulates the reception of 80 to 100 mA of rail current.

The speed sensor simulator output from the test unit shall be presented to the speed sensor inputs of the overspeed protection and speed regulation equipment through suitable isolation circuitry and test relay contacts. The resultant signal level applied to the overspeed protection and speed regulation equipment shall equal the normal operating signal level, ± 5%.

11.2.1.2.5 *Daily Safety Testing Process*

Integrated "on-board" DST circuitry shall be provided. The features and systems tested shall be, as a minimum, consistent with the Authority's existing DST procedures. Any additional features and systems proposed by the Contractor shall be subject to Authority approval. The test circuitry shall operate automatically after initiation via a keyed switch and shall also be capable of manual step by step operation. Successful completion of the DST test shall be visually indicated. The date and time of the latest successful DST test shall be stored in memory for retrieval via a convenient means by maintenance or engineering personnel.

11.2.1.2.6 *Interface to Car System*

The interfaces to other car systems shall be in the form of vital relay contacts to control the energization of trainline wires.

11.2.1.3 Door Control

Door control circuits shall be provided in the ATP system to cause automatic opening and closing of the train doors on the platform side in accordance with: ATP commands from the wayside; selected direction of movement of the "A" car; on-board safety checks; and the position of the Manual Door Control Mode Selection switch described in Exhibit 9-1.

Signals received by the front-end receiver of the train shall determine on which side of the train the platform is located, and shall also prove that the frontmost side door of the train is within the platform limits. The signal received by the back-end receiver of the train shall prove that the rearmost side door of the train is within the platform limits. MOD 3

The output of the back-end receiver shall be decoded to detect the presence of Code Rate 1 (3.0 Hz). The presence of this rate shall cause energy to be applied to trainline wires at the back of the train as shown on Contract Drawing 97936-024. Door control circuits in the controlling "A" car shall monitor these trainline wires to provide back-end status as shown on Contract Drawing 97936-020.

A cycle check system is provided in the passenger stations via the Train-to-Wayside Communication (TWC) System, which shall be used to confirm that the train is located in a passenger station before the doors can be operated. This cycle check shall cause a vital signal in the door control logic to be generated to permit the doors to be operated if all other required conditions are being met. Refer to Contract Drawing 97936-020.

A momentary door-open signal shall be applied to the trainline wires that control the doors when <u>all</u> of the following conditions exist:

A. The Door Control Mode Selector switch in the controlling cab is in a position permitting automatic opening of doors

B. The door control buttons in the controlling cab are not depressed

C. The ATP Zero Speed detector relay is energized

D. The Program Stop System is indicating the completion of a stop (Train Berthed)

E. The Passenger Station Check via the TWC is complete

F. A door-control command is being received by the back-end receiver on the last married pair

G. The fail-safe direction monitoring circuit on the front (controlling) married pair is indicating that a direction of movement is selected

H. A door control command is being received by the front-end receiver on the controlling married pair

I. "Brake Applied" relay is energized.

The door-open signal generated per conditions A through I above shall be applied to the trainline wires controlling the doors on the console side of the controlling "A" car under either of the following conditions:

A. The fail-safe direction monitoring circuit of the controlling married pair indicates that the "A" car is conditioned for forward movement and the Open-Right-Doors command is being received by the front-end receiver of the controlling married pair.

B. The fail-safe direction monitoring circuit of the controlling married pair indicates that the "A" car is conditioned for reverse movement and the Open-Left-Doors command is being received by the front-end receiver of the controlling married pair.

The door-open signal generated per conditions A through I above shall be applied to the trainline wires controlling the doors on the non-console side of the controlling "A" car under either of the following conditions:

A. The fail-safe direction monitoring circuit of the controlling married pair indicates that the "A" car is conditioned for forward movement and the Open-Left-Doors command is being received by the front-end receiver of the controlling married pair.

B. The fail-safe direction monitoring circuit of the controlling married pair indicates that the "A" car is conditioned for reverse movement and the Open-Right-Doors command is being received by the front-end receiver of the controlling married pair.

A momentary door-close signal having a duration of 0.2 seconds to 0.75 seconds shall be applied to the trainline wires controlling the doors on the side that was last commanded open when the following conditions exist:

A. The door control selector switch in the controlling cab is in a position permitting automatic closing of doors

B. The door control buttons in the controlling cab are not depressed

C. Loss of:

   1. The Train Berthed indication; or
   2. The door control command at the front end.

An additional momentary door-close signal having a duration of 0.2 seconds to 0.75 seconds shall be applied to the trainline wires that control the doors on both sides once motion is detected.

Each time the ATC System generates a door-close signal, positive battery energy shall be applied to the Motor Overload Reset trainline wires for the duration of the door-close signal. Interfaces to the other car circuits shall allow complete manual override of the ATC door controls.

The ATC System shall be interfaced to the door interlock circuit such that a Full Service Brake application will be enforced by the ATC system when any side door on the train is not fully closed and locked.

Operation of the Door/Traction Interlock By-Pass switch to the "BYPASS" Position shall inhibit ATO operation and the ATC system control of doors.

11.2.1.4 Automatic-Manual Circuits

An automatic-manual circuit shall be provided to condition the ATC System for the proper mode of operation by the positioning of the manually-operated controls described in Exhibit 9-1. This circuit shall condition the ATC System for Automatic Train Operation when all of the following conditions exist:

A. The MASTER CONTROLLER in both cabs is in the AUTO/STORE position

B. The CONTROL LOCK in only one of the cabs is in the ON position (this shall determine the control cab)

C. The MODE-DIRECTION switch in the control cab is in the AUTO/STORE position

D. ATP speed commands are being received and coded

E. Zero Speed is detected

F. Brake Applied relay is energized.

When the ATC System is conditioned for Automatic Train Operation, the AUTOMATIC indicator on the Operator's control console shall be energized.

Once conditioned for Automatic Train Operation, the ATC System shall remain in that mode of operation until any of the following conditions exist:

A. The MASTER CONTROLLER is no longer in the AUTO/STORE position

B. The CONTROL LOCK is no longer in the ON position

C. The MODE-DIRECTION switch is no longer in the AUTO/STORE position; or

D. A rollback condition is detected.

The automatic-manual circuit shall condition the ATC system for Manual Operation with Overspeed Protection mode when all of the following conditions exist:

A. The CONTROL LOCK in only one of the cabs is in the ON position (this shall determine the control cab)

B. The MODE-DIRECTION switch in the control cab is in the MAN/FWD position

C. Zero speed is detected.

When the ATC System is conditioned for Manual Operation with Overspeed Protection, the MANUAL Indicator on the Operator's control console shall be energized. A MANUAL Indicator shall also be provided on the exterior of both the "A" and "B" cars. The indicator light shall be blue in color and located on the side of the car over the right rear window, consistent with the Authority's existing 1000 Series cars. The exterior indicator energization shall duplicate that of the control console MANUAL indicator.

Once conditioned for Manual Operation With Overspeed Protection mode, the ATC System shall remain in that mode of operation until any of the following conditions exist:

A. The CONTROL LOCK is no longer in the ON position

B. The MODE-DIRECTION switch is no longer in the MAN/FWD position; or

C. The ATP CUTOUT switch is actuated.

The automatic-manual circuits shall condition the ATC system to permit manual operation at speeds up to 15 mph after stopping while the system is conditioned for manual operation and no ATP speed command is being received. This mode of operation shall be termed Stop and Proceed and shall become effective when all the following conditions exist:

A. The ATC System is conditioned for Manual Operation with Overspeed Protection

B. The MASTER CONTROLLER in the controlling cab is in the Full Service Brake or Maximum Service Brake position

C. Zero Speed is detected

D. No ATP speed command is being received.

Once conditioned for Stop and Proceed, the ATC system shall remain in that mode until any of the following conditions exist:

A. An overspeed condition is detected (actual train speed exceeds 15 mph)

B. An ATP speed command is received; or

C. The system is no longer conditioned for Manual Operation with Overspeed Protection.

All ATP control shall be bypassed when the ATP CUTOUT switch is activated while the MODE-DIRECTION switch is in a manual position and a B4 or B5 brake application is applied. Once the ATC system is in the ATP cutout mode, it shall remain in that mode until the MODE-DIRECTION switch is returned to the AUTO/STORE position or the CONTROL LOCK is no longer ON.

When the ATC system is in the ATP cutout mode, the ATP CUTOUT indicator on the Operator's control console shall be energized. An ATP Cutout Indicator shall also be provided on the exterior of both the "A" and "B" cars. The indicator light shall be amber in color and located on the side of the car over the right rear window, consistent with the Authority's existing 1000 Series cars. The indicator shall be energized whenever the ATP system is placed in the cutout mode and remain illuminated even when the ATP function is restored, until the indicator is manually reset at the ATP apparatus. A manual reset switch shall be provided at an approved location at the ATP apparatus.

If the ATC system is not conditioned for one of the operating modes described above, a Full Service Brake application shall be enforced.

11.2.1.5 Braking Interface

A braking interface shall be provided to initiate and enforce Safety Brake applications. Safety (Full Service) brake applications shall be initiated by any of the following:

A. Loss of speed command reception
B. Overspeed condition
C. Change in automatic-manual status
D. Actuation of the ATO STOP button while in the Automatic Train Operation mode
E. Actuation of the Emergency Braking System
F. Loss of door check signal.

In the Automatic Train Operation mode, Full Service brake applications, initiated by loss of speed command reception, shall be enforced until speed command reception is resumed. In the Manual Operation With Overspeed Protection mode, Full Service brake applications initiated by loss of speed command reception shall be enforced until speed command reception is resumed and the Master Controller is placed in the Full Service brake (B4) position or the ATC System is conditioned for Stop and Proceed.

Full Service brake applications initiated by Overspeed Protection shall be enforced as specified in Section 11.2.1.2.3.

Full Service brake applications initiated by the Automatic-Manual circuits shall be enforced until the ATC System is once again conditioned for an operating mode and the ATO START button is actuated if the operating mode is Automatic Train Operation.

Full Service brake applications initiated by actuation of the ATO STOP button or the Emergency Braking System shall be enforced until the initiating condition no longer exists, Zero Speed is detected, and the ATO START button is actuated.

When actuation of the ATO START button is required to initiate brake release, such as after transfer to automatic operation or after actuation of the ATO STOP button, the ATO START indicator on the Operator's control console shall be energized.

The ATP interface to the brake control trainline wires shall be through vital relay contacts.

11.2.1.6 Microprocessor-Based ATP System

The Contractor may propose, as an alternative to the vital relay based ATP System, a microprocessor-based ATP System. The microprocessor-based ATP System shall provide the same functionality as the specified vital relay based ATP System, including but not limited to those functions identified in the specification as being performed by vital relays and fail-safe circuits. The microprocessor-based ATP System shall use service-proven fail-safe design methods to implement all vital functions.

All requirements specified for the vital relay based ATP System and the Automatic Train Control System shall pertain to the microprocessor-based ATP System.

The Contractor shall submit fully detailed explanations:

1. Method by which vitality is ensured in the system. With this explanation, the Contractor shall explain its understanding of the concepts "vital and fail-safe," and its methods of quantifying the hazard rate.

2. Method by which the hardware and software was certified as meeting the specified vital and fail-safe requirements.

3. Method by which diagnostic requirements of the specification are implemented.

4. Method by which the maintenance requirements of the specification are implemented. This explanation shall describe the features of the proposed maintenance program.

5. Provisions made for repairing the printed circuit boards which comprise the microprocessor-based ATP System and for maintaining the software to the latest revisions.

These explanations shall be sufficiently detailed for the Authority to determine whether or not the microprocessor-based ATP System will fail only in a safe manner and whether the diagnostics are capable of detecting these failures.

The Contractor shall provide the microprocessor-based ATP System hardware configuration, software and source code, drawings and documentation, and other technical information, under a non-disclosure agreement, to permit the Authority or an Authority contractor to conduct a safety analysis of the microprocessor-based ATP System.

11.2.2 <u>Automatic Train Operation (ATO)</u>

An Automatic Train Operation (ATO) subsystem shall be provided to perform the functions of automatic speed regulation and program station stopping.

The speed measurement, comparison, and computation logic required to perform the function of this subsystem shall be performed through the use of digital circuitry, fixed wired or programmable. Solid state controls shall be used instead of electromagnetic relays. Alternative circuits may be presented for approval by the Authority provided that they assure full compatibility with the Authority's existing cars.

11.2.2.1 Automatic Speed Regulation

The automatic speed regulation equipment shall use solid-state digital logic circuits for speed measurement, speed comparison, and cab display drives.

11.2.2.1.1 *Speed Sensing*

The ATO speed sensor shall be identical to the ATP speed sensor and shall be installed identical to the ATP speed sensor installation. Refer to Section 10.4.11 for locations of speed sensors.

11.2.2.1.2 *Speed Measurement*

Wheel wear adjustment shall be provided to compensate for wear of the wheels on the axle monitored by the ATO speed sensor. Adjustment shall be accomplished by means of a lap top computer or a multi-positioned switch. If a multi-positioned switch is used, a permanent label clearly showing the wheel size range for which each numbered position compensates shall be provided and affixed to a readily visible surface near the switch. Sufficient steps shall be provided for wheel wear compensation to provide an overall speed measurement accuracy of ±1% from 25 mph to 75 mph and ±0.25 mph below 25 mph.

The length of the sample time and the system configuration shall be such that the response time from recognition of ATP command change to trainline energization for the proper vehicle response shall be 1 second maximum.

There shall be an adjustable time between consecutive sample times to provide adjustable response time of the automatic speed regulator. This adjustment shall not degrade the accuracy of the sample time and shall either be a hard-wired adjustment or programmed into logic memory.

Electronic storage shall be provided for the Train Speed Indicator. This storage shall be updated from the counter at the end of each sample time. Circuits associated with the Train Speed Indicator drive shall operate to drive the display in 1-mph increments from 0 mph to 79 mph. The Automatic Speed Regulator shall include converters and drivers to convert the counter storage output to lamp-drive energy for the seven-segment displays as described in Section 9.7, Exhibit 9-1.

11.2.2.1.3 *Speed Comparison*

The Automatic Speed Regulator shall determine the desired train speed by reading the inputs from the speed command decoding fan in the ATP System, the performance speed circuitry in the ATS subsystem, and the program station stopping logic. To determine the desired speed, prior to each sample time, the ATP speed and the ATS speed shall be compared and the lower speed shall be selected. Before the ATS speed is updated from the TWC receiver, the ATS speed shall be 49 mph. The speed thus selected (regulated speed), shall be further compared with the program station stop profile speed and the lower selected as the desired speed. To prevent overshoot, the regulated speed shall be offset by a fixed amount for comparison to the profile velocity. The selected speeds shall be stored for the duration of the sample time to avoid errors in speed comparison due to a change in commands or contact bounce. The desired speed shall be input to the speed comparison circuits. The regulated speed shall be converted to the proper form and output to the seven-segment REGULATED SPEED display in the cab as described in Section 9.7, Exhibit 9-1.

The desired speed shall be compared to the actual train speed, using digital logic arranged for a minimum resolution of 0.25 mph.

The comparison shall produce an error signal which shall be presented to the motor control logic, so that the correct rate wires are energized.

11.2.2.1.4 ***Motor Control Logic***

Acceleration rates selected to cause the train to accelerate to and be maintained within the band of +0 mph to -4 mph of the desired speed, when the desired speed is either the ATP speed or the ATS speed, shall be determined by digital logic. When the desired speed is the program stop profile speed, the tolerance shall be that required to provide the specified accuracy of the station stops. The digital logic shall make use of the results of the comparison, the desired speed, and the grade and curve data in making the determination.

The number of changes in acceleration rates shall be held to a minimum. The number of changes which result in a decrease in either positive or negative tractive effort shall be kept to a minimum.

Provisions to minimize tractive effort changes shall include, but not be limited to:

A. Logic to prevent overshooting when the desired speed is changed

B. Damping by providing hysterisis on all rate selections

C. Minimizing the effects of slips, slides, and electrical noise by requiring that motor connections be changed only after two consecutive sample time results call for the same change, or one of the two results calls for a greater change in the same direction.

11.2.2.1.5 ***Rate Control***

The Automatic Speed Regulator shall limit the requested positive rate of acceleration in accordance with the ATS performance acceleration control (power limit) received via the ATS subsystem. The absence of the power limit signal shall result in maximum acceleration during motoring requests. The presence of the power limit signal shall result in an acceleration of 50% of maximum during motoring requests.

11.2.2.1.6 ***Interfacing***

All acceleration levels shall be selected by energizing trainline wires in fixed patterns.

Interface to the trainline wires shall be in the form of relay contacts. The configuration of the interface relays shall be such that in Automatic Train Operation all energy applied to these trainline wires shall be supplied from the ATC system. Further, in the AUTO-STORE position of the Master Controller, all contacts used to control rate trainlines shall be open to preclude runaround paths. In Manual Operation, energy to these trainline wires will be supplied from the console in the Operator's cab, but shall be routed through the ATC equipment for brake enforcement. Circuitry shall be arranged to provide battery voltage to the ATO relay trainline energization contacts only when the Automatic mode vital relay is energized.

11.2.2.2 Program Station Stop (PSS)

The Program Station Stop (PSS) equipment shall cause the train to decelerate smoothly to a stop at a passenger station, properly aligned with the required location at the platform. The PSS profile shall be consistent with the Authority's existing operating schedules. Two-car and four-car trains shall be required to stop with their front ends aligned with the platform centerline, with their front ends aligned with the leaving end of the platform, or with their centerlines aligned with the platform centerline, all as determined by signals received from the wayside markers. Six-car and eight-car trains shall always stop with their centerlines aligned with the platform centerlines. Station stop accuracy shall be ± 6 feet. The

PSS equipment shall have the capability of causing the train to skip any station stop when so commanded by (1) Central Control via signals received from the wayside markers, or (2) the Operator when the Station Stop Cancel push-button is depressed.

Operation of the carborne PSS equipment shall be initiated by wayside markers located at distances of 2,700 feet, 1,200 feet, and 484 feet from the platform centerline. Where stations are less than 3,000 feet apart, the 2,700-foot marker will be eliminated and ATP speed limits set to ensure that the train speed at the 1,200-foot marker is equal to or less than the speed required for executing a reliable program stop from the 1,200-foot marker. A typical marker arrangement may be found on Contract Drawing 97936-032.

Program station stops shall be conducted in accordance with predetermined speed-distance profiles. The profile selected for a stop shall be reproduced in the carborne equipment using digital logic, and shall be a function of:

A. Train length
B. Desired train-platform alignment
C. Value of acceleration due to grades and curves.

The train length data shall be as determined by the train length circuits in the ATS System. The desired train-platform alignment and the value of acceleration due to grades and curves shall be determined by the marker recognition circuits.

The nominal deceleration rate used in generating the profiles shall be an agreed-to rate that approximates 1.8 mphps.

The profile from the 484-foot marker to the stopping positions shall assume an acceleration due to grades and curves of zero. The profile from the program station stop initiation point to the 484-foot marker shall be influenced by the value of acceleration due to grades and curves stored at the initiating marker. This value shall be a representation of the grade and curve conditions between the initiating marker and the 484-foot marker. The value shall not be changed at intermediate recalibration markers.

Resolution of the profile reproduction shall be such that the overall system accuracy (±6 feet of stopping position) shall be maintained with a minimum number of brake-level changes. The distance-traveled data, required to reproduce the profile, shall be obtained by counting the output pulses from the speed sensor used for automatic speed regulation.

Wheel wear compensation circuits shall be provided and shall respond to the setting of the ATO wheel wear switch.

The PSS equipment shall generate the TRAIN BERTHED signal to be transmitted to wayside via the TWC System. The TRAIN BERTHED signal shall be initiated as noted below, or when the train has completed a Program Station Stop, and shall be maintained until the PSS equipment is reset. The point on the stopping profile at which the TRAIN BERTHED signal is to be initiated shall be adjustable to occur at a profile speed of from 0 mph to 7 mph. The initial setting shall be 7 mph.

The PSS equipment shall be reset on the loss of Door-Open Command reception at the front of the train, or upon actuation of the STATION STOP CANCEL push-button.

Actuation of the TRAIN BERTHED push-button shall cause the TRAIN BERTHED output of the PSS equipment to be energized and remain energized until the Program Station Stop is reset.

11.2.2.2.1 *PSS Indicators*

Indications shall be provided in the Operator's cab to enable the Operator to monitor the operation of the PSS equipment. These indications shall be energized from the PSS equipment as follows:

A. PROGRAM STOP indicator: This indicator shall be energized upon the initiation of a Program Station Stop and shall remain energized until the stop is completed (removal of Door-Open Command), or until cancellation of the stop by the STATION STOP CANCEL push-button.

B. SKIP STOP indicator: This indicator shall be energized upon receipt of a Skip Stop signal and shall remain energized until the platform marker is received.

C. PROGRAM STATION STOP ABORTED indicator: This indicator shall be energized upon receipt of PSS profile malfunctions which would result in a station overrun. See PSS Monitoring Section 11.2.2.2.4.

11.2.2.2.2 *PSS Markers*

Marker reception equipment shall be provided to respond to the wayside markers and perform the logic required to interpret the markers. The marker reception equipment shall have sealed, weathertight connections with a pre-amp within 10 feet of the signal pick-up coil for signal boosting to improve system performance. Equipment mounting shall be such as to enable removal and installation within 10 minutes. Refer to Contract Drawing 97936-025 for location of the marker receiving coil.

The system is organized so that four marker positions are used at each station for each direction of approach.

The wayside markers, which shall be detected by the marker reception equipment, are tuned circuits, the inductance of which is an air-core coil with an inside diameter of approximately 11 inches. The coil is the coupling element to the carborne equipment and is located between the running rails with its axis vertical. The top edge of the coil is between 1/2-inch and 1-3/4 inches below the top of the rail. The relationships between the coil center and the track centerline are as follows:

Radius of Curve (feet)	Offset from Centerline (inches)
Tangent to 5,000	0
5,000 – 2,000	2
2,000 – 1,500	3
1,500 – 1,100	4
1,100 – 900	5
900 – 700	6

Offset from centerline of track is toward the outside of the curve.

Each wayside marker location (except the 160-foot marker) consists of two independent, tuned-circuit members. This configuration is used to provide for running in either direction and to provide the required amount of data with fewer frequencies. The determination of marker validity for the direction of travel shall be accomplished as described below.

11.2.2.2.3 *PSS Marker Validation*

When a wayside marker member (tuned circuit) is detected by the marker reception equipment, it shall be stored and a distance window shall be created to condition the equipment to respond to a second member after traveling a distance of between 2-1/2 feet and 20 feet. If the first member detected and stored is F1 through F5, it shall be assumed that the marker pair is valid for the direction of travel. If the first member detected and stored is F6 through F10, it shall be assumed that the marker pair is invalid for the direction of travel. After detection of the second member or after traveling a distance of 10 feet from the first member, the valid marker data shall be transferred to the proper circuitry to be acted upon and the marker validation circuitry shall be cleared in preparation for detection and validation of the next marker. The system shall be provided with a check feature to ignore F1, F2 and F3 markers that are detected after receipt of any valid one of the three.

Failure to detect marker members shall result in the following:

A. Failure to detect first member of any marker except the 484-foot marker: No action.
B. Failure to detect first member of the 484-foot marker: Simulate the detection based on distance traveled after detection of the 1200 foot marker.
C. Failure to detect second member when first member is F1 or F5: Simulate detection of F10.
D. Failure to detect second member when first member is F2 or F3: Simulate detection of F9.

Data received from specific station stopping markers is shown in Exhibit 11-1.

Exhibit 11-1 – Data Received from Specific Station Stopping Markers

2,700-Foot Marker	Function
1st Member	• Always tuned to F1 • Initiate PSS • Initialize “Type A” stop logic • Indicate 2700 feet from platform centerline
2nd Member	• Convey grade information (tuned to one of five frequencies–F6,F7,F8,F9 or F10)

1,200-Foot Marker	Function
1st Member	• Always tuned to F2 • Initiate PSS in absence of 2,700-foot marker • Indicate 1,200 feet from platform centerline
2nd Member (Tuning is controlled by the wayside station control logic as required)	• Sets the type of stop logic • Tuned to one of four frequencies: F6, F7, F8, or F9

484-Foot Marker	Function
1st Member	• Always tuned to F3 • Set the grade storage logic to zero grade • Initiate PSS in the event of a turnback move • Indicate 484 feet from platform centerline
2nd Member	• Sets the type of stop logic • Tuned to one of four frequencies: F6, F7, F8, or F9

160-Foot Marker	Function
	• Always tuned to F4 • Resets the Skip Stop logic • Indicate 160 feet from the platform centerline

The frequency assignments are shown in Exhibit 11-2.

Exhibit 11-2 – Frequency Assignments

Frequency ID	Frequency	Tolerance	Information Conveyed
F1	110 kHz	+400, -700 Hz	• 2,700-foot marker • Grade change annunciator
F2	100 kHz	+400, -600 Hz	• 1,200 foot marker
F3	92 kHz	+400, -600 Hz	• 484 foot marker
F4	170 kHz	+600, -1,100 Hz	• 160 foot marker
F5	120 kHz	+450, -750 Hz	• Grade change annunciator
F6	130 kHz	+500, -850 Hz	• Skip stop if first member of pair was F2 or F3 • Maximum (2.5 to 4.0%) upgrade if first member of pair was F1 or F5
F7	140 kHz	+500, -900 Hz	• Type A stop (front of train to centerline of station) if first member of pair was F2 or F3 • Intermediate (0.75 to 2.5%) upgrade if first member of pair was F1 or F5
F8	160 kHz	+1,000, -1,050 Hz	• Type B stop (front of train to leaving end of station) - if first member of pair was F2 or F3 • Zero (± 0.75%) grade if first member of pair was F1 or F.
F9	180 kHz	+1200, -900 Hz	• Type C stop (centerline of train to centerline of station) if first member was F2 or F3 • Intermediate (0.75 to 2.25%) downgrade if first member of pair was F1 or F5
F10	150 kHz	+500, -1,000 Hz	• Maximum (2.25% to 4.0%) downgrade if first member of pair was F1 or F5

11.2.2.2.4 *Program Station Stop (PSS) Monitoring*

The PSS system shall include software algorithms to monitor the performance of the vehicle while it is in the PSS profile and detect malfunctions which will result in station overruns. In the event such malfunctions are detected, the vehicle should be commanded to B4 until it comes to a stop. Additionally, a Program Station Stop Aborted indicator shall be displayed to the Operator.

A. A software algorithm shall be added to check and monitor the Program Station Stop flag. The software would verify each transition of the flag from a high to low state. If the transition was made for a valid reason such as (1) receipt of a cancel-station-stop command from the train Operator's console or from a wayside marker, or (2) receipt of an open-door command, no action would be taken. Any transition for an invalid reason would set the commanded speed to zero to stop the train and give an indication to the train Operator by displaying "97" in the speed readout.

B. A software algorithm shall be added to check the distance-to-go counter for a sudden jump or increase during a programmed station stop. The algorithm would set two limits on the maximum distance-to-go update allowable, one for a wayside marker update and one for an update between wayside markers. Any distance-to-go update greater than the limit would set the commanded speed to zero and give an indication to the Operator by displaying "99" in the speed readout if the limit is exceeded at a marker, and "98" if the limit is exceeded between markers.

11.2.3 <u>Automatic Train Supervision (ATS)</u>

An Automatic Train Supervision subsystem shall be provided to interface with the existing Authority ATS System. The ATS subsystem shall consist of train-to-wayside communication and train length determination equipment.

11.2.3.1 Train-to-Wayside Communications (TWC)

The TWC system shall provide the communications link for the following ATS functions between trains and the wayside:

Train-to-Wayside	Wayside-to-Train
Train Identification (ID)	Train Identification (ID)
Train Berthed	Power Limit
Train Ready	ATS Speed Limit
Passenger Station Check	Passenger Station Check
Train Length	
Motion Detect	
All Doors Closed	
Manual Push-button Right	
Manual Push-button Left	
Doors Closed Right	
Doors Closed Left	
PSS Active	
ATP In	
Train in Automatic	

The TWC system shall be a continuous-scanning, time-division, multiplex transmission system in which communication transmitted to wayside and received from the wayside are time-shared.

The carborne TWC system shall be inductively coupled to the wayside TWC system via coils on the cars. Refer to Contract Drawing, 97936-028 for the basic system configuration. At wayside receiver locations other than flyby locations, the area of effective two-way communications shall be at least 350 feet long.

The carborne encoder shall receive parallel coded signals and shall convert these signals to form a serial output message. Inputs to the encoder shall be: TRAIN NUMBER and TRAIN DESTINATION, in BCD code from the storage unit; TRAIN LENGTH, from the Train Length circuit; TRAIN READY, from the ATO START push-button; TRAIN BERTHED, from the Program Station Stop System; PASSENGER STATION CHECK, from the carborne door control circuit; MOTION, from the Motion Detect Relay; ALL DOORS CLOSED, from the door interlock circuit. MANUAL PUSH-BUTTON RIGHT, from the operating cab right side door button; MANUAL PUSH-BUTTON LEFT, from the operating cab left side door button; DOORS CLOSED RIGHT, from door closed status relay right; DOORS CLOSED LEFT, from doors closed status relay left; PSS ACTIVE, from PSS software flag; ATP IN, from COR relay; and TRAIN IN AUTOMATIC, from the ATO relay contact.

The encoder shall form a message in the following formats:

Bit No.	Short Message Format
1-3	Message Prefix
4-11	Word 1 (Train Destination)
12	Parity, Word 1
13-15	Message Suffix

Bit No.	Long Message Format
1-3	Message Prefix
4-11	Word 1 (Train Destination)
12	Parity, Word 1
13-24	Word 2 (Train Number)
25	Parity, Word 2
26	Manual Push-button Right
27	Manual Push-button Left
28	Doors Closed Right
29	Doors Closed Left
30	PSS Active
31	ATP In
32	Train in Automatic
33	Spare
34	Spare
35-37	Spare
38	Parity, Word 3
39	Passenger Station Check
40	Train Ready
41	All Doors Closed
42	Train Berthed
43	Parity, Word 4
44	Motion Detect
45-47	Train Length
48	Parity, Word 5
49-51	Message Suffix

The prefix bit configuration for the short message mode shall be MARK-SPACE-MARK. The prefix bit configuration for the long message mode shall be MARK-MARK-MARK. The suffix bit configuration for both long and short message modes shall be MARK-MARK-MARK.

The encoder shall output the message to the transmitter as a non-synchronous, return-to-zero, serial code. There shall be a 100-millisecond pause between successive message transmissions. The message shall start 60 milliseconds after the transmitter is keyed ON and end 20 milliseconds before the transmitter is keyed OFF. The bit rate shall be 100 bps.

The encoder shall key the transmitter for the entire message transmission period. During the entire message transmission period, the encoder shall also inhibit the carborne receiver.

The carborne encoder shall be arranged to transmit only Word 1 except when a reply is received from the wayside. After such a reply is received, all words shall be transmitted.

The carborne TWC transmitter shall have a carrier frequency of 9,800 Hz and shall be of the return-to-zero, frequency-shift keying type.

A frequency of 9,950 Hz shall be interpreted as “MARK.” A frequency of 9,650 Hz shall be interpreted as a “SPACE.” Parity shall be “ODD.”

The transmitter and transmitting coil shall be such that a minimum of 40 mA rms shall be induced into the rails as circulating current between the train and a 0.06 ohm impedance located 200 feet from the train. The transmit frequency tolerance shall be ± 0.5%. Refer to Contract Drawing 97936-025 for location of the transmit coil.

The carborne TWC receiver shall be designed to receive the same type of signals as the transmitter produces. The receiver shall receive the signals from the wayside via the ATP receiving coils and convert the signal to a serial coded message to the carborne decoder. The receiver sensitivity and receiving coils (TWC winding on ATP coils) shall be such that a rail current of 90 mA RMS will be detected. The receiver shall have a dynamic range of 35 dB.

The decoder shall check all words for proper parity and shall output each correct word to storage. In the case of Words 1 and 2, both must be valid before either is loaded into storage. When the decoder determines that received words have bad parity, the information contained in the word with bad parity shall not be stored.

All storages shall be reset to zero initially when the married pair becomes the controlling pair, except that the ATS speed shall be initialized at 49 mph.

Both Word 1 and Word 2 storage shall provide continuous Train Destination and Train Number input data to the encoder and to the converter units used to drive the Train ID displays located in the controlling cab.

Word 1 storage shall also drive interface relays, the contacts of which shall output the destination in BCD form to the destination sign interface.

In the event a “bad” parity status is received for Word 1, Word 2, or Word 5, the respective error light located on the controlling cab console shall be energized and remain energized until valid data is received.

Both Word 1 and Word 2 storages shall also have the provision to accept Train Number and Train Destination data provided from the Train ID thumbwheel selector switches located in the cab.

The Contractor shall organize the input facilities of Word 1 and Word 2 storage to accept only Train Number and Train Destination data provided by the thumbwheel switches, whenever the Train ID selector switch is placed in the Manual position. When the Train ID selector switch is in the Auto position, the decoder shall provide the inputs to Word 1 and Word 2 storages.

The information contained in the received message shall be: Train Number; Train Designation; ATS Speed Limit; Power Limit; and Passenger Station Check.

The received message format shall be as follows:

Bit No.	Short Message Format
1-3	Message Prefix
4-7	Word 5 (ATS speed limit)
8	Word 5, Parity
9-11	Message Suffix

Bit No.	Long Message Format
1-3	Message Prefix
4-11	Word 1 (Train Destination)
12	Word 1, Parity
13-24	Word 2, (Train Number)
25	Word 2, Parity
26-37	Word 3 (Spare)
38	Word 3, Parity
39	Passenger Station Check
40	Power Limit
41-42	Spare
43	Word 4, Parity
44-47	Word 5, (ATS Speed Limit)
48	Word 5, Parity
49-51	Message Suffix

11.2.3.2 Train Length Circuit

A train length measuring circuit shall be provided to automatically indicate the number of cars in the train. Four trainline pairs shall be provided on each car for this purpose and shall be circuited as indicated on Contract Drawing 97936-023. Isolation may be accomplished by alternate means subject to Authority approval. The ATS System shall include the relays as indicated on the above-referenced drawing. The contacts shall be circuited to provide two-car, four-car, six-car, and eight-car outputs to the Program Stop System, the Train ID Display, and the TWC Encoder.

The Train Length data to the Train ID Display shall be in seven segment format. The Train Length data to the TWC and Program Stop subsystems shall be in the BCD format.

11.2.4 Test and Diagnostic Requirements

The ATC equipment shall include a vital Test Relay, which shall be de-energized during all ATC tests. When the Test Relay is de-energized, a Full Service Brake application shall be enforced by the ATC system.

Test receptacles shall be provided as part of the ATC equipment to interface with all applicable portable test units and bench test equipment.

11.2.5 Fail-Safe Design Requirements

The fail-safe design criteria for the ATC system shall be as specified in Section 1.11.4.

11.2.6 Power Supply

The ATC system shall include all required power conditioning equipment to operate the ATC system. The power conditioning equipment shall operate from the car battery system. The power conditioning equipment shall be equipped with remote control such that the ATC system on each pair of the cars is energized when the CONTROL LOCK is in the ON position in any cab of the train.

Power conditioning equipment shall be capable of continuous operation at loads of 125% of the maximum steady state ATC system load with input voltage between 23 and 42 volts.

Power conditioning equipment shall have built-in protection against:

A. High and Low Input Voltage
B. High and Low Output Voltage
C. Overcurrent

Power conditioning equipment shall have input-to-output isolation of 5 megohms minimum. Power conditioning equipment shall achieve regulation stability within one second of turn-on. Power conditioning equipment for the ATC system may be located under the car.

11.2.7 Microcomputer

Microcomputers used to perform Automatic Train Control functions shall conform to the requirements of Section 15.30.

11.2.8 Vehicle Monitoring System (VMS) Interface

The input and output signals from each critical system performance-dependent equipment, together with its power supply voltage, shall be monitored; and this data stored with time and date stamping in a data acquisition module (DAM). Non-volatile data storage shall be a minimum of 15 minutes. Old data shall be overwritten and the most recent data saved as a redundant source for investigations. Recording of data shall cease if there is no input signal change or request for data from the VMS central unit (VCU) during a 5-second interval. Data recording shall resume immediately whenever there is a change in signals or query from the VCU. The data in this module shall be capable of being readily downloaded via a PCMCIA or other standard PC connector and shall also be available at a standard port for transfer via RS485, or a high speed data bus, to the central vehicle monitoring system equipment specified in Section 12.6. A functional block diagram of the system and its equipment together showing all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process.

The DAM shall perform signal isolation, signal input acceptance, conversion, and short-term storage of data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 12.6.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via high speed data bus or RS485. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol.

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

11.3 COMPONENTS AND HARDWARE

All components and hardware used in the ATC system shall meet the requirements specified in Section 15.

11.4 TESTS AND INSPECTIONS

11.4.1 General

This section provides a general description of the tests and inspections which the Contractor shall perform to demonstrate that the ATC systems, subsystems, assemblies, subassemblies, and components supplied under this Contract are in compliance with the specifications.

All tests shall be performed and documented to meet the requirements specified in Section 1.8.

11.4.2 Design Tests

The Contractor shall submit, for approval, a detailed plan for conducting design tests no later than 90 days after award of the Contract. Detailed test procedures for conducting these tests shall be submitted for approval no later than 90 days after approval of the plan. Test reports shall be submitted for approval a minimum of 30 days prior to the scheduled commencement of manufacturing of the equipment. The following minimum design tests shall be conducted.

11.4.2.1 Development Tests

Development tests shall be conducted during the design phase to ensure proper interface with the Authority's existing ATC system. As a minimum, prototype models of the ATP reception and decoding equipment, the TWC transmitting and receiving equipment, and the marker reception and validation equipment shall be thoroughly tested to demonstrate proper operation to the Authority and subsequently against the wayside system by installation on a pair of the Authority's existing cars. Test procedures for conducting these tests shall be submitted for approval a minimum of 60 days prior to the scheduled commencement of the test.

11.4.2.2 Compatibility Tests

The speed regulation and station stopping equipment shall be tested with the propulsion supplier's prototype system in a dynamic test configuration in a laboratory environment to ensure compatibility of the two systems. The test procedure for conducting this test shall be submitted for approval a minimum of 60 days prior to the scheduled commencement of the test.

11.4.2.3 Qualification Tests

The ATC system and all major components shall be subjected to qualification tests to verify that they comply with the requirements of this contract. As a minimum, these tests shall include complete functional tests while the equipment is subjected to the environmental and input variations specified in this contract. Equipment so tested shall conform to the manufacturing drawings.

11.4.3 Factory Tests and Inspections

The Contractor shall develop a factory test plan and factory test procedures in accordance with the requirements of this specification. The term "replaceable unit" as used below means a device or assembly of devices which is normally removed from the car as a unit for replacement or repair in the event of a failure within the unit.

11.4.3.1 Plan

The factory test plan shall be submitted for approval no later than 180 days after award of the Contract. 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.

11.4.3.2 Procedures

Detail procedures shall be developed for the inspection and test of all replaceable units, major assemblies, and the complete ATC system. The procedures shall be submitted for approval a minimum of 60 days 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 (non-standard) test equipment or test fixtures are required for the test, a description of such equipment and instructions for its use shall be included in the procedure or attached thereto.

11.4.3.3 Minimum Test and Inspection Requirements

The following tests and inspections shall be performed:

A. Each replaceable unit shall be 100% mechanically and electrically inspected and functionally tested.

B. Each major assembly shall be 100% mechanically and electrically inspected and functionally tested.

C. ATC equipment shall be functionally tested in a system configuration prior to delivery to the Contractor's facility.

D. All wiring that affects the safety of the ATC equipment shall be thoroughly tested to ensure exact compliance with the approved circuits. The test shall be designed to detect all wiring faults including errors, extra wires, opens, shorts, and crosses.

E. ATC equipment assembled into a system configuration as in C above shall be tested for leakage resistance. This test shall verify that the resistance between all circuit elements and all case or rack members is greater than 20 megohms at 37 VDC.

11.4.3.4 Not Used

11.4.3.5 Test Reports

Test reports shall be submitted for each test required by the approved test plan. The test reports shall give:

A. Part number of equipment tested
B. Serial number(s) of equipment tested
C. Identity of test conducted
D. Date of test
E. Identity of person(s) conducting test
F. Identity of witnesses and/or inspector
G. Summary of test results
H. Copy of data recorded

Test reports shall be submitted at or before time of shipment of the equipment to the Contractor's facility.

11.4.4 Installation

11.4.4.1 Plan

The Contractor shall submit a detailed installation and test plan for approval no later than 180 days after award of the Contract. 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.

11.4.4.2 System Test

After installation of the ATC equipment, a functional system test shall be conducted to verify proper installation and interface of the ATC equipment. During this test all ATC equipment and all interfaces shall be exercised. The test procedure for this test shall be submitted for approval a minimum of 60 days prior to the schedule date of the first such test.

11.4.4.3 Reports and Records

A record of the ATC equipment, by serial number, installed in each car shall be made at the time of installation and shall be kept current by the Contractor until the car is accepted. This record shall be a part of the Car 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 car history book.

11.4.5 Field Tests

The Contractor shall perform static and dynamic tests to verify that the ATC system of each car complies with the contract requirements. The tests shall demonstrate proper and safe operation in the environment of the existing Authority system.

11.4.5.1 Plans and Procedures

The Contractor shall submit, for approval, a detailed plan for conducting these tests a minimum of 180 days prior to the scheduled delivery of the first cars.

The Contractor shall submit, for approval, detailed test procedures for conducting each test a minimum of 60 days prior to scheduled delivery of the first cars.

11.4.5.2 Minimum Requirements for Static Tests

Immediately prior to conducting dynamic tests, the Contractor shall demonstrate proper operation of the installed system utilizing the ATC portable test unit described in Section 12.2 and shall conduct the Daily Safety Test described in Section 11.2.1.2.4.

11.4.5.3 Minimum Requirements for Dynamic Tests

Dynamic tests will be carried out on existing operating sections of mainline track which shall be designated by the Authority for these purposes. The tests shall be conducted in both the normal and reverse direction of traffic.

These tests shall be performed only after all of the required static tests have been completed and all modifications installed are entered into the car history book. The dynamic tests shall require a minimum of 2 hours of operation to simulate conditions of actual service. A successful Daily Safety Test is required prior to any dynamic testing.

The dynamic tests shall consist of, but are not limited to, the following:

A. Proper operation of the ATC equipment and all interface circuitry in the automatic mode. Functions to be tested shall include:

   1. ATP
   2. Marker Receipt
   3. Speed Regulation
   4. Station Stopping Accuracy
   5. Skip-Stop
   6. Door Control Circuitry
   7. Cab Controls and Indications including Emergency Brake
   8. TWC and Train ID and Destination
   9. Power Limit

B. Proper operation in the manual mode. Functions to be tested are:

   1. Overspeed Protection
   2. Stop and Proceed (Forward and Reverse)
   3. ATP Cutout

C. Test results and corrective action taken shall be entered in the Car History book.

11.4.6 <u>Qualification Demonstrations</u>

The acceptability of the system design shall be determined by test runs between Silver Spring and Dupont Circle made under typical revenue operating conditions (Performance Level 2). Diagrams depicting track routing and profiles will be made available upon Contractor request.

11.4.6.1 Test Conditions

A. Train Length: 2 cars

B. Routing: All routes, except automatically initiated routes, appropriately cleared and fleeted for normal traffic

C. Destinations: Southbound - Dupont Circle; Northbound - Silver Spring

D. Performance Level: Maximum

E. Dwell Time: Fixed at 15 seconds for intermediate stations, 30 seconds each platform at Dupont Circle, and 60 seconds at Silver Spring

F. Station stop alignment: All set for centerline to centerline stops except for Takoma Park, which is short stop outbound and long stop inbound

G. Wayside condition: All required circuits functioning within normal limits and no temporary speed restrictions set

H. Mode of Train Operation: Automatic Train Operation

I. Mode of Door Control: Automatic Open and Close.

11.4.6.2 Test Sequence

A. Start at inbound platform at Silver Spring

B. Run to outbound platform at Dupont Circle

C. Make turnback move Dupont Circle crossover with crossover move made during outbound travel

D. Run from inbound platform at Dupont Circle to inbound platform at Silver Spring

E. Repeat A through D until three round trips have been accomplished.

11.4.6.3 Data Recording

The test charts shall be changed during the inbound dwell time at each terminal. Each test chart shall be labeled with the date, time, trip number, elapsed time from departure at previous terminal to arrival at platform where chart was changed, and identity of test engineer.

11.4.6.4 Data Reduction and Analysis

A. Each test chart shall contain:

1. Car Number
2. Destination
3. Train Number
4. Speed Command
5. Train Speed
6. Program Stop Status
7. Overspeed Protection Status
8. Rate Request

B. All test charts for the test sequence shall be analyzed to determine:

1. Test conditions were correct
2. Speed regulation accuracy

11.4.6.5 Pass/Fail Criteria

The system will be considered to have passed if:

A. Speed regulation accuracy does not exceed +0, -4 mph

B. Total elapsed time of the specified run is within 1,325 seconds, ± 30 seconds

C. Station stopping accuracy is ± 6 feet, per Section 11.2.2.2.

11.4.6.6 Sampling

One pair of cars to be selected by the Authority shall be subjected to these qualification demonstrations. Should any such demonstration result in failure and subsequent design change and retrofit, the cars that failed the demonstration and one additional retrofitted pair shall again be subjected to the qualification demonstration.

SECTION 12
SPECIAL TOOLS, TEST, AND DIAGNOSTIC APPARATUS

TABLE OF CONTENTS

Section **Page**

SECTION 12
SPECIAL TOOLS, TEST, AND DIAGNOSTIC APPARATUS

12.1 GENERAL REQUIREMENTS

The Contractor and his Suppliers shall provide on-board diagnostics, portable test devices, bench testers, and other test apparatus for the cars as specified herein.

The Contractor shall make all modifications to test equipment specified herein which are required because of changes and modifications to the transit Car or any of its subsystems made to meet the requirements of this Contract.

Each piece of test apparatus shall be accompanied by the following:

A. Complete diagrams, schematics, parts listings, theory of operation, assembly and construction drawings, and maintenance and calibration instructions for the device itself.

B. Complete maintenance, calibration, and troubleshooting procedures for the associated carborne system and its circuit boards written around use of the test device.

The above documentation shall be supplied in addition to and in accordance with the Maintenance Manuals required by Section 1.5.5.

In addition to the quantities of test devices specified hereinafter, the Contractor shall provide for all test devices required by the qualification and/or acceptance test programs. Under no circumstances will test apparatus be loaned or made available to the Contractor by the Authority.

On-board Vehicle Monitoring System and equipment shall be installed in each car in accordance with Section 12.6.

Six sets of special tools, as defined in Section 12.7, shall be provided.

12.2 PORTABLE TEST DEVICES

All periodic tests, calibration and trouble diagnosis required to maintain the vehicle subsystems specified below shall be accomplished through the use of portable test devices. The first two portable test devices of each type shall be delivered prior to acceptance of the first pair of cars. The remaining units shall be delivered prior to acceptance of the sixth pair of cars.

The test devices and the carborne equipment design shall make use of multi-pin connectors and antennas to establish all interfaces required for utilization of the test devices. Power to operate the portable test devices shall be from either self-contained power packs or from the car low voltage power supply via the test unit connectors. The portable test devices powered from the car low voltage power supply shall be designed for operation with input voltages ranging from 23 VDC to 42 VDC. There shall be no high-voltage connections (700 VDC) required for any portable test device. It shall not be necessary to remove, dislodge, dismount, or disconnect any carborne component, card, wire, chassis, terminal, or cable in order to perform periodic calibration or trouble diagnosis while using portable test devices. Each portable test device shall be designed such that it cannot initiate car movement while connected to the system.

Portable test devices shall be designed to produce all of the operating commands and other input signals necessary to perform all functional tests of the particular system or subsystem under test, and to measure or indicate (by means of indicator such as lamps, meters, oscilloscopes, gauges, etc.) all signals, responses and outputs produced by the system. The device shall be capable of testing for every combination of input and output signals the subsystem might encounter during actual train operation while simultaneously monitoring the system responses to determine whether it performs in accordance with design specifications. It will be acceptable to require a visual check for system response, such as closure of a contactor, provided that such visual check does not require the removal of other components or equipment or use of hand tools and does not require the test device operator to move more than 15 feet to make the required observation.

When used according to the instructions supplied by the Contractor, each portable test device shall enable the maintenance technician to fully check out and calibrate the system or subsystem under test and shall indicate any removable component which has fully or partially failed. The device shall be capable of indicating the line replaceable unit which must be replaced to restore the system to proper operation. All messages to the test operator shall be in plain English and shall not require the use of tables, look-up charts, or decoding of numerical sequences to determine the defective component to be removed. Testing shall be automated to the maximum extent possible and require a minimum amount of physical interaction from the operator. It shall be possible to repeat an entire automated test or any portions thereof for the purpose of troubleshooting intermittent problems. Response indicators and input-signal generators shall be built into the portable test devices as necessary and shall have accuracy commensurate with the alignment tolerances applicable to the subsystem under test.

Unless otherwise specifically approved, portable test devices shall not require connection of external apparatus for their operation. In such cases, terminals shall be provided to allow connection of the external apparatus to the device. Such external apparatus shall be considered part of the portable test device and shall be supplied with it on a one-to-one basis.

Each portable test device shall be housed in an enclosure constructed of heavy-duty fiberglass reinforced plastic of sufficient strength suitable for use in a transit shop environment. The enclosure shall have a removable cover and a suitable carrying handle and include stowage space for cabling required for unit hook-up. If a laptop computer is used, it shall be suitable for use in harsh industrial environments and shall be shock- and vibration-resistant to the following criteria:

A. Shock: 40g – 1ms sawtooth/30g – 6ms half sine wave (non-operating)
20g – 11ms sawtooth/15g – 6ms half sine wave (operating)

B. Vibration: 5 - 500 Hz 2g, 3-axis (non-operating)
5 - 500 Hz 1g, 3-axis (operating)

Laptop or notebook computers, if used, shall include state-of-the-art microprocessors at the time of delivery and include CD-ROM, color screens, integral pointing devices, and the latest version of the Windows operating system. Unless otherwise approved, the weight for any portable test device shall not exceed 15 pounds.

Portable test devices shall be provided for the following equipment in the quantities indicated:

A. Automatic Train Control, 16 each
B. Propulsion System, 16 each
C. Friction Brake System, 16 each
D. (Not Used)
E. Converter, 8 each
F. Communications System, 8 each
G. Heating and Cooling System, 10 each
H. Side Doors, 10 each
I. Destination Signs, 10 each
J. Coupler, 8 each
K. AC Auxiliary Inverters, 16 each

12.2.1 Unique Portable Test Device Features

In addition to the above general requirements for portable test devices, the following unique capabilities shall be incorporated into the individual devices as listed:

1. The ATC system portable test unit shall test the ATP, ATS, and ATO subsystems. It shall provide for testing the cab signal reception and decoding equipment, the overspeed protection equipment, door controls, program station stopping controls, and the automatic speed regulation equipment.

2. The propulsion tester shall be capable of testing the control logic functions and operation of all external control devices (e.g., contactors, relays, etc.); verifying the operation of the high voltage semiconductors (with high voltage present); checking for spin/slide detection of all axles, including synchronous spin/slide conditions, downloading fault information and stored data; and modifying operational parameters under password protection.

3. The friction brake system test device shall monitor the feedback signals to determine whether any electrical or electronic problems exist. It shall also check for spin/slide detection of all axles, including synchronous spin/slide conditions. The tester shall also examine these signals for timing or other discrepancies to determine whether there are any mechanical, hydraulic, or pneumatic defects in the system and shall indicate which part, if any, if faulty.

4. The communications test device shall be designed so as to measure actual sound levels at various points throughout the transit car. While verification of electrical signal levels and operation is required, it shall be possible to establish consistent sound levels in each operating car. The use of sound generators at different levels, frequencies, distances, and distortions will be required at the passenger call stations and microphones. When these sounds are input as stated, their outputs must then be monitored at the various speaker locations to determine whether they are within specifications. The test device must also examine inputs and outputs to trainlines and couplers so as to standardize the level of announcements to other cars in the train. The test device shall provide the capability for calibrating the sound system on each pair of cars to a set level.

5. The heating and cooling system tester shall be capable of commanding each stage of heating and cooling and verifying proper operation, displaying car temperature, and permitting maintenance personnel to input varying desired car temperatures while verifying proper system response.

6. The door system portable test device shall automatically measure door currents and timing sequence of opening and closing. The device shall provide for setup, calibration, and adjustment of the door equipment for proper timing and operation. It shall be possible to connect the tester at any pair of doors and at a central location for general system testing.

7. The destination sign test device shall indicate whether sign problems are caused by the sign itself or the input signals to it.

8. The coupler test device shall test for circuit continuity from the coupler face through the connecting cable and for shorts between pins or connections.

In the event that more than one subsystem is supplied by the same vendor, the individual testers may be combined into a single unit.

If a laptop is used as a portable test device common to more than one subsystem, all applicable test software shall be included with the laptop and the number of laptops supplied may be reduced accordingly. However, in no event shall the number of laptops supplied be less than fifty. MOD 1

12.3 BENCH TESTERS

Bench testers shall be capable of testing all modules of all subsystems as a whole and to troubleshoot all circuit boards, transducers, relays and assemblies of the equipment specified below to the component level, either by insertion of such items directly into the Bench Tester unit itself or into an adapter which connects to the bench tester.

Unless otherwise approved, bench testers for electric and electronic controls shall be fully automated IBM PC compatible devices. Each bench tester shall include a desktop or rack-mounted computer, which shall incorporate state-of-the-art microprocessor and include CD-ROM, 17-inch color monitor and latest version of the Windows Operating System. All associated computer programs, data, test scripts, etc. shall be delivered at the time the bench tester is delivered. The Contractor shall supply any instructions, source code, software or equipment, including compilers, necessary to maintain, add to, or modify any part of the test programs. All directions, scripts, schematics, drawings, parts lists, and required information shall be provided on diskette and hard copy.

Complete maintenance, calibration and troubleshooting procedures for the associated carborne systems and its circuit boards shall be written around use of the bench test devices. All bench testers shall be capable of troubleshooting to the lowest component part of the unit under test. Bench testers shall not be designed as simple “go/no-go” test devices, i.e., if a circuit board is the smallest repairable part, the tester shall be capable of indicating, with operator assistance, which component(s) on the board are defective or out of tolerance. The unit under test shall attach to or plug into the tester with a minimum effort. A “guided probe” approach is an acceptable method for troubleshooting to the component level. Each tester shall be operable from an IBM or compatible computer which provides, whenever possible, for unattended, multiple, repetitive testing of electronic systems so as to either verify proper operation or capture intermittent failures and identify the faulty components. It shall be possible to repeat an entire automated test or any portions thereof for the purpose of troubleshooting intermittent problems and logging any failures. Provision shall be made to enter the model, serial number, date, and any pertinent data for test record purposes.

All bench testers shall be neatly packaged as single, integrated units and shall be designed to prevent injury to test personnel. Testers shall present all input signals that the item under test encounters when in actual operation and simulated loads for each output. If such inputs and outputs are capacitive or inductive, the I/O should reflect that. Each load shall simulate as closely as possible the actual loads normally encountered by the device under test.

Each item under test shall be subjected to all combinations of input and output, including high and low operating voltages and skewed, distorted, or off-frequency signals, which may be presented to it at any one time when in actual service. If inputs and loads are variable on the train, a sampling of at least 10 levels across the full range of operation shall be presented to the item under test. Where applicable, such as in the case of a communications panel, a test script may be provided to prompt the technician to operate switches, buttons, or potentiometers to ensure proper operation of the item under test. Similarly, the script may prompt the technician to observe and report/record the status of any audible or visual indicators associated with the item under test.

The bench testers shall be capable of distinguishing between properly operating and defective modules and shall provide for making necessary adjustments and proper calibration of items under test. Suitable connectors for the modules shall be provided. Unless otherwise approved, external power for bench testers shall be limited to 115 volt, 60 Hz, AC.

Except as noted for items “E” and “O” below, one bench tester shall be provided for each of the following systems and/or equipment:

A. Automatic Train Control
B. Propulsion Control Logic
C. Braking Control Unit (Electronic)

D. DC to DC Converters
E. Friction Brake (Mechanical, Hydraulic and/or Pneumatic); two bench testers shall be provided
F. Not Used
G. Not Used
H. Auxiliary Motors
I. Destination Signs
J. Heating and Cooling Control Logic
K. Communications (Control Panel, Public Address, and Intercom Systems)
L. Side Door Control (General, Local, and Chime)
M. Power Supplies (ATC, Lamp Dimmer, Console)
N. High Voltage Propulsion Components
O. Traction Motors (Variable Voltage, Variable Frequency, Vibration, Windings); two bench testers shall be provided
P. High Voltage Auxiliary Power Systems Components
Q. AC Auxiliary Inverter.

The Contractor shall submit a list of bench testers to be delivered under the contract. The list shall include a functional and physical description of each tester, demonstrating compliance with the requirements herein. The list shall be updated at 90-day intervals as the development of the testers progresses. The updates shall clarify the functional descriptions and highlight any changes that occur. *(CDRL 1201)* Bench testers shall be delivered prior to acceptance of the sixth pair of cars.

12.3.1 Unique Bench Tester Features

In addition to the above general requirements for bench testers, the following unique capabilities shall be incorporated into individual devices as listed:

1. The friction brake mechanical bench tester shall be a test stand providing variable pressure air supply and connection manifolds, control voltage (with connectors to operate and test components) and mounting fixtures to hold rebuilt components under test.

2. The high voltage propulsion and APS bench testers shall provide high voltage and loads for semiconductors, control logic to gate semiconductors on/off, switching time measurements, forward voltage drop measurements, and forward and reverse bias leakage current measurements.

3. The traction motor bench tester shall be cart mounted providing motor mounting surfaces and fittings; variable voltage-variable frequency power supply with sufficient power to operate the motor while connected to the truck (with wheels unloaded); instrumentation to accurately measure and display phase voltage and phase current for each phase, motor speed, and vibration levels.

4. The auxiliary motor bench tester shall provide three-phase power for motor operation; variable loading capability; and instrumentation to accurately measure and display phase voltage and current for each phase, motor speed, and vibration levels.

In the event that more than one subsystem is supplied by the same vendor, individual system bench testers may be combined into a single unit.

12.4 (NOT USED)

12.5 (NOT USED)

12.6 VEHICLE MONITORING SYSTEM

This section defines requirements for the Vehicle Monitoring System (VMS). All equipment, including interface equipment, wiring to and from other systems and high speed data bus that is necessary to accomplish the functions defined below shall be provided. Exhibit 12-1 shows the VMS functional block diagram.

12.6.1 General

The VMS shall be considered as a separate vehicle system which complements the diagnostic requirements defined elsewhere in this Specification for each individual system. The VMS consists of the following main equipment: (a) data acquisition modules (DAMs), which act as the VMS signal data bank for each major system and which may be separate from, or integral to, the individual monitored system; (b) a VMS Central Unit (VCU) mounted in the "A" car of each married vehicle pair; and (c) a Fault Display Unit (FDU) on the Operator's console of each vehicle. The VCU in the lead vehicle pair shall be automatically designated as the VMS Lead Unit (VLU). The VMS shall perform the following two main functions:

1. Record vehicle command and operating data for use by investigators in the event of an accident. This data shall include all Federal Railroad Administration (FRA) mandated vehicle signals.

2. Monitor, analyze, and record data from each major system (i.e., propulsion, brakes, ATC, doors, HVAC, auxiliary power and trainlines) to enable ready identification of a defective circuit, or a failed component in the event of a vehicle malfunction.

One VCU shall be installed on each "A" car in the right front seatwell, in accordance with Section 3.5. It shall interface with each vehicle system DAM in the married-pair, the Operator's fault display units (FDUs) in the married-pair, the vehicle/train high speed VMS data bus and the user interface portable laptop PC.

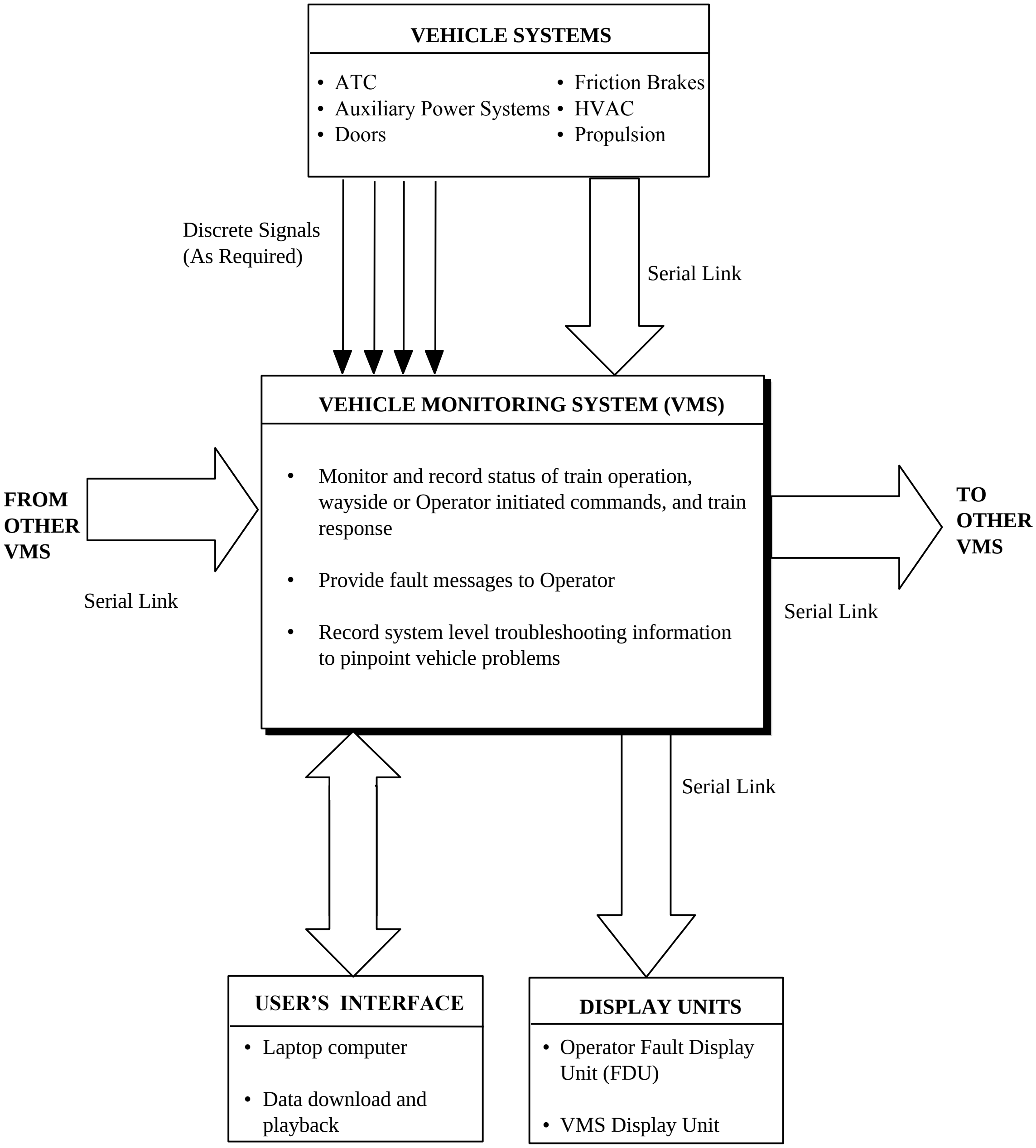
The VCU shall be solid state, microprocessor-based, utilizing reliable EIA certified industrial grade hardware, EIA/IEEE certified connectors, windows based open system architecture preferable and programming shall be done in a high level language, such as FORTRAN or C. It shall also be self-testing and shall go through a complete self-test routine whenever it is energized. The self-test shall include detection of shorts, open circuits or other impedance abnormality at input and output terminals. After completing a good self-test routine, a "ready" indicator shall be illuminated on the monitor and the train Operator's console. If the self-test routine fails, or whenever there is a VCU system malfunction, a "fault" indicator shall be illuminated on the monitor and the train Operator's console.

The VCU shall interface with all microprocessor-based vehicle systems identified in Section 12.6.2.2 via the respective system DAM over the VMS data bus, using Lon Works serial data communication or other Authority approved protocol, to monitor various parameters. *(CDRL 1202)* The monitored parameters shall be processed by the VCU, and fault indication shall be communicated in real time to the train Operator to support fault management actions.

In addition, the VCU shall store a subset of failure events and vehicle conditions. This data shall primarily be used by maintenance and operations support staff for troubleshooting specific vehicle failures and by investigators in the event of an accident.

A user interface shall provide access to the logged failure events, conditions, and operating statistics. This system shall also provide the capability to set up and modify data acquisition and storage variables.

EXHIBIT 12-1 – VMS Functional Block Diagram



12.6.2 VCU Functional Requirements

12.6.2.1 Train Status Monitoring

The lead VCU (i.e., the VLU) shall monitor the status of train operations in the lead car and receive fault data from all other VCUs in the train consist via the dedicated high speed VMS data bus. Each monitored vehicle system shall provide, via the DAM, the necessary signals to the respective VCU on each vehicle pair to enable the operating status of the train to be determined. Exhibit 12-2 lists the minimum number of individual vehicle signals that the VCU shall monitor. The full complement of signals to be monitored by the VCU will be based on the signals provided by system manufacturer's in the respective DAMs.

The VCU shall provide a time-base signal to time and date stamp the various signal inputs received from the monitored systems in the married pair of cars.

Signals that will be monitored by the VCU shall be conditioned by the DAM as required and shall be made available in the specified communication protocol to the high speed communications network. The Contractor shall provide a list of all VCU signals by name, supplier, and signal type during the VMS design review. *(CDRL 1203)* Explanatory notes shall be provided as necessary. The final list of signal inputs to the VCU shall be subject to approval by the Authority.

12.6.2.2 Data Acquisition

In addition to the trainlines designated herein, the following systems shall be monitored by the VCU, using a high speed communication network from the DAMs in each married pair:

A. ATC
B. Doors
C. Friction Brakes
D. Propulsion
E. Auxiliary Power Systems
F. HVAC
G. Couplers

The VCU shall receive inputs from each monitored system and:

A. Annunciate to the Operator's console FDU any fault that prevents the train from operating as intended (i.e., safely and such that equipment will not be damaged). Refer to Exhibit 12-2.

B. Identify the particular vehicle and component that has a fault problem to facilitate fault isolation and, if possible, real time correction of the fault.

C. Record enough failure related data to enable maintenance personnel to readily identify a failed device suffering either an intermittent or "hard" failure.

D. Record data as specified in Section 12.6.3.

Exhibit 12-2 — Vehicle Signals Monitored by the VMS

Processed System Signals	
ATO	Wheel Slip Indication
Manual	Power/Brake Trainline
Propulsion	Brake Rate Trainlines (5)
Dynamic Braking	Propulsion Motor Current
Friction Braking	Door Summary (Right and Left) (Change of State)
Limited Speed	Doors Bypassed (Activation)
Regulated Speed	Car Number
Actual Vehicle Speed	ATP Cut-out Switch
Vehicle Traction Current	Propulsion Cut-out Switch
Primary Voltage	Station Stop Cancel Pushbutton (Activation)
Auto Door Open (Right and Left) Command	Skip Stop Command
Auto Door Close (Right and Left) Command	Speed From Axle Tachometer
Manual Door Open (Right and Left) Command	Motor Configuration (Series or Parallel)
Manual Door Close (Right and Left) Command	Propulsion System Operating Mode
Air Reservoir Pressure	Motor Overload Signal
Brake Pipe Pressure	4 Brake Tachometers
Brake Cylinder Pressure	Ground Detection (Change of State)
Hydraulic Pressure (if applicable)	Load Weigh Signal
Nitrogen Pressure (if applicable)	Brake Overload Signal
Control Lock Interlock	Zero Speed (Change of State)
Dynamic Brake Cut-out	Door Motor Current (Right and Left)
Trainline Tripped	ATC Signal Frequency
DC Control	ATC Signal Level
Couple	Station Stop Profile Speed
Uncouple	Train Berthed Indication (Change of State)
TCR Indication	Program Stop Command
Regenerate Brake Cut-out	Marker Frequency
Brakes Applied	Type of Station Stop (A, B, C)
Brakes Released	Power Level
Door Control	Train Number
Emergency Stop	Train Length
Air Recharge	Train Destination
Door Interlock	Train Ready
Coupler Relay	Park Brake Applied or Released
Emergency Slip/Slide	Third Rail Voltage

Exhibit 12-2 — Vehicle Signals Monitored by the VMS (continued)

Trainline Signals			
17	Rate Common	11A	To Monitor Train Lg. (T.L. 12A for "A" Car)
18	Rate Selection (1)	11B	To Monitor Train Lg. (T.L. 12b for "A" Car)
19	Rate Selection (2)	12A	To Monitor Train Lg. (T.L. 11A for "A" Car)
20	Rate Selection (3)	12B	To Monitor Train Lg. (T.L. 11b for "A" Car)
21	Rate Selection (4)	77	Regenerate Brake Cut-out
8	Brake Pipe Recharge	22	Power Brake
24	SW2	40	B -
25	Series (FS1)	34	B +
26	Parallel (FS1)	37	B +
27	Field Shunt # 1 (FS2)	58	B -
28	Field Shunt #2 (FS3)	70	Brakes Applied +
29	Field Shunt #3 (FS4)	38	B +
30	SW1	39	B -
31	Control Lock Interlock	35	B -
32	Motor Overload Indication	79	Brakes Released
33	Trainline Tripped	57	B +
55	Dynamic Brake Cut-out	71	Brake Released
76	Crawl	3	Door Control
69	M-G Lockout	82	Emergency Stop
75	Environmental Control Off	51	Air Recharge
44	DC Control	53	Door Interlock
45	Environmental Control On	13	Coupler Relay
49	Reset, Communications	7	Brakes Applied
41	Communications Intercom	4	Door Control
42	Communications Intercom	14	Coupler Relay
46	Communications P.A.	52	Door Interlock
47	Communications P.A.	59	Destination Signal - BIT 1
15	Forward-Reverse (T.L. 16 for "B" Car)	60	Destination Signal - BIT 2
16	Forward-Reverse (T.L. 15 for "B" Car)	61	Destination Signal - BIT 4
54	Couple	62	Destination Signal - BIT 8
56	Uncouple	63	Destination Signal - BIT 10
67	TCR Indicator	64	Destination Signal - BIT 20
23A	To Monitor	65	Destination Signal - BIT 40
23B	To Monitor	72	Emergency Slip Slide
10A	To Monitor Train Lg. (T.L. 6A for "A" Car)	73	Snow Brake Set-up
10B	To Monitor Train Lg. (T.L. 6B for "A" Car)	74	Brakes - Man. - Auto
6A	To Monitor Train Lg. (T.L. 10A for "A" Car)	48	Uncouple
6B	To Monitor Train Lg. (T.L. 10B for "A" Car)	83	Couple

Note: Indicated Trainlines are for both "A" and "B" cars unless otherwise indicated.

12.6.2.3 Self Test

The VCU shall perform self-diagnostics, and annunciate on the VDU in the Operator's cab, whether the system is ready or an error exists.

Hardware and firmware within the VCU shall provide for self-test of critical system functions. Detection of a failure will cause an indication to be displayed on the monitor of the failed unit and on the train Operator's console in the operating cab.

Internal test patterns shall be written onto the Data Bus and then stored and read back onto the Data Bus and compared with those originally generated. Actual data patterns generated shall simulate and verify both a high and low bit condition.

Self-test of the random access memory (RAM) portion of the operational memory shall be accomplished by writing, reading, and then comparing test patterns to ensure proper operation. Small areas of RAM shall tested at a time. Prior to test, data resident in the area to be tested shall be transferred to another section of RAM and restored upon test completion.

Self-test shall be performed in a "background" mode, interlaced with normal operation on a non-interfering basis. It shall be automatically accomplished at twenty four hour intervals. It shall be possible for maintenance and operation support staff to select different time intervals and have the firmware simply modified by insertion of this new interval value.

Error conditions flagged by the VCU shall include:

A. I/O error (out of range)
B. Microprocessor Timing Error
C. Memory Capacity Reached 85% Utilization (memory log or counter)
D. Watchdog Time Invoked Reset

If during self-diagnostics, it is determined that the VCU is not functioning properly, such failure shall be annunciated on the FDU in the affected car and annunciated on the FDU of the lead cab in the train.

12.6.2.4 Data Processing

The VCU data processor shall schedule, control and initiate data acquisition, processing, and analysis. It shall be possible for engineering personnel to modify selected data acquisition signals and parameters.

To enable statistical analysis on a daily, weekly, or continuous basis, records shall be stored for later download and analysis. These records shall include all fault categories, and a subset of failure events and vehicle conditions. The Authority shall be provided with the capability of setting the parameters for each statistic recorded by the system.

The VCU shall retain a non-volatile record of train Operator initiated commands and system responses for a minimum of 2 hours before overwriting. Overwriting shall be such that the latest information is retained. This will provide vital information for post analysis in the event of an incident. Manual down loading of data recorded to a floppy disk or other non-volatile storage shall be possible. In addition, the Contractor shall ensure that sufficient memory is allocated to allow the Authority to analyze intermittent problems for recorded events and associated signals over a period of 30 hours minimum.

A shut down method, which stops recording of new data based on a vehicle operations failure (such as a collision or major vehicle malfunction), shall also be provided. Continuous recording shall cease upon such failure so that the record of events preceding the failure are retained. The Contractor shall recommend shut down conditions and the technique for the implementing them for approval by the Authority. *(CDRL 1204)*

All data shall be time and date stamped and then stored for later download and analysis.

12.6.3 Data Recording

The VCU shall perform two recording functions :

A. Record vehicle command and operating data for use by investigators in the event of an accident. Recording of this data shall be automatically halted upon detection of events such as excessive impact or other detectable catastrophic event. This data shall include all FRA mandated signals and other data as listed in Exhibit 12-2. The final list shall be prepared by the Contractor and presented for approval during the design review. *(CDRL 1207)*

B. Record events, event related data and other data as necessary in order to identify vehicle defects.

The above recording functions may be performed by one or two units. If two units are provided, one shall record the FRA mandated signals, and that unit shall be environmentally hardened (i.e., fire, water and explosion proof) and shall remain fully functional after catastrophic vehicle accidents. The other unit shall perform the remaining data recording functions and need not be environmentally hardened. If only one unit is used, that unit shall be fully environmentally hardened.

12.6.4 Data Reporting

All data retrieved from the VMS, shall enable ad-hoc query for analysis by maintenance and engineering staff and the production of tabular reports, strip charts and graphs.

12.6.5 Design Criteria

The VCU design and installation shall not degrade in any way the reliability and safety of vehicle systems. It is unacceptable for a failure in the VCU or its wiring to cause a fault in the vehicle system. Specifically, the train lines are particularly vulnerable in this respect, since they are normally detected directly as a voltage.

The VCU design shall account for the following:

A. Complete galvanic isolation on all inputs and outputs. The isolation and input protection shall meet the electromagnetic compatibility requirements of Section 1.4.5.

B. Protection from damage due to transient over and under voltage conditions, as specified in Section 2.2.

C. Operation without equipment degradation due to environmental conditions, as specified in Section 2.4.

12.6.6 VCU Hardware Requirements

12.6.6.1 Microcomputer

The VCU microcomputer shall consist of a central processing unit, other processors as required, a real time clock, working memory, and input and output devices.

A. **Chassis**. The VCU microcomputer chassis shall be a fully enclosed unit with dimensions suitable for installation under a passenger seat. The chassis shall be designed such that the unit can be easily installed and/or replaced. All microcomputer boards and the visual display shall be easily accessible once the passenger seat is removed. The microcomputer boards shall meet the requirements of Section 15.29.

B. **Memory**. The VCU microcomputer shall be capable of storing in RAM, a minimum of 2 hours of the identified train operator initiated commands and data from the DAMs, including FRA mandated signals. It shall also store in non-volatile memory, 30 hours of events and associated signals. Expansion capabilities shall be provided to increase non-volatile memory capacity by 35 percent.

C. **Input/Output Capabilities**. The VCU shall provide sufficient input and output capability to accomplish the functions defined in Section 12.6.2, plus 35% to allow for future expansion. This 35% includes both analog and digital input/output capabilities. Input/output interface hardware of the VCU shall be compatible with the vehicle system interfaces. Serial data communication links shall also be provided as required. The VCU shall be capable of monitoring all the serial inputs at a rate no less frequent than 25 msec, and monitoring all analog and digital inputs at a rate no less frequent than 2 msec.

D. **Signal Conditioning and Filtering**. Signal conditioning and filtering for all VCU interfaces shall be provided to reduce the effects of noise and provide transient protection. The filter cut off frequency shall initially be compatible with the 2 msec sampling rate. Provisions shall be made for the cut off frequency to be adjusted during initial field testing.

12.6.6.2 Vehicle Interface Requirements

The VCU shall be interfaced to the vehicle systems in a manner that shall prevent failures of the monitoring system from affecting proper operation of the vehicle. Interfacing to fail-safe circuits shall not degrade the safety of the circuits. Conversely, failure of vehicle systems shall not affect operation of the VCU. All monitoring points shall be terminated in a connector or at a terminal block which are readily accessible for maintenance inspection and troubleshooting. The type and location of these terminations shall be approved by the Authority.

A. **Signal Wiring**. It is the responsibility of the Contractor to provide the required essential vehicle system signals to the VCU. The signal wiring type, routing and installation used shall meet the requirements specified in Sections 15.17 through 15.22.

B. **Serial Communications Network**. A serial data link shall be used for the following VCU interfaces:

1. DAM to VCU
2. VCU to Operator’s cab
3. VCU-to-VCU within a multi-vehicle consist
4. VCU-to-user’s interface laptop computer (RS-232).

C. **Power Supply Connection**. Each VCU shall be powered from a non-loadsheded circuit of the vehicle’s 37.5 VDC system. The battery system source, with the voltage between 23 and 42 volts, is defined in Section 9.1.4. This cable shall be protected by a suitable over-current device. In addition, the return of the VCU shall be connected to the battery ground.

12.6.7 <u>VCU Software Requirements</u>

12.6.7.1 Operating System

The VCU operating system shall provide the following functionality:

A. Start-up, initialization, and system test
B. System timing and scheduling

C. Interrupt routine
D. System error watchdog
E. Memory management
F. Data input and output routine(s)
G. Serial interface driver(s)
H. VCU-to-VCU communication protocol
I. User interface communication protocol.

The operating system shall form the basis for all VCU application software.

12.6.7.2 VCU Application Software

The VCU system baseline application software shall consist of the following six functions, as a minimum:

A. System Test
B. Signal Acquisition
C. Data Processing and Output Control
D. Train Commands and Systems Responses Recording
E. Data Communication
F. VCU Display Unit
G. VCU/PC Interface.

The VCU shall incorporate the following features:

A. Use of graphics to illustrate the origin of a problem

B. Ability to mix and match signals to yield the optimum configuration

C. Ability to zoom in on events to get better resolution on the cause of the problem

D. Software shall be open architecture, and able to be ported to other software packages, such as, Microsoft Access, Excel, etc.

E. Software shall be able to locate faults, whether they are intermittent or hard failures, by fault type, etc.

F. The system shall be capable of being upgraded on site, in situ. That is, the units shall not require removal from their mountings in order to upgrade their firmware.

G. It shall be possible for the user to define and qualify fault types and parameters. The fault may be complex, consisting of 4 or 6 different signals that need to be monitored.

12.6.8 Consist Fault Logic

Faults shall be communicated to each vehicle's respective VCU, which shall then be communicated to the Train Operator via the VCU Operator's Fault Display Unit (FDU). The VCU shall process the inputs from the essential vehicle systems and be able to determine a vehicle fault based upon the defined vehicle fault parameters. Vehicle fault parameters shall be defined by the manufacturer and approved by the Authority. The Authority shall have the capability of changing fault parameters.

12.6.9 <u>Fault Messages</u>

The VCU will facilitate fault isolation and real time correction of the fault, if possible, by identifying the particular vehicle and component that needs to be reset or cut out. The fault messages displayed to the Train Operator must be displayed in real-time with respect to the fault condition.

Example fault messages to be determined by the VCU include, but are not limited to the following examples:

1. "BRAKES IN EMERGENCY: Brake pressure < ___ psi on Car # ___."
2. "BRAKES NOT RELEASED: Car # ___ A or B Truck."
3. "BRAKES BINDING: Car # ___, Parking Brake Engaged."
4. "LOSS AIR PRESSURE: Car # ___, Compressor Failure."
5. "ALL DOORS NOT CLOSED: Door number ___, leaf ___ not locked."
6. "AUTOMATIC DOOR OPERATION DISABLED: Brake Loop Bypass Operated."
7. "NO WAYSIDE COMMUNICATIONS: Car # ___, Communication Failure."
8. "NO ATO: Car # ___, Tachometer Failure."
9. "PROPULSION FAULT: Inverter on Car # ___ failed."
10. "NO PROPULSION: Car # ___, Loss of Third Rail."
11. "ATC CUTOUT: Car # ___, ATC Bypass Switch Engaged."

Additional faults messages shall address car/system conditions and events such as cold/hot/dark car, coupler malfunction, station overrun, train/operator circuit breaker trip, door malfunctions, no/low traction power, no primary power and the like. The final list shall be developed by the Contractor and presented for approval during the design review. *(<u>CDRL 1205</u>)*

12.6.10 <u>VCU User Interface</u>

The VCU system user interface platform shall be an IBM-compatible computer, which shall include the state-of-the-art microprocessor at the time of delivery, CD ROM active matrix color monitor, integral pointing devices and the latest version of Windows operating system. Fourteen (14) separate but identical units, suitably packaged to prevent damage in the field, are required. The minimum random-access memory (RAM) of the interface platform shall be 32M. The Contractor shall also provide a spare battery for each interface platform.

The user's interface shall provide the capability to:

A. Define any spare inputs for use in the VCU system processing

B. Re-define and/or modify the vehicle fault messages

C. Define the train status and system performance setup conditions

D. View VCU data

E. Download VCU data to disk or other non-volatile storage

F. Set and/or reset all input and output ports, including spares

G. Provide utilities, including setting up the system configuration (time, date, vehicle identification), print data (similar to print screen) and the conversion of event and condition data to ASCII format.

The user's interface shall be menu driven and provide password protection. The VCU user interface shall consist of a software package capable of communicating train status and fault conditions.

The user's interface shall also provide the capability to set up and modify data acquisition and storage variables. Typical variables, which shall be software selectable, include:

A. Interface type
B. Data sampling rate
C. Logic definition for vehicle parameters
D. Data logging rate
E. Memory reset.

12.6.11 VCU Information Displays

Two types of information displays shall be available to annunciate train status and vehicle systems performance information: a single VCU Display Unit mounted on the VCU case and separate Operator's Fault Display Units (FDU) mounted in each cab of a married pair. Alternatively, a single display unit mounted in each cab of a married pair and combining the functionality of both the VCU and the FDU may be used. In this latter case, the VCU functions in the operating cab unit shall be inhibited to restrict the availability of excess and unnecessary data and control to the Operator.

12.6.11.1 VCU Display Unit

The VCU Display Unit shall be capable of annunciating, in real time, the status and logical values of all discrete inputs and outputs, and the status of all connected subsystems (ATC, propulsion, brake and door systems, etc.).

The VCU shall include a visual display unit, located such that it is visible when the VCU is viewed looking down into the seatwell. The VCU display unit shall annunciate specific fault conditions. Fault messages to be annunciated shall be derived by each vehicle system and shall be as defined and approved during the Design Review process. The Authority shall be able to scroll both forwards and backwards on the display unit to view stored fault messages. Displays shall be menu driven.

12.6.11.2 Fault Display Unit (FDU)

A Fault Display Unit (FDU) shall be installed in each Operator's cab in a location to be approved by the Authority. The FDU shall:

A. Provide capacity for annunciating specific system failure conditions not to exceed 80 alpha numeric characters per message.

B. Provide an audible alert to the Operator that a visual fault message has been transmitted.

It shall be possible for the Authority to select which messages are annunciated at the FDU.

12.7 SPECIAL TOOLS

Special tools are those tools that are not commonly available from commercial tool suppliers, but which are necessary to properly maintain the equipment. Special tools include items such as jigs, fixtures, special gauges, printed circuit board extender cards, and non-standard hand tools.

Except for bench test devices, which are separately addressed herein, all special tools used by the Contractor and subcontractors to assemble, test, calibrate, or align components and equipment shall be provided. Sufficient quantities of special tools to supply six maintenance shops shall be provided.

Complete drawings, and parts lists for purchased parts, shall be provided for all special tools.

One set of special tools shall be delivered with the lead married pair of cars. The remaining five sets shall be delivered no later than 6 months after delivery of the lead car.

The Contractor shall provide a list of all special tools to be delivered under the contract. The list shall be arranged by system and include a description of each item, nomenclature, and manufacturer's part number. The list of special tools shall be updated or verified as accurate and all-inclusive at 60-day intervals. *(CDRL 1206)*

SECTION 13
COMMUNICATIONS

TABLE OF CONTENTS

Section **Page**

Section **Page**

SECTION 13
COMMUNICATIONS

13.1 SCOPE

13.1.1 General

This specification states the functional and design requirements for the carborne communications system.

13.1.2 Subsystems

The complete system-wide mobile radio facilities consist of three discrete subsystems that provide continuous two-way communications, without environmental restrictions, between Central Control and Trains, Security, and Maintenance. The carborne mobile radio communications equipment specified herein will communicate with the fixed base stations of the Revenue Train Operation subsystem.

A. The fixed portion of the Revenue Train Operation subsystem is comprised of base stations, control facilities, repeater networks, and antenna arrays. The latter arrays are used in conjunction with other mobile radio subsystems by the use of appropriate filters to provide the necessary isolation between subsystems.

B. Each of the subsystems is arranged in a half-duplex configuration with a push-to-talk operational mode.

C. Separate VHF radio frequencies are assigned to individual routes and services. This requires all carborne radio equipment to be capable of selectively operating on eight frequencies.

13.1.3 Functions

The carborne communication equipment shall provide the following functions:

A. Separate two-way communication between Central Control, Yard Control and Security, and the train Operator via existing wayside base stations, and two-way communications between mobile maintenance radios supplied by others and the train Operator.

B. One-way communication to the passengers from the train Operator, via the public address system.

C. One-way communication to passengers from Central Control via the carborne radio and the public address system.

D. Two-way communication between the passenger section of the car and the train Operator via the passenger call system.

13.2 FUNCTIONAL DESCRIPTION

13.2.1 General

All messages shall be intelligible and acoustically pleasing to passengers under all operating conditions. Speech peaks shall be limited to approximately 3 dB above the average input level.

Refer to Contract Drawing 97936-030 for a block diagram of the audio-interconnections for the carborne communications equipment.

13.2.2 Mobile Radio Functions

The Carborne Radio System shall selectively provide two-way voice communications between Central Control and the train Operator, Yard Control and the train Operator, and the train Operator and other mobile radio subsystems. The carborne Mobile Radio System shall also provide one-way communication from Central Control to the train Public Address (P.A.) System.

13.2.3 Public Address Functions

A. Central Control Announcements: Personnel at Central Control shall be able to speak directly over the train P.A. system via the mobile radio, with the assistance of the train Operator.

B. Train Operator Announcements: The same microphone that is used for the mobile radio shall also be used for addressing the train passengers over the P.A. system.

13.2.4 Passenger Call System

Call stations shall be located at each end of each car to permit two-way communication as an intercom between the passengers and the train Operator. Call stations shall be clearly designated and located as follows:

A. “F” End: 48 inches from the floor, located on the passenger compartment side of the Operator’s cab. It shall be readily accessible when the cab door is closed.

B. “R” End: on the left hand end door post (facing the door from inside the car) in a small projection from the surrounding lining, at a height of approximately 48 inches from the floor.

The call stations shall be enclosed to prevent entry of moisture.

Depressing a momentary action red illuminating push-button associated with any call station shall connect the call station to a cab loudspeaker and alert the train Operator. The push-button at the call station shall remain illuminated after it has been depressed and the call station shall remain on line until the call station has been reset by the Operator.

An illuminated momentary action push-button designated “Reset Intercom” located in the communications control panel of the active cab shall be illuminated and a single stroke chime in the Operator’s cab shall be actuated when a call station push-button is depressed.

When the momentary action push-button in the cab designated “Talk Intercom” is depressed, the Operator shall be able to address all activated call stations. When this push-button is released, all activated call stations shall be able to address the Operator. A volume control shall be located in the communications control panel of each cab to adjust the volume of the call station talking to the Operator. When the “Reset Intercom” push-button is depressed, the lamp in the “Reset Intercom” push-button on the Operator’s cab and the lamp in the push-button at the passenger call station shall be extinguished and the connection to the call station released.

A total of four intercoms shall be capable of being operated simultaneously allowing communication with the Operator without appreciable degradation, regardless of train length.

13.3 CARBORNE CONTROL SYSTEM

13.3.1 Cab Equipment

Carborne equipment shall have a control position in the Operator's cab at each end of each married pair of cars. Each cab shall have a microphone, speakers, trainwide Public Address (P.A.) system, trainwide passenger call system, and necessary cabling and accessories to allow it to control the operations of one common transmitter/receiver installed in the "B" car.

A. The communications control panel shall be a flush mounted self-contained unit and held in place by Allen socket screw fasteners. This panel shall be installed from the top of the console to facilitate maintenance. Interconnecting cables shall be of sufficient length to provide for internal adjustments without the need for disconnecting the cables. The panel design shall ensure that elements such as switches, potentiometers, and relays will operate for extended periods without debilitating oxidation or corrosion. This panel shall include a receptacle that conforms to MS-3102E: 1992 for a screw-on gooseneck microphone stand as well as all controls and displays required for train communications. MOD 1

B. Audio circuits between control points and communication units shall be at +7 dBm level.

C. Controls shall be mounted in a convenient but not vulnerable position on the left-hand side of the Operator's console, as shown on Contract Drawing 97936-009.

D. The microphone shall be of the dynamic type working in conjunction with audio compression circuitry to suppress or reject unwanted cab noises from broadcast. The microphone shall be semi-permanently mounted on a flexible 6-inch "goose neck" extension compatible with the receptacle specified in "A" above. See Section 13.5.3 for frequency response and output level details.

E. Separate interface circuitry shall be provided for interfacing between the radio set and communications control panel. The interface board shall provide for the following:

   1. Circuitry to prevent simultaneous operation of the radio set from two control panels
   2. Frequency selection
   3. Transmitter power output indication
   4. Transmitter audio isolation
   5. Single tone generation and timing to provide an RF transmitted 1 kHz Central Call signal.

F. Descriptions of the various carborne communication control functions and displays follow:

   1. Passenger Call Volume Control: Rotary clutch-type potentiometer. Control shall provide continuous variation from 10% to 100% of maximum volume at the cab loudspeaker.

   2. Passenger Call Chime: A single stroke chime or equivalent friction tone generator. Chime shall operate once each time a call button at a passenger call station is activated.

   3. Reset Intercom: Nonlocking push-button. When this push-button is momentarily depressed, at the termination of a conversational transaction, any attached passenger call station shall be detached and annunciator lamp of that call station shall be extinguished.

      The Annunciator Lamp shall be part of the "Reset" push-button and shall be lit when a call button at a passenger call station is activated and remain lit until the "RESET" push-button is depressed.

   4. Talk Intercom: Nonlocking push-button. The train Operator must depress and hold this push-button in order to reply to a "passenger call." When the push-button is released, the Operator shall hear the passenger side of the conversation over the cab loudspeaker.

5. Radio Squelch: Rotary clutch-type potentiometer. This control shall provide manual adjustment of the radio squelch threshold. If the transceiver provided by this contract is designed with an automatic squelch control feature, the manual potentiometer shall still be functional for use with transceivers incorporating manual squelch control.

6. Radio Volume Control: Rotary clutch-type potentiometer. Control shall provide continuous variation from 10% to 100% of maximum volume at the cab loudspeaker.

7. Radio Channel Selector: Four-position rotary stepper switch. Each position shall select a specific operating channel for the two-way VHF mobile radio telephone. A lamp under each setting shall display the digit corresponding to the channel that has been selected. The selected channel display shall be lighted at all times in the keyed-up cab.

8. Radio Band Selector: A push-on, push-off selector button shall give a color coded visual indication of which band of frequencies is in use. Two parallel connected blue lamps shall indicate the selection of radio channels 1-4, while two parallel connected amber lamps shall indicate the selection of channels 5-8. The actual selection of each band shall be accomplished by providing the appropriate electrical ground or nominal 12 VDC to the radio channel select lines as described under AAR guidelines.

9. Talk-Public Address: Nonlocking push-button. The train Operator must depress this push-button and hold it in order to make an announcement over the public address system. Radio audio output shall be attenuated by 20 dB when this push-button is depressed. The radio attenuation circuitry shall be designed such that any failure of this circuit results in full radio output.

10. Radio-Public Address: Nonlocking push-button. This push-button must be depressed and held to allow the dispatcher in Central Control to make an announcement in the train over the public address system via the VHF mobile radio telephone.

11. Central Call: Nonlocking push-button. When this push-button is momentarily depressed and released, the VHF radio transmitter shall be keyed and modulated with a 1,000 Hz tone for a period of 1 second.

12. Radio Transmit: Large nonlocking push-button. In order to talk over the mobile radio, this push-button must be depressed and held to key the transmitter.

    The Radio Transmit push-button shall include two lamps which shall give an RF activated red indication that the transmitter is keyed and a green indication when receiving or in a non-squelched operation.

13. P.A. Level VU Meter: Sound Level Indicator. A color band VU Meter shall be installed on the Operator’s console to provide the Operator with voice level/line level monitoring of PA announcement. Color bands shall be as follows:

    a. Green = Voice level too low
    b. Yellow = Satisfactory voice level
    c. Red = Voice level too high

14. Automatic level control shall be provided.

G. The radio loudspeaker shall be ceiling mounted, in a manner similar to that of the Authority’s existing cars.

H. The passenger call loudspeaker shall be mounted on the right hand side of the cab on the KL panel approximately 5 feet from the floor as shown on Contract Drawing 97936-011.

I. All surface mount potentiometers shall be of the clutch type and shall be linear or audio taper, as appropriate.

13.3.2 <u>Availability of Functions</u>

All communications control functions shall be operable only from the selected cab whenever the Control Lock Switch of that specific cab is in the "ON" position. Transmission to other cars in a train consist shall be as shown on Contract Drawing 97936-030.

A. The Control Lock Switch shall provide a connection to the prime ground through an interposing interlocked relay for all controls, indications and loudspeakers associated with the cab. The control lock switch shall also provide a connection to the positive battery connection for all communications equipment associated with that cab and shall provide a positive battery connection to the VHF radio, in the same manner.

B. The interposing relay contacts for communications shall be silver plated and rated for no less than 5 amperes.

13.3.3 <u>Panel Layout</u>

The required layout for the control panel in each cab is contained on the Contract Drawing 97936-009.

13.4 VHF RADIO EQUIPMENT

13.4.1 <u>General</u>

Radio equipment shall have a fully solid state receiver, transmitter, and power supply and shall comply with Section 12-10 of AAR Communication Standards. This equipment shall also be capable of operation by cab remote control head and provide remote annunciation of both transmit keying and signal received functions, as on the Authority's existing cars. All equipment, including the transmitter, shall operate at the voltages specified in Section 13.7 and shall be designed for continuous service and shall be resistant to shock, vibration and moisture.

Radio equipment shall operate on the following frequencies:

A. Channel #1 – 160.260 MHz
B. Channel #2 – 160.380 MHz
C. Channel #3 – 160.620 MHz
D. Channel #4 – 161.025 MHz
E. Channel #5 – 161.235 MHz
F. Channel #6 – 160.605 MHz
G. Channel #7 – 161.415 MHz
H. Channel #8 – 161.385 MHz

13.4.2 <u>Transmitter Technical Characteristics</u>

Carrier frequency stability shall be ± 0.0002% throughout the ambient temperature range of -22°F (-30°C) to +140°F (+60°C).

Spurious and harmonic radiation shall be attenuated or filtered to comply with all applicable FCC requirements. (See Section 13.8.3.)

RF output power shall be nominal 30 watts at 37.5 volts, having a minimum of 20 watts at 23 volts and a maximum of 35 watts at 42 volts measured at the radio. VSWR measured at the radio shall not exceed the ratio 2:1. RF output impedance shall be 50 ohms nominal.

Modulation deviation shall be ± 5 kHz for 100% modulation at 1,000 Hz; the audio frequency response shall be within + 1 to -3 dB of 6 dB octave pre-emphasis characteristics from 300 to 3,000 Hz.

Automatic compensation for speech level variation shall be included to prevent deviation in excess of 100% modulation.

FM noise shall be at least 65 dB below 60% of maximum deviation at 1,000 Hz.

Test points critical to operation and alignment shall be accessible at a metering receptacle.

13.4.3 Receiver Technical Characteristics

A. RF input impedance shall be 50 ohms nominal.

B. Audio output shall be not less than 10 watts at less than 5% distortion (into an 8 ohm load at 1,000 Hz).

C. Spurious and image rejection shall be 100 dB minimum.

D. Intermodulation spurious response attenuation at the useable sensitivity level shall be at least 80 dB.

E. Oscillation frequency shall be maintained to within +0.0002% from -13°F (-25°C) to +140°F (+60°C).

F. Modulation acceptance shall be ± 7 kHz.

G. Receiver shall have sensitivity of 1.00 microvolts or better for 20 dB quieting.

H. Test points critical to operation and alignment shall be accessible at a metering receptacle.

13.4.4 Location

The transmitter/receiver shall be located in a dust-free enclosure, readily accessible for maintenance.

A. Standard AAR mountings shall be used.
B. Radio units shall be eight-channel, with carrier operated squelch and shall conform to all AAR specifications. See Section 13.8.4.
C. Transmitter shall have an adjustable time-out timer to automatically cut off transmission and sound an alarm in the cab loudspeaker, after three minutes of continuous emission. When the radio transmit button is released, the transmitter shall instantly reset for normal operation.

13.4.5 Antenna

The antenna shall be a low profile type, Sinclair Excaliber Model 221LP or approved equal, surface-mounted on the roof of the “B” car, 11-1/2 inches left of the longitudinal centerline of the car and longitudinally consistent with the Authority’s existing cars. The installation shall be waterproof and shall not project more than 2-3/4 inches above the roof, including gaskets and mounting plates. Provisions shall be made to ensure electrical continuity between the antenna and the carbody. The antenna radiation pattern shall be omnidirectional and vertically polarized with a minimum gain of unity over the operating band width.

The antenna shall be constructed to withstand the Authority’s car washing machines without damage to the antenna or its attachment to the car body.

13.5 PUBLIC ADDRESS EQUIPMENT

13.5.1 Loudspeakers

13.5.1.1 Interior

All passenger area and Operator's cab loudspeakers, except the passenger area call station loudspeakers, shall be of the direct radiator cone type, having a nominal 6-1/2-inch outside diameter. Each shall be mounted in an enclosure. The entire interior surface of the enclosure shall be covered with a sound absorbing material.

The loudspeakers, except for those used at passenger call stations, shall have an axial-free field sound pressure of 90 dB re 0.0002 dynes/cm^2 at a distance of 4 feet from the loudspeakers with an 80-1,250 Hz, 1 watt warble input signal. They shall have a continuous power rating of at least 8 watts. In its enclosure, the frequency response of the loudspeaker from 300 Hz to 8 kHz shall be no more than 7 dB below its response at 1 kHz.

Radio and passenger call loudspeakers in the Operator's cab shall have a nominal coverage angle of 90 degrees; except for the passenger call station, all passenger area loudspeakers shall have a nominal coverage angle of 120 degrees.

A transformer shall be used in conjunction with each passenger compartment speaker to match a 70.7 volt line to the loudspeaker impedance.

The power delivered to the loudspeaker from the transformer shall be 4, 2, 1 or 1/2 watts, selected by soldering to the appropriate tap on the transformer secondary. The transformer frequency response shall be at least 100 Hz to 10 kHz, ± 1 dB. Total harmonic distortion shall be 0.5% maximum at 100 Hz, and 4 watts output. Transformer efficiency shall be 85% minimum, at 4 watts output. The first pair of cars shall be delivered with their transformers tapped for 1 watt delivered to the passenger loudspeakers. Adjustments, if necessary, shall be made during field tests and shall be used on the remainder of the cars.

A matching transformer shall not be used in conjunction with the radio and passenger call loudspeaker. The loudspeaker's impedance shall be 8 ohms.

Passenger compartment loudspeakers shall be mounted at not more than 10-foot intervals in the car ceilings. At least six loudspeakers are required. Locations of cab loudspeakers shall be consistent with those of the Authority's existing cars. Adequate insulation/isolation must be provided at each PA speaker to preclude an "echo chamber" effect.

The Passenger Call Station loudspeakers in each car shall have a nominal 4-inch outside diameter and shall be mounted in an enclosure. The entire interior surface of the enclosure shall be covered with a sound-absorbing material.

Impedance of the Call Station loudspeaker shall be 45 ohms. Used as a loudspeaker it shall have an axial free field sound pressure of 79 ± 2 dB re 0.0002 dynes/cm^2 at a distance of 10 feet with an 80-1,250 Hz, 1 watt warble input signal. It shall have a continuous power rating of at least 5 watts RMS. The frequency response of the loudspeaker in its enclosure shall be at least 300 Hz to 5 kHz, ± 5 dB. It shall have a nominal coverage angle of 100 degrees; response shall be no more than 10 dB down, 50 degrees off axis. The microphone element of the Passenger Call Station shall have a sensitivity of -50 ± 5 dB re 1 volt/microbar and its frequency response shall be measured in conjunction with the amplifier specified in Section 13.5.2.

Grilles for all loudspeakers in the passenger area ceiling panels shall be flush, of the same material as the ceiling, perforated with round holes, removable for access to the speaker, and held in place with flathead screws. The Contract Drawing 97936-016 shows the desired size and arrangement of perforations, although deviations from these may be made if such deviations are required to permit the loudspeakers to comply with the functional requirements of the specifications and are approved by the Authority.

13.5.1.2 Exterior

The exterior loudspeakers shall have an axial free-field sound pressure of 121 dBA re 0.0002 dynes/cm^2 at a distance of 4 feet from the loudspeakers and shall have a continuous power rating of at least 15 watts. In their mounted location, the frequency response of the loudspeakers from 475 Hz to 14 kHz shall be no lower than 7 dBA below their response at 1 kHz.

A transformer shall be an integral part of each exterior loudspeaker to match a 70.7-volt line to the loudspeaker impedance. The power delivered to the speaker from the transformer shall be screwdriver switch adjusted to 0.9, 1.8, 3.8, 7.5, or 15 watts. The first pair of cars shall be delivered with their transformers tapped for 1.8 watts delivered to the exterior speakers. Adjustments, if necessary, shall be made during the field tests of Section 13.9 and shall be used on the remainder of the cars.

The volume of the exterior loudspeakers shall be no lower than 6 dBA down 50 degrees off axis with a test tone of 5 kHz.

Two exterior speakers per vehicle, one per side, shall be centered above window R2 on the right hand side of the car and centered above window L5 on the left hand side of the car. These speakers shall be impervious to environmental conditions and shall be mounted to provide a watertight seal with the car body. Speakers shall be easily replaced from within the car. Speaker locations shall not violate the vehicle's dynamic outline. Speakers shall be impervious to the chemicals and detergents normally used during car washing; shall not interfere with, or damage, or be damaged by mechanical car wash equipment.

13.5.2 <u>Amplifiers</u>

All preamplifiers, mixer amplifiers, and power amplifiers shall have a frequency response of at least 200 to 10,000 Hz +1, -2 dB at rated output. Response of power amplifiers below 100 Hz shall fall off at a rate of 6 dB per octave. Total harmonic distortion of all amplifiers without compression circuits shall not exceed 1% at 1,000 Hz and full output. Compression circuits shall provide no more than 3 dB difference in output level for a 36 dB range of input and introduce no more than 2% distortion at full compression. All amplifiers shall be of completely solid state design and be able to sustain shorts, opens, or overloads on inputs and outputs indefinitely without damage. Output regulation shall be +1, -0.5 dB, no load to full load.

All passenger loudspeakers in each car shall be driven from a single power amplifier from the activated car. The amplifier shall be rated not less than 30 watts RMS minimum at 1,000 Hz. It shall have a compression circuit and 70.7 volt output. Input shall be bridging, 600 ohms nominal, balanced.

The cab microphone preamplifier shall raise the level of the cab microphone to +7 dBm nominal. It shall contain a compression or noise cancellation circuit.

The line amplifier associated with the Operator's control console shall have two inputs: one from the cab microphone compression/cancellation amplifier, and the other from the mobile radio. The line amplifier shall be capable of delivering not less than +17 dBm to the passenger speaker power amplifiers. The output of the line amplifier shall be connected to the train line only when one of the two inputs is keyed. Keying shall be by interlocked priority in a descending manner as follows: cab microphone, followed by the mobile radio. Output impedance of the line amplifier shall be 600 ohms nominal.

The amplifier which is used to drive every Passenger Call System Talk-Back loudspeaker in the car shall be rated at not less than 6 watts RMS into 45 ohms. It shall contain compression circuits.

The amplifier in the car, which is used to drive the cab Passenger Call speaker, shall be rated at not less than 6 watts RMS into 8 ohms. It shall contain a compression circuit. Used in conjunction with the Car Call Station speakers and preamplifiers, an overall frequency response of 300 Hz to 3 kHz, ± 5 dB shall be obtained. All amplifiers shall be separate units and shall not be dual purpose.

The radio output amplifier will be used for the cab radio speaker.

The amplifier for the monitor speaker shall be rated at 3.0 watts RMS minimum at 1,000 Hz into 8 ohms.

13.5.3 Microphone

The cab microphone shall be of the dynamic type, meeting requirements of Section 13.3.1.D. The microphone shall have a frequency response of at least 200 Hz to 10 kHz, ± 7 dB. Output level shall be -56 ± 3 dB referenced to 1 volt/microbar.

13.6 INSTALLATION CONSIDERATIONS

13.6.1 Location

The amplifier, radio, AAR base and interface unit and "A" car-"B" car communication control equipment shall be installed under the left front back-to-back seatwell of the "B" car. The PA amplifier with power supply shall be installed under the left front back-to-back seatwell of the "A" car.

Accessibility shall be provided as specified in Section 3.11.6.

Sufficient airflow to maintain the specified equipment operating ambient temperature range of -4°F (-20°C) to +120°F (+49°C) within the enclosure shall be provided.

All modules shall be single function plug-in units and removable for servicing without adversely affecting other functions or devices.

Housing, circuit, components, and interconnections shall be resistant to shock, vibration, and moisture.

13.6.2 Wiring

All cabling and interconnections shall be in accordance with the requirements of Section 15. There shall be no splices between terminals, except as noted in Section 15.19.9.

A. All audio pairs shall be shielded twisted pairs; shields shall be grounded at only one end at the prime ground of the married pair.

B. All wires shall be run separately in metal conduit, allowing for individual wire replacement, with no more than two, 90 degree angles per run without an accessible pull box.

C. RG-8/X or equivalent low-loss coaxial cable shall be used between radio unit and antenna with no angle connections. A VSWR of 2.0 or better shall be provided after installation. The antenna coaxial cable run shall be kept as short as possible, avoiding frequency band fractional wave lengths.

D. At any required interconnection points which cannot be accommodated by rack harness or direct cabling, barrier type terminal strips shall be used. No components shall be mounted on terminal blocks.

13.6.3 Inter-car Connections

Connections between married pairs shall be made through the electrical portion of the automatic coupler.

Connections between cars of a married pair shall be through a separate shielded cable with individually shielded audio pairs. Connectors shall be heavy duty weatherproof twistlock type with gold contacts.

13.6.4 Speaker Phasing

Speakers in the passenger section of a car shall be made to function in phase.

13.7 POWER REQUIREMENTS

13.7.1 Supply Voltage

A nominal supply voltage of 37.5 VDC shall be used.

A. All equipment shall accommodate variations between 23 and 42 volts.

B. A transient filter shall be provided to protect all equipment from transients up to 2,500 volts and durations up to 20 milliseconds.

C. Communications equipment shall not electrically interfere with any other carborne systems.

13.7.2 Energization of Equipment

The power amplifier to passenger public address speakers and the passenger call stations shall be automatically turned on from each car's electrical system whenever any Operator's cab in a consist is keyed up. P.A. power amplifiers may be normally off until an announcement is to be made providing that no annoying noise is created when the amplifiers turn on and off. This is permitted only if better system reliability can be gained with respect to the "continuously on" operation.

All other communications equipment shall be turned on or off from the Operator's control panel in the keyed up cab.

13.8 STANDARDS

13.8.1 Duty

All communications equipment shall be rated for continuous duty.

13.8.2 Environmental Conditions

All communications equipment shall perform reliably under the following environmental conditions:

A. Ambient temperature range of -4°F (-20°C) to +120°F (+49°).

B. Maximum Relative Humidity of 95%.

Equipment shall be subject to a storage temperature range of -22°F (-30°C) to +140°F (+60°C). Equipment operated within the storage temperature range shall not be damaged but may operate in a degraded mode.

13.8.3 Federal Communications Commission Rules

Radio transmitters are required to comply with the applicable rules and regulations of the Federal Communications Commission (FCC). Applications and authorization for frequency assignment and mobile licenses have been filed by the Washington Metropolitan Area Transit Authority. Radio equipment installed in the cars shall be certified as having FCC type acceptance.

13.8.4 Association of American Railroads Standards

All RF and audio equipment shall conform with applicable standards of the Association of American Railroads (AAR), Section 12-10. Standard AAR housings and mountings shall be used for all units.

13.8.5 Other Standards

All RF and audio equipment shall conform with the following applicable standards of the Electronics Industries Association:

A. TIA/EIA 603: 1993 – Minimum Standards for Land-Mobile Communications FM or AM Transmitters 25-470 MHz

B. TIA/EIA 603: 1993 – Minimum Standards for Land-Mobile Communications FM or AM Receivers MOD 1

C. TIA/EIA 603: 1993 – Minimum Standard for Land-Mobile Communications Systems, using FM or AM in the 25-470 MHz Frequency Spectrum

D. SE-101 – Amplifiers for sound equipment

E. SE-103 – Speakers for sound equipment

F. SE-105 – Microphones for sound equipment.

13.9 TESTS AND INSPECTIONS

Inspections, including but not limited to source, shipping, receiving, in-process, and first article inspections shall be planned, scheduled, accomplished, and documented to the requirements of Section 1.7. Qualification, installation and acceptance tests shall be planned, developed, scheduled, accomplished and documented in accordance with the requirements of Section 1.8.

13.9.1 Factory Tests and Inspections

In addition to the requirements of Sections 1.7 and 1.8, the Contractor shall develop and submit a factory test plan for the communication equipment. The plan, covering all replaceable units and major assemblies, shall be submitted for approval 180 days prior to the scheduled commencement of manufacturing. The plan shall identify the in-process testing and inspections, the anticipated schedule for tests and inspections and the schedule for submittal of detailed procedures. As a minimum, factory tests shall include all technical parameters delineated in this Section. Test and inspection procedures shall be submitted for approval 60 days prior to their first scheduled performance. The Authority shall be notified in writing, not less than two weeks in advance, when any test or inspection is to be performed. Factory tests shall include verification that each antenna conforms to the specified radiation pattern.

Six copies of test sheets, with serial numbers of equipment tested, shall be furnished to the Authority certifying that the Standards listed in this Section are met and that the method of measurement specified in the Standards was followed in conducting the tests.

13.9.2 Installation Tests and Inspections

Installation tests shall verify proper installation of equipment and continuity of circuitry. Installation inspections shall verify as a minimum:

A. Only approved products have been used.

B. Equipment installed is in agreement with approved installation drawings and covered by certified factory test reports.

C. Proper routing, color coding and termination of wire and cables.

A record by serial number of communications equipment installed on each car shall be made at the time of installation and shall be kept current by the Contractor until the car is accepted. This record shall be inserted in the Car History Book.

13.9.3 Qualification and Field Tests

13.9.3.1 General

The Contractor shall perform tests to verify that the communication system of each car complies with contract requirements. These tests shall be tailored to each specific system and shall include all operating parameters and functions defined in this Section.

13.9.3.2 Plans and Procedures

The Contractor shall submit for approval a detailed plan for conducting field tests a minimum of 180 days prior to the scheduled delivery of the first cars.

The Contractor shall submit, for approval, detailed test procedures for conducting each test a minimum of 60 days prior to the scheduled delivery of the first cars. Additionally, the Contractor will obtain FCC certification for each transmitter installed in each car. Certification certificates will be furnished to the Authority prior to final acceptance.

Test results and corrective action taken shall be entered in the Car History book.

The Authority shall be advised in writing, not less than two weeks in advance, when and where such tests are to be performed and it shall be permitted to witness them if it elects. Waiving of this privilege shall in no way relieve the Contractor of full responsibility for the proper testing, the quality of equipment supplied, or compliance with the standards and specifications.

SECTION 14
TRUCKS

TABLE OF CONTENTS

SECTION 14
TRUCKS

14.1 GENERAL

Each car shall be equipped with two, four-wheel, inside frame, equalized, roller bearing trucks having a rubber primary suspension system and an air-spring secondary suspension system. Each truck shall be equipped with two traction motors, each geared to a single axle using a parallel drive in accordance with the requirements of Sections 10.3 and 10.4, and two disc brakes per axle in accordance with the requirements of Section 10.8.7. Achieving a low overall truck weight shall be a key design aim, consistent with meeting the strength and life requirements of this Section.

The trucks shall be of an electric-railway passenger-car motor-truck design that has been used successfully in revenue passenger service for a minimum of 250,000 miles, that complies with all performance, strength, and ride-quality requirements of this specification, and that has been produced by a manufacturer of trucks with 5 or more years of successful experience using the fabrication techniques required by the design.

The trucks shall be designed to permit full interchangeability between ends of the cars and between cars furnished under this Contract with no modifications to the truck except for installation and removal of the handbrake rigging. No welding, drilling, tapping, riveting, or cutting shall be necessary for conversion from a non-handbrake truck to a handbrake truck. Any handbrake rigging to be installed or removed from a truck shall be attached with bolted connections. All cars furnished shall have handbrake rigging installed on the front truck.

The trucks furnished under this Contract shall be compatible with the wheel-turning/truing equipment now in use at maintenance facilities operated by the Authority. The truck design and installation shall permit wheel-turning operations to be performed without the need for detrucking or disassembly of any parts from the truck or the carbody.

Provisions shall be made for emergency removal of the truck from under the car in areas of minimum headroom. It shall not be necessary to raise the carbody more than the minimum distance required for the truck and traction motors to pass beneath the coupler and coupler carrier. Any parts requiring removal to permit this shall be fastened with accessible bolts, pins or other approved, removable fasteners.

14.2 DESIGN CONSIDERATIONS

The following qualities shall be incorporated in the design of the truck frame and bolster assemblies. The design shall, in all respects, meet the standards prescribed by this specification in the following areas.

14.2.1 <u>Safety</u>

The design shall comply with the strength requirements of this specification under all loading conditions described in the requirements for truck structural tests. The design shall be such that the stresses developed under absolute maximum load, when running on minimum quality track under all operating conditions and at speeds up to and including 80 mph, do not exceed the yield strength of the material.

14.2.2 <u>Service Life</u>

The trucks shall be designed so that, in normal service under the stated conditions and with proper maintenance and servicing, they shall have a service life equal to or exceeding that of the carbody, without requiring structural repairs or alteration.

14.2.3 Ride Quality

Trucks shall provide a ride quality for both empty and fully-loaded cars as measured over the trucks and at the center of the car, equal or superior in all respects to the ride quality provided by the Authority's existing 1000 Series cars. Ride quality shall be tested by the Contractor, as specified in Section 14.11. The ride quality specified must be achieved at all speeds up to 75 mph. It shall be the Contractor's responsibility to prepare the necessary test procedures for Authority approval and to conduct the test to determine the existing ride quality of the car. The procedure shall be the model for the final car qualification test procedures so that results of both are directly comparable. To ensure comparability, test equipment should be identical in both tests.

14.2.4 Maintenance Economy

The design shall offer minimum maintenance costs for the car as a whole. It shall provide unobstructed access to all parts that require periodic inspection, lubrication, and/or removal and replacement without requiring removal of any other apparatus. Inspection covers on equipment, when removed, shall provide visibility of all apparatus that requires periodic inspection or maintenance. Oil level and lubrication fittings on the truck are to be accessible for servicing from a pit or from the side of the car. Different lubrication fittings shall be used for each lubrication point which requires use of a different lubricant on the truck.

Lifting eyes of sufficient strength shall be provided at four points on the truck frame to permit level lift and transport by shop crane of the fully assembled truck.

14.2.5 Motion Restrictions

The suspension system shall so restrict the motion of the carbody that it cannot, under any combination of conditions, including wear, exceed the dynamic outline shown on Contract Drawing 97936-017.

All truck parts except wheels, gear box, and contact shoes shall clear the horizontal plane formed by the tops of the rails by no less than 2-1/2 inches under conditions of maximum wear, secondary spring deflection, primary spring deflection or rubber creep. The gearbox shall clear by not less than 2.35 inches.

14.2.6 Truck Side Bearing

Side bearings, if used, shall be coated with a material which meets or exceeds the expected life exhibited by Roulon J, manufactured by DuPont.

14.2.7 Truck Equalization

Truck equalization shall be such that the following conditions are met with an empty car on level track:

A. Jacking or lowering any one wheel 2-1/2 inches vertically shall not cause any other wheel tread to lose contact with the rail with air springs inflated.

B. Jacking or lowering any one wheel 2 inches vertically shall not result in a change of more than 35% of the load on any wheel with air springs deflated and brakes released.

14.2.8 Truck Dynamic Stability

The Contractor shall provide a truck assembly that will resist hunting (nosing) at all speeds up to 80 mph and be sufficiently free to turn, such that wheel treads do not exhibit double groove type tread wear patterns or flange wear below the condemning thickness (thin flange) before reaching condemnable high flange condition. High speed stability shall remain acceptable for all normal wheel wear and truck assembly wear or aging. Truck stability and turning stiffness shall not cause abnormal wheel or rail wear.

An analysis of the truck's dynamic stability, when operating as part of the vehicle system on the Authority's track, shall be submitted for review with the truck drawings when they are submitted for approval.

The truck swiveling index, defined as follows, shall be in the range of 0.04 to 0.08 for all conditions of wear pads at swiveling surfaces:

Truck Swiveling Index (TSI) =

$$\frac{T}{2 \times Q \times d}$$

where:

T =	Truck Turning Torque in foot-pounds	
Q =	Wheel Load at AW0 in pounds	
d =	Truck Wheel Base in feet	

The TSI shall be calculated for the following conditions:

A. New vehicle, AW0 wheel load
B. New vehicle, AW3 wheel load
C. Fully worn truck attachment, AW0 wheel load
D. Fully worn truck attachment, AW3 wheel load.

The truck swiveling index, as calculated above, shall be submitted at the time the truck drawings are submitted for approval.

14.2.9 Primary Suspension

Service-proven primary suspension systems shall be provided by the Contractor. The vertical resonance frequency of the primary suspension system shall be separated from that of the carbody by at least 3 Hz. MOD 2 The longitudinal spring rate shall be selected such that all the requirements of this Specification are met. The spring rate shall permit the axles to align in curves and shall in no case exceed 90,000 pound-per-inch for chevron, clouth, or similar suspensions.

Primary suspension shall provide for a useful life of a minimum of 12 years.

14.2.10 Secondary Suspension

Each truck bolster shall be supported by a secondary suspension system consisting of air springs. The springs shall be augmented by elastomeric stops to support the carbody in the event of air spring failure. Safe operation of the vehicle shall be assured at all speeds and car loading conditions when any or all air springs are inoperative. Air spring pressure with AW0 vehicle weight, as specified in Section 2.3, shall not exceed 55 psi.

Vertical and lateral damping of spring action required to meet the ride quality specified herein, and not provided by the air springs and air-spring orifices, shall be provided by hydraulic shock absorbers or approved equal. Shock absorbers shall be non-adjustable.

Lateral stops are required to restrict carbody motions. They shall be provided with elastomeric cushions providing not less than 1/2-inch of compression and a spring characteristic appropriate to attainment of the ride quality specified herein. Any truck parts contacted by elastomeric cushions shall be provided with stainless steel wearing surfaces.

A cut-out cock (one per truck), of approved type and design, shall be provided in the air supply line to the air springs of each truck to vent both springs and to close the air supply to the springs. The cut-out cock shall be located adjacent to each truck and shall be readily accessible from one side of the vehicle without going under the vehicle. Their location shall be identified by the letters "ASC" 1-1/8 inches high, painted in permanent, black glossy enamel on the side sill immediately adjacent to the cut-out cocks. Cut-out cocks shall be lock-wired in their normal operating position.

If separate pressure vessels external to the truck structure are used for air or hydraulic suspension system reservoirs, they shall be designed, tested, and stamped in accordance with the ASME Code for Unfired Pressure Vessels. The reservoirs shall contain telltale holes, if required, in accordance with the requirements of Section 10.8.9. In addition, external reservoirs, if used, shall be provided with manual drain cocks mounted on the lowest point on the vessel. External reservoirs shall be supplied and mounted in accordance with the requirements of Section 10.8.9.

All air reservoirs must provide drainage at their lowest point.

14.2.11 Leveling (Height Control)

The inflation of the air springs shall be regulated by height-control valves to compensate for passenger load changes but not for truck part wear. With the car at standstill, on level tangent track, the height-control valves shall maintain the average floor height within 3/8-inch of nominal (40 inches) when measured at the side door thresholds above the truck bolster. The suspension system shall be such that the car shall not roll just prior to and during unloading to the point that the car floor on the side adjacent to the station platform becomes lower than the station platform. The height-control valves shall be insensitive to dynamic changes of loading due to road shocks. The air volume characteristics of the air-spring system on each truck shall provide for such a contribution to damping of spring action as the Contractor may elect, and for limitation of short-time air demand such that the height-control valve supply can meet normal air consumption while not permitting a flow that would impair the function of other pneumatic systems on the car in the event of loss of air-spring pressure. The suspension system design shall provide for simultaneous deflation of the air springs on both sides of the truck in the event of loss of air pressure in one spring.

14.2.12 Flange Forces

The Contractor shall prove by calculation during the design phase that flange forces which may cause derailment have been minimized. The method for this calculation shall be proposed by the Contractor but, in any case, the L/V ratio shall not exceed 1.2 (where L=Lateral force on wheel flange and V=Vertical force on wheel tread). Only L and V forces applied for more than 0.05 seconds should be considered for this calculation.

14.2.13 Track Forces and Ground-borne Vibration

The Contractor shall demonstrate by calculation or test that vertical and horizontal track forces have been minimized. Rail damaging forces and ground-borne noise and vibration levels shall be no higher than those generated by the Authority's 4000 Series cars. It shall be the Contractor's responsibility to prepare the necessary test procedures for Authority approval and to conduct the test to determine the existing track forces and ground-borne vibration of the Authority's 4000 Series car. The procedure shall be the model for the final car qualification test procedure so that results of both are directly comparable. To ensure comparability, test equipment should be identical.

14.2.14 Corrosion Protection

The truck shall be designed to avoid dirt and snow traps, and areas where moisture buildup could occur inside frame members. The Contractor shall describe the measures to be taken to prevent corrosion of the truck frame.

14.3 SERVICE CONDITIONS

The trucks shall be designed to operate under the following service conditions:

A. Maximum Speed: 80 mph

B. Track conditions (All measurements in inches and made under load):

	Standard Quality (Construction Tolerances)	Minimum Quality (Maintenance Tolerances)
Gauge Variation	± 1/8-inch	+1/4-inch, -1/8-inch
Cross Level and Superelevation Variation	± 1/8-inch	±1/4-inch
Vertical Track Alignment		
Total Deviation	±1/2-inch	±1-inch
Middle Ordinate, 62-foot Chord	±1/8-inch	±1/4-inch
Horizontal Track Alignment		
Total Deviation	±1/2-inch	±1-inch
Middle Ordinate, 62-foot Chord	±1/8-inch	±1/4-inch

All variations of gauge, cross level, and superelevation, with respect to tolerances, will be at a rate not exceeding 1/4-inch per 31 feet of track.

A. Average miles of operation per year: 65,000

B. Station Stops per mile, average: 0.85

C. Rail: 115 RE canted 1:40

D. Minimum Horizontal Curve: Refer to Section 2.1.1

14.4 DESIGN CRITERIA FOR STRENGTH

The truck frame and all truck parts, including motor and gear unit supports and friction brake equipment supports shall be capable of withstanding the maximum loads imposed by the forces acting on the frame, including forces resulting from track shocks, motor torque, friction brakes, and any combination of these forces, without developing stresses which are greater than 60% of the fatigue endurance limit at 10 million cycles for the specified materials.

The ultimate strength of the truck and the truck-to-carbody connection shall be sufficient to secure the entire truck to the carbody in a manner which will prevent separation of the truck from the carbody during derailments, collisions, or other adverse events in which a horizontal load of 150,000 lbs. is applied in any direction at any point on the truck frame. This load may be transmitted from the truck frame through structural members, positive stops, or other rigid, mechanical safety devices or combinations thereof to the carbody bolster. Bolster-locating radius rods shall not be used to provide any part of this strength. The carbody bolster shall be designed to resist this load without damage.

If the truck is restrained longitudinally by bolster anchor rods, radius rods, or similar devices, the rods and any brackets by which they are attached to the truck, the truck bolster, and the carbody, and the members to which these brackets are attached, shall, as a minimum, withstand a longitudinal load equal to four 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.

The truck-lifting hooks and other members used to attach the truck to the carbody shall be designed to provide a factor of safety of 2, based on the yield strength of the material, during vertical jacking or lifting of the carbody. The lifting hooks and other members used to attach the truck to the carbody shall be designed and located in a manner which shall minimize the possibility of damage during low-speed derailments.

All structural and load bearing members of the truck shall be of steel.

Maximum stresses at any point recorded during the tests specified in Section 14.11 shall not exceed the following levels:

A. For Static Load Tests (Section 14.11.1): 40% of yield strength of material.

B. For Overload Test (Section 14.11.2): Yield strength of material.

The fatigue design of the truck frame and bolster shall use the Fatigue Test loads defined in Section 14.11.3. The fatigue stress range used shall be the maximum stress less the minimum stress at a point using any load combination as described in Section 14.11.3. The endurance limit shall be 10 million cycles.

For welded structures, the fatigue stress range shall be within the allowable fatigue endurance limit for non-redundant structures obtained from AAR C-II, Section 7.4 or AWS D1.1, Section 9.

For cast steel structures, the fatigue stress range shall be limited to the published endurance stress values for smooth, flat tension-tension specimens. Alternatively, the Contractor may use recent test results with sufficient data to establish the endurance stress value for 95% survival at the 84% confidence level, as defined in the ASM Metals Handbook, Ninth Edition, Volume 8.

If stresses are found to exceed the specified limits in any tests, the design shall be corrected and the truck re-tested to prove compliance. Any trucks already produced shall be corrected to comply with the revised design.

If any part of the truck structure is required to function as an air reservoir, that part of the structure shall be designed, and tested to a pressure 1-1/2 times the maximum operating pressure expected in service. Stresses associated with the pressure-vessel function shall be included in the above stresses.

Truck frames and bolsters shall be of a service-proven design fabricated by welding or casting or a combination of the two methods. Materials shall be according to Section 15.4 for steel plate and according to Section 15.5 for castings. All welding shall be in accordance with welding and brazing requirements specified in Sections 15.5.4 and 15.23. All cast steel welds shall be inspected to MSS SP-55 “Quality Standard for Steel Casting” and steel plate welds shall be inspected to AWS D1.1, Section 9 requirements. Non-destructive sampling provisions for inspection of welds specified by Section 15.23.4 shall be applied to both cast steel and plate steel weldments.

14.5 DESIGN FEATURES

14.5.1 General

Journal bearing housings, if used, shall be mounted in rubber. No sliding contact surfaces shall be used to guide the journal boxes.

The truck design shall use a minimum number of load-bearing parts, and no metal-to-metal moving contact points, except pivot pins, bolts, and frame articulation joints.

Bolster radius rods, if used, shall be elastomerically cushioned at both ends, and so located as to minimize transmission of longitudinal truck oscillations to the carbody.

The design shall provide for lifting the truck with the carbody without loss of centering engagement. The strength of the members used for lifting the truck with the carbody shall be as specified in Section 14.4.

Threaded fasteners, adjustment points, and structurally critical locations shall be accessible for inspection and maintenance using conventional means.

The design shall provide for shimming to compensate for wheel wear and other lost height in the truck due to wear without resulting in any effect on air spring pressure. Elastomeric suspensions shall have provisions for shimming to compensate for sag or creep. Shimming adjustment range shall allow for a 20-year life with worst-case truck and elastomeric spring tolerances. Shims required to compensate for truck construction tolerances shall be welded in place. Any shimming required to correct for carbody construction tolerances which result from excessive carbody warpage or twist shall be permanently welded to the carbody.

Safety support members shall be provided for emergency support of the traction motors and gearboxes which, in the case of loss of primary support, might present a hazard to safe operation. The safety supports shall not allow any portion of the traction motors or gearboxes to fall lower than 1.39 inches above the head of the rail under any condition while the vehicle is in motion.

Moving contact surfaces shall be provided with renewable low-friction wearing elements. These elements shall minimize the transmission of noise and vibration. Low friction wearing elements shall not require lubrication.

Applicability of novel features shall be substantiated by citation of service experience under comparable conditions and by comprehensive reports of realistic laboratory tests.

Truck parts adjacent to or above current-collector devices and uninsulated power connections shall be shielded against arc damage by approved, dielectric, noncombustible barriers and protective shielding of adequate mechanical strength.

The truck shall be a true rectangle as measured between the centers of axle outer ends within 1/16-inch between the centers on each side and within 1/8-inch between diagonally opposite centers. Axles shall be parallel within 3/16-inch when the truck frame is loaded to the AW2 weight. The truck shall be equipped with gauging points which permit these dimensions to be readily checked. Seven sets of plugs or other gauges required for this purpose shall be furnished by the Contractor.

Wheel, axle, bearing, gearbox, and motor assemblies shall be interchangeable between ends of the truck, and between trucks.

Articulated trucks (trucks with other than a rigid frame) shall have an approved means for keeping side frames parallel when axles are removed and reinstalled.

Jacking pads, if required, shall be provided beneath the truck frame to assist with re-railing.

14.5.2 Cast Steel or Cast Weld Truck Frame Options

The following requirements apply to cast steel or cast-weld truck frames. All production truck castings supplied shall be equal to or better than the design qualification castings in all respects and shall be subjected to the following inspections:

A. Magnetic particle inspection to ASTM E 709 of all critical areas of the castings by personnel certified to MIL-STD-410, latest revision. The maximum permissible magnetic particle indication shall be 1/4-inch in the direction transverse to the usual direction of loading and 3/4-inch in the direction parallel to the usual direction of loading.

B. Radiographic inspection meeting the requirements of ANSI/ASTM E 94 using reference radiographs to ASTM E 446. A sampling frequency shall be selected and submitted for approval. Severity level III of ASTM E 446 is required in all critical areas of such castings, with level V permitted in all other areas. After such severity levels have been demonstrated, the sampling frequency for truck castings shall be one casting out of each twenty-five produced.

Critical welds or critical areas shall be as identified by the truck manufacturer and approved by the Authority, and shall include, as a minimum, all areas, all welds or portions of welds which, based on the results of the stress analysis and truck tests, are expected to be critical in fatigue.

Prior to beginning truck manufacture, the Contractor shall submit for approval an inspection and acceptance plan that includes, as a minimum, the requirements of this section. The inspection and acceptance plan shall also include provisions for written reports to be submitted to the Authority for all tests and inspections described herein. Production of truck frames prior to approval of the required inspection plan shall be at the Contractor's risk.

14.6 WHEELS

Wheels shall be multiple wear, Class C, and made of wrought steel in accordance with AAR Specification M-107, current issue. Wheel design shall provide for 1-1/2 inches wear; that is, a reduction in diameter of 3 inches from new to fully worn. The wheel design in use on the existing cars shall be used. The reference drawing for the wheel is Contract Drawing 97936-018. Disc mounting provisions shown on Contract Drawing 97936-018 shall be used.

Wheels shall be machined all over, removing mill scale and decarburized material from the plates, and plates shall be shot-peened to an agreed-upon standard following finish machining.

Wheels shall be bored and mounted on the axles in accordance with the practices set forth in the AAR Wheel and Axle Manual. Wheel sets shall be concentric within 0.005-inch total indicated run-out when rotated in their bearings.

MOD 2 The thread design shall be as shown in Contract Drawing 97936-018. Wheels shall be marked in accordance with AAR Standards for rim stamping.

14.7 AXLES

Axles shall be hollow and made of alloy steel tubing meeting all AAR Specification M-101 Grade G requirements except mechanical properties, which shall be:

Tensile Strength	105,000 psi, minimum
Yield Strength	65,000 psi, minimum
Elongation in 2 in.	18%, minimum
Reduction in Area	35%, minimum

Bores of hollow axles shall have a finish of 250 micro-inches RMS, or better, before subcritical quench and shall be surface inspected for cracks or injurious defects. Surface inspection shall be visual with the aid of a borescope, dye penetrant or magnetic particle inspection techniques. Hollow axles shall be ultrasonically inspected in accordance with AAR Specification M-101 requirements or as proposed by the Contractor and approved by the Authority.

Inboard journal axles shall be furnished. In no case shall the maximum static unit stress at the center line of the bearing exceed 5,000 psi, the axle being considered as a simple beam under full AW3 load.

All axles shall be subcritically quenched following rough machining and finish machining of the bore. Finish machining shall not remove more than 1/8 inch of metal. Relief grooves shall be provided at changes of section, and the relief grooves shall be cold rolled following finish machining.

Exterior finish shall be in accordance with Section 1 of the AAR Wheel and Axle Manual and shall be given, as a minimum, a magnetic particle inspection following machining.

Axles shall have standard 60-degree lathe centers and shall be marked in accordance with AAR standards.

14.8 JOURNAL BEARINGS

14.8.1 General

Journal bearings shall be an AAR approved NFL design, roller type, and grease lubricated. The design shall have a record of successful service in similar or more exacting service. They shall be designed for an ANSI/AFBMA L_{10} rating life equivalent to 1,300,000 miles under the specified load cycle of 40% at AW0, 40% at AW1, 15% at AW2, 5% at AW3, and an application factor of 2.00.

In addition to serial numbers, journal bearings must be clearly stamped with the manufacturing date. Bearings shall not require inspection more than once every 500,000 miles. Bearings shall be fully sealed and shall not require field lubrication.

14.8.2 Journal and Truck Frame Numbers

Journal bearing locations shall be numbered 1, 2, 3, and 4 on each truck, with odd numbers applied to the left side of the truck and even numbers applied to the right side with the truck installed under a car. Number plates with raised, painted numerals shall be applied to the truck frames at locations which are clearly visible when looking at the side of a completed truck assembly.

14.9 HUBODOMETER

Mounting provisions for hubodometers shall be made on both ends of all axles for all trucks furnished under this contract.

14.10 MANUFACTURING PROCEDURES AND INSPECTIONS

Before starting to manufacture the trucks, the Contractor shall provide to the Authority a list of those procedures involved in the construction including manufacturing inspections except where these are covered by standard specifications, and thereafter the Authority shall be notified of changes therein, and its approval obtained, before they are placed in effect. The procedures embodied in the first truck to be successfully tested shall not be changed in any respect without the concurrence of the Authority.

14.11 TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 1.8.

The first truck shall be subjected to tests in accordance with the requirements of Sections 14.11.1, 14.11.2 and 14.11.3 herein. The Static Load and Overload Tests will be witnessed by the Authority. The Authority will witness the dye penetrant inspection required by the Fatigue Test and may observe the test at any point in its progress.

Tests of the primary suspension system in accordance with the requirements of Section 14.11.4 are to be performed by the Contractor and the report of these tests submitted to the Authority for approval.

The first car or pair of cars shall be used in performance of truck equalization, stability and ride quality tests. These tests will be witnessed by the Authority.

No fewer than 75 strain gauges shall be applied to the truck for static load, overload, and fatigue tests at maximum stress points as approved by the Authority. Location of maximum stress points shall be determined by a finite element analysis. In these truck tests, the term “empty car weight” means the weight of an empty carbody, less trucks. The Contractor is responsible for selecting loads that will develop a high level of confidence in the adequacy of the truck design.

Truck clearances, lengths and locations of hoses and cables, and coupler and drawbar clearances and operations shall be checked by moving a train composed of two married pairs over a curve and a crossover duplicating or exceeding the most restrictive track work specified in Section 2.1.

Height-control valve adjustments, measurement of carbody floor height, and air spring heights shall be checked and recorded for each car.

14.11.1 Static Load Test

The purpose of the Static Load Test is to verify that the maximum allowable stresses specified in Section 14.4 are not exceeded. The test shall be repeated two additional times for a total of three tests with complete release between applications. The truck shall be tested either by individual, load bearing components or as an assembly, as the Contractor elects. If the load bearing components of the truck, rather than the complete assembly, are tested, provision must be made to apply all input loads described herein and for the member under test to react to these input loads in a manner that 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. Maximum unit stresses shall be determined by summation of the maximum stresses developed by the worst case combination of all possible loads. The stress readings for the two applications shall be averaged for comparison with the estimated stresses. The vertical load component shall be 55% of the empty car weight plus 20,800 lbs., the latter representing 55% of the absolute maximum load. The lateral component shall be 15% of the vertical component. The longitudinal component shall be 15% of the vertical component. Accessory loads, such as brake units and traction motors, shall represent maximum steady state conditions; for example, maximum motor 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. At no point shall the averaged stress under the worst case combination of all possible loads exceed the allowable stress specified in Section 14.4. If it does, the Authority shall have the right to require that the design be corrected to bring the test stresses within the allowable stresses; the trucks shall be retested at the expense of the Contractor, and all trucks installed in the cars shall be in accordance with the corrected design.

14.11.2 Overload Test

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 as follows: the vertical component shall be equal to the total empty car weight plus 50,000 lbs.; the lateral component shall be equal to 15% of the vertical component; the longitudinal component shall equal 15% of the vertical component; and accessory loads shall be applied equal to twice their estimated maximum loads (except for gear unit support reaction, which shall be taken at the flashover value). Unit stresses at critical locations and dimensional measurements shall be taken before and after the test between representative points on
MOD 2 the truck as approved by the Authority. There shall be no permanent deformation as determined from strain gauge 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 retested at the expense of the Contractor, and all trucks installed in the cars shall be in accordance with the corrected design.

14.11.3 Fatigue Test

To demonstrate that the truck has adequate fatigue strength under dynamic loading, it shall be subjected to two million cycles of combined loading within the limits specified below. The truck shall be tested as a unit and may contain its internal elastomeric cushioning and springs, if any, or an approved substitute therefore, but not hydraulic damping devices. The vertical component shall vary between 50% of the empty car weight plus 5,000 lbs. and 85% of the empty car weight plus 10,000 lbs. The lateral component shall vary with the vertical component and shall be l5% of the mean vertical load and will vary to the right and left as the vertical load varies. The longitudinal component shall vary with the vertical component and be 15% of the average vertical load with reversal about the zero load point. Accessory loads shall vary between +100% and -100% of their maximum steady state or harmonic dynamic conditions: motor under full motor current and brake unit under full cylinder pressure with l4% adhesion. Loads applied to the truck bolster shall include those resulting from the transfer vertically of the applied lateral force from the height of loaded carbody center of gravity to the lateral bumper height. The phasing of the loads shall be selected by the Contractor and approved by the Authority, and shall be such as to produce the worst-case stresses at critical locations. All tests shall result in maximum combined stresses at the critical locations which do not exceed those required by Section 14.4. Critical locations shall be approved by Authority. The frequency of the load cycling shall be approximately equal to the natural vertical frequency of the truck assembly or as otherwise agreed to by the Authority.

Prior to the test, 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 those defects.

During the fatigue tests, the truck shall be visually inspected periodically to detect possible crack initiation and progression. If evidence of progressive cracking or failure is found, the cause shall be assessed by the Authority and the Contractor, after which an appropriate correction shall be established and the test repeated, at the Contractor's expense.

At the conclusion of the test, a magnetic particle or dye penetrant inspection shall be made for cracks in the presence of the Authority. If any crack is found, the design shall be corrected, the truck retested at the expense of the Contractor, and all trucks installed under the cars shall be modified in accordance with the corrected design.

14.11.4 Primary Suspension Test

A load deflection test and accelerated aging tests shall be performed to demonstrate that the spring rate of the primary suspension system and the creep rate for the materials used are within the design limits. These tests shall prove that the primary suspension system behaves as predicted and will not result in excessive deflection or a decrease in truck clearance above top of rail to less than the minimums prescribed in Section 14.2.5.

14.11.5 Equalization Tests

The following tests shall be conducted to verify equalization provided by the truck design:

A. The test car on level track, with air springs inflated, shall have one wheel on one truck jacked up 2-1/2-inches while contact between the other three wheel treads and the rails is verified. Alternatively, one wheel may be run up on a wedge to obtain the 2-1/2-inch elevation, the other wheels remaining on level track.

B. The test car on level track with air springs deflated and with the brakes on both trucks released, shall have one wheel jacked up 2 inches without resulting in a change of more than 35% in the load on any wheel. A second car may be used to prevent longitudinal motion of the test car.

In the event the required equalization is not attained as indicated by the results of these tests, the truck design shall be corrected and retested repeatedly until satisfactory results are attained and all trucks modified in accordance with the corrected design.

14.11.6 Stability Test

To verify the car stability provided by the truck design, the first car with simulated full load shall be run up on a rail or blocking on one side to simulate 6 inches of superelevation. Lateral displacement and roll angle of the carbody shall be measured. In the event that the degree of motion restriction required by Section 14.2.5 is not attained as indicated by the test, the truck design shall be altered, the truck retested at the expense of the Contractor, and all trucks installed under the cars shall be modified in accordance with the corrected design.

14.11.7 Ride Quality Test

To verify conformance to the ride quality requirements of Sections 14.2.3 and 14.2.10, the first pair of cars shall be subjected to road tests on the Authority's tracks.

Ride quality tests shall consist of operating cars, as a minimum, at speeds of 25 mph, 50 mph, and 75 mph over track selected by the Authority, under two load conditions: empty and with simulated full load. Instrumentation capable of measuring and charting the magnitude and frequency of the vertical, longitudinal, and lateral shocks expected, up to 1.0g and 15 Hz, shall be provided and operated by the Contractor. Sensing units shall be located on the car floor above the intersection of the car longitudinal center line and one truck transverse centerline, and also at the center of the car. They shall be applied directly to the plymetal floor. Provision shall be made for recording vertical, lateral, and longitudinal shocks (vibrations) concurrently, speed, and distance in 100-foot increments, and to allow entry of event markers on recorded data for these tests.

Weights used in simulating full load shall be provided by the Contractor.

After each group of runs, the instrumentation shall be relocated to an existing Authority car in the 1000 Series chosen by the Authority and a series of runs at the same speeds, at the same loads, and on the same track shall be made for comparison. Comparison runs shall be conducted within 24 hours after the start of tests on the new cars, unless weather conditions or other events severely alter the test environment (e.g., track conditions, heavy weather, strong winds, etc.), in which latter case they shall be run with minimum elapsed time. In any event, the maximum elapsed time between the two series of comparison tests shall not exceed 2 weeks. Tests shall be rerun on the new cars if necessary to meet this requirement.

Acceptability of the ride quality will be made by a comparison of the recorded root mean square (RMS) accelerations in the vertical, lateral, and longitudinal directions, during the test runs, of the new and existing cars. In each case, the RMS value of the accelerations will be determined by preparing a power spectral density (PSD) plot for the entire test run and measuring the area under the curve in the frequency range of 0.2 Hz through 15 Hz. The comparison will be made by adding the RMS accelerations in all three directions and at all three speeds for each car. If the total for the new car does not exceed the total for the existing car, the new car will be judged to have complied with the ride quality specification.

In the event that the dynamic behavior of the car is inferior in any respect to the Specification requirements, the Contractor shall submit to the Authority, within 60 calendar days, a program containing a mathematical analysis of the problem and a course of action for its correction. If the Authority approves the analysis and corrective measures, the latter shall be made effective on the test car within 90 calendar days at the expense of the Contractor, the car shall be retested, and, if the measures are successful, they shall be applied to all the cars. If not, the analysis and correction steps shall be repeated, resubmitted, and retested until success is attained, except that, after unsuccessful tests of two sets of corrective measures, the Authority may, in accordance with the General Provisions, require delivery of the cars at a reduction in price.

SECTION 15
MATERIALS AND WORKMANSHIP

TABLE OF CONTENTS

Section **Page**

Section	Page

Section **Page**

Section	Page

Section **Page**

Section	Page

SECTION 15
MATERIALS AND WORKMANSHIP

15.1 GENERAL

15.1.1 <u>Quality</u>

Material and workmanship shall be in accordance with the stated Specification or description, unless written approval for substitution is obtained.

Inclusion of a material or method in this Section does not indicate approval for application or use in a specific situation. When a material or method is specified in this Section, this Section shall be applicable; however, specific requirements detailed in appropriate Technical Specifications Sections take precedence over this Section.

15.1.2 <u>Standards</u>

The following domestic standards and specifications define materials for this contract: Federal or Military Specifications or Standards, the Specifications of the Aluminum Association of America, AAR, ANSI, ASME, ASTM, FRA, IEEE, and additional requirements, as specified herein. Where other or foreign standards are proposed by the Contractor, the Contractor shall submit documentation for Authority review and approval demonstrating that the proposed standards are the equivalent of the foregoing standards and specifications. Proposed substitute specifications shall be submitted in both English and the language of the country of origin.

15.1.3 <u>Marking</u>

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 <u>Cleaning Agents</u>

A list of recommended cleaning agents shall be provided to the Authority for all materials exposed to normal cleaning operations. This information shall also be included in the maintenance documentation for the vehicle.

15.2 JOINING AND FASTENING

15.2.1 <u>Joining</u>

15.2.1.1 General

Certain combinations of materials require particular care in joining to avoid the possibility of corrosion. Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be used at all times where these combinations exist.

15.2.1.2 Joint Fitting

Joints shall be properly fitted, whether exposed or concealed. When not otherwise specified in drawings or specifications, gaps between joints shall be held to a dimension not greater than 10% of the thinner material being joined, or 0.002-inch (0.05-mm), whichever is greater. Gaps shall be uniform in width. 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 the Authority. 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.

15.2.1.3 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 that conforms to Federal Specification TT-P-664. Metal primer may be omitted for like-stainless steel to like-stainless steel joints.

For proper treatment of a connection involving aluminum, refer to Section 15.6.4.

15.2.1.4 Wood-to-Metal Connections

Where wood and ferrous metal surfaces are placed together, the wood shall be coated with aluminum paint conforming to Federal Specification TT-P-38, and the metal shall be coated with a primer that conforms to Federal Specification TT-P-664.

All bolts or rods passing through wood shall be coated with aluminum paint conforming to Federal Specification TT-P-38.

15.2.1.5 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.

15.2.2 <u>Fasteners</u>

15.2.2.1 General

The Contractor and suppliers are responsible for selecting fastener types, sizes, styles, lengths, materials, grades, and finishes that will meet the requirements of this Specification. The Contractor shall minimize the number of different sizes and styles of fasteners used.

Fasteners used throughout the car shall be inch standard fasteners, except that ISO Metric fasteners may be used in conformance with Section 15.2.2.2.2. Cadmium plated fasteners shall not be used.

All fasteners used on this car shall be specified under one of three categories: electrical and electronic; structural and safety-related; or decorative. Fasteners internal to electrical or electronic components are specified in appropriate Materials and Workmanship subsections for electrical devices and wiring. All structural and safety-related fasteners are specified under Structural Fasteners. Fasteners used to attach interior lining or trim and exposed to passenger view are specified under Decorative and Appearance Fasteners.

Safety-related fasteners include, but are not limited to, those applied to trucks, bolsters, brake equipment, couplers, and power collection devices. A fastener is safety-related if failures cannot be tolerated, i.e., if even a single fastener fails there is a possibility of brake failure, derailment, or an accident. In the event of a dispute, the Authority will be the final arbitrator on which fasteners are safety-related.

15.2.2.2 Threaded Fasteners

Prevailing-torque type locknuts shall be nylon insert type, ESNA or approved equal, conforming to Industrial Fasteners Institute (IFI) Fastener Standards or Military Standard MS-21044. Distorted thread 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 (93°C).

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 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.

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 1-1/2 screw threads shall be visible beyond all nuts. When used without elastic stop nuts, bolts shall not project more than 1-1/2 threads plus 1/4-inch (6.4 mm) for bolts 1/4-inch (6.4 mm) diameter or less and shall not project more than 8 threads for larger diameter bolts. With elastic stop nuts, bolt threads shall not project more than 1/4-inch (6.4 mm), regardless of bolt size. MOD 2

15.2.2.2.1 ***Inch-Standard Fasteners***

All inch-standard threaded fasteners shall conform to ANSI B1.1 Standard, Unified Inch Screw Threads, (UN and UNR Thread Form) or IFI 1970 Fastener Standards.

15.2.2.2.2 ***Metric Fasteners***

Specific components, control groups, or individual units supplied to the Contractor by a Supplier or Subsupplier may be supplied with metric fasteners that conform to ANSI B1.13M (ISO-metric) Standards. All internal fasteners and threaded components of the approved assembly shall have ISO-metric threads. Internally, there shall be no mixing of metric and inch threaded fasteners. External mounting fasteners and threaded connecting components shall have ISO-inch threads that conform to ANSI B1.1 Standards. Each unit, component, or group assembled with or containing ISO-metric threads shall be indelibly identified, in an approved manner and in a conspicuous, approved location, to signify that the unit was assembled using metric threaded fasteners or components. 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.

15.2.2.3 Structural Fasteners

All structural fasteners shall have documentation identifying manufacturer and purchase specifications available for examination by the Authority 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 Subcontractor, Supplier, or the Contractor, the Contractor shall obtain and hold this documentation for a period of not less than termination of the warranty period of the last car.

All safety-related fasteners shall either: a) be manufactured, tested, and distributed in accordance with ASME FAP-1-1990, Quality Assurance Program for Fastener Manufacturers and Distributors, 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, and 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 the Authority. 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 car.

All safety-related fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement. If non-standard, structural, or safety related fasteners are plated by other than the OEM, a representative sample of these fasteners shall be tested for hydrogen embrittlement by the Contractor or a supplier. Any failures shall reject the entire lot.

All structural bolts for undercar equipment shall be a minimum Grade 5 and the bolt diameter shall be no less than 3/8-inch (9.5 mm), regardless of design load. Stronger fasteners shall be used if the application requires. The mounting and attachment bolts for undercar-mounted equipment and equipment support structures or brackets shall be sized to the design strengths for Grade 2 bolts and Class A nuts.

15.2.2.4 Decorative and Appearance Fasteners

All interior fasteners exposed to passengers shall be either bright or finished to match the surfaces being joined, and installed such that the fastener head is flush with the mating surface. Bright finished fasteners used for stanchions shall be austenitic grade stainless steel. Bright finished interior fasteners may be either austenitic or plated martensitic stainless steel. Self-tapping screws are only permitted where they will not be removed for normal maintenance more frequently than once in 5 years and shall be plated martensitic stainless steel.

All exterior fasteners visible to passengers shall be austenitic stainless steel for steel, LAHT steel, and stainless steel car bodies. Exterior aluminum shall be joined by austenitic stainless steel or aluminum alloy fasteners, as appropriate to the design and appearance requirements. Fasteners used on the side sill to attach heavy equipment brackets are structural fasteners specified under the structural fasteners section.

Fasteners on access panels, plates, covers, or other components accessible by passengers shall be a tamper-resistant type approved by the Authority.

All fasteners used to secure access covers 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 5 years, access panels shall be equipped with quarter-turn fasteners. Quarter-turn fasteners shall have a minimum shank diameter of 1/4-inch (6.4 mm), be of adequate strength, and as manufactured by Southco, or approved equal.

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 the Authority to review for a period of not less than the expiration of the warranty on the last car delivered.

15.2.2.5 Torquing

All safety-related fasteners, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, shall be torqued to a minimum preload equal to 75% of their proof load and “torqued 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, 5th Edition, 1970 equations using values for “K” of 0.18 for unplated 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," the Authority may require bolt torque-tension tests to verify that installed preload is equivalent to 75% of proof loads.

15.2.2.6 Washers and Lock Washers

Washers shall be used under the heads of all bolts and under all nuts. Where high strength fasteners are applied, washers shall be hardened and comply with IFI 1970 Fastener Standards.

Lock washers, when applied, shall conform to IFI 1970 Fastener Standards. Lock washers shall not be used for fatigue applications where the fastener must be torqued and marked. If applicable, prevailing torque nuts shall be used for these applications.

Other types of washers, including Belleville washers, may be used for special applications with the Authority's approval.

15.2.2.7 Rivets and Lock Pins

Rivets and lock pins exposed to passengers shall be austenitic stainless steel or aluminum, as appropriate to the materials being joined. Structural steel rivets shall conform with ASTM-A-502 or ANSI 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. The Authority shall be the final arbiter in determining whether an application is hazardous to maintenance personnel.

15.2.2.8 Plating of Fasteners

All carbon, alloy, and martensitic steel fasteners shall be plated with zinc, unless specifically waived by the Authority. Zinc plating shall conform to ASTM-B-633, Type II SC2, SC3 or SC4.

15.2.2.9 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 IFI'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.

15.3 STAINLESS STEEL

15.3.1 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.

15.3.2 Austenitic Stainless Steel

Structural austenitic stainless steel components assembled by fusion or resistance welding shall be of AISI-type 201L or 301L and shall conform to the requirements of ASTM-A-666 except that the carbon content shall not exceed 0.03% and type 301L shall not exceed 0.25% nitrogen. Other stainless steels conforming to ASTM-A-666 are acceptable for non-welded applications.

Stainless steel used in structural applications covered by this Specification shall also conform to paragraph (f) from Section 2 of AAR "Specifications for the Construction of New Passenger Equipment Cars."

General requirements for delivery of stainless steel shall be as required by the Certification Provisions of ASTM-A-666, and stainless steel to be used in structural applications shall be tested for susceptibility to intergranular corrosion in accordance with ASTM-A-262, latest revision. Practice A of ASTM-A-262 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.

15.3.3 Ferritic Stainless Steels

When specified, ferritic stainless steel conforming to ASTM-A-176 may be used for carbody structural sheeting up to 4 mm thickness. Ferritic stainless steel sheet shall have a ductile-to-brittle transition temperature (DBTT) or nil-ductility temperature (NDT) below 0°C. Weld heat-affected-zones shall also have a DBTT or NDT below 0°C. Ferritic stainless steel sheet shall have a balanced composition (low carbon and/or suitable titanium content) that will, for all conditions of fabrication and assembly into the carbody, inhibit formation of martensite and limit chromium depletion in weld-heat-affected zones so that material shall meet ASTM-A-736 requirements for resistance to intergranular corrosion.

General requirements for delivery of stainless steel shall be as required by ASTM-A-480.

Where ferritic stainless steels are welded to other structural steels, the less-noble steel shall be painted with weld through primer.

15.3.4 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. *(CDRL 1501)* 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-A-666 and frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM-A-262. 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-A-763.

15.4 LOW-ALLOY, HIGH-TENSILE STEEL

15.4.1 General

Low-alloy high-tensile (LAHT) steel structural shapes, plates, and bars shall, as a minimum, conform to the requirements of ASTM-A-588, where available. Plate steel may alternatively conform to ASTM-A-710, Grade A, Class 1 or Grade C, Class 1. Where not available in A-588, hot rolled or formed structural shapes conforming to ASTM-A-36 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-A-6. Welded LAHT steel shall develop 15 ft-lbs Charpy V Notch impact strength in the Coarse Grain Heat Affected Zone (CGHAZ), 1 mm from fusion area at -20°F (-29°C).

Cold and hot rolled LAHT sheet and strip shall, as a minimum, conform to the requirements of ASTM-A-606, Type 4. General requirements for delivery of these products shall be as required by ASTM-A-568.

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.

Requests by the Contractor for alternate materials will be considered. The Contractor shall provide detailed and specific information on the proposed alternate material, using a U.S.-recognized trade name or UNS number. Chemistry and properties shall be provided in English and SI Units.

15.4.2 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. *(CDRL 1502)* The test and inspection plan shall include provisions for submission of reports and certification to the Authority for each shipment in accordance with the applicable requirements of Purchase Specification and specified CGHAZ impact tests.

15.5 STEEL CASTINGS

15.5.1 General

The Contractor is responsible for selecting casting grade, composition, strength and finishing. However, steel castings used in the truck structure, bolster, and center bearing arrangement shall meet AAR Specification M-201 latest revision, Grade "B" plus 2% nickel, minimum. These castings shall be heat treated to develop a minimum tensile strength of 75,000 psi, a minimum yield strength of 48,000 psi, elongation of not less than 25% in 2 inches, and reduction of area of not less than 50%. Also, steel castings used for coupler, drawbars and anchors shall meet AAR Specification M-201, latest revision, Grade "C" quenched and tempered. Cast steel to ASTM A-27, grade 65-35, may be used for truck structure, bolster and center bearing arrangements as an alternative to the AAR M-201 material specified above.

15.5.2 Design Qualification of Structural Castings

One casting, selected by the Authority from the first lot of production 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, including static and fatigue load testing of truck frames and bolsters.

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 the Authority before any castings are produced. Radiographs shall meet the requirements of ANSI/ASTM-E-94 and E-142, and the quality level in the area of inspection shall be at least 2% (2-2T).

A qualification test report shall be prepared and submitted to the Authority for approval. The production of any castings before receipt of the Authority's approval of this report shall be at the Contractor's risk. All radiographs that resulted from the qualification test shall be made available to the Authority for review. In case the casting selected for qualification fails to qualify, a plan of action including details of how failed material will be handled shall be included in the qualification test report. Once a design is qualified and accepted by the Authority 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.

15.5.3 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. In addition, the inspections below shall be performed and a written report of the results of the tests and inspections shall be furnished for each lot of castings produced.

15.5.3.1 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 that include coupler, bolster, articulation (where applicable), and truck castings, the maximum permissible magnetic particle indications shall be 1/4-inch in the direction transverse to the usual direction of loading, and 3/4-inch in the direction parallel to the usual direction of loading.

15.5.3.2 Radiographic Inspection

Radiographic inspection shall be conducted according to the requirements of ASTM-E-94 using reference radiographs to ASTM-E-446. A sampling frequency shall be proposed by the Contractor and submitted for Authority approval. *(CDRL 1503)*

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 trucks shall be reinspected 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 1 casting out of each 10 produced. If no castings are rejected by radiographic inspection, this frequency may be extended to 1 casting in 25.

15.5.4 Repair Welding and Cast-Weld Design

Repair welding of castings is permitted, provided the casting supplier performs all repair welds according to the structural welding requirements of Section 15.23. 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.

15.5.5 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.

15.6 ALUMINUM

15.6.1 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 used for door thresholds shall conform to ASTM-B-26, ASTM-B-85, or ASTM-B-108 for, respectively, sand, die, or permanent mold castings. Aluminum alloy forgings shall conform to ASTM-B-247. Copies of all test reports for sheet, extrusion, and forgings used in the car structure shall be submitted to the Authority.

15.6.2 Design Stresses

All aluminum structural members shall be designed so that calculated stresses under the specified AW3 passenger load do not exceed the allowable stresses listed in the latest revision of the Aluminum

Association of America's "Specification for Aluminum Structures" for bridge and similar type structures and "Engineering Data for Aluminum Structures." Proper allowance shall be made for the effects of fatigue, for column and plate stability effects, and for strength reduction at welded regions. Permissible fatigue stresses under the specified AW3 passenger load shall be established, with approval based on available relevant research data or on prototype testing under the variable load patterns expected to occur in service.

15.6.3 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 or the surface finish permanently marred or discolored during construction.

15.6.4 Protection of Contact Surface

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.

A. Aluminum alloy surfaces shall not be secured to or make direct metal-to-metal contact with the surfaces of copper, copper bearing aluminum alloy, brass, bronze, silver, nickel, nickel alloys, nickel plated parts, lead, tin, or wood.

B. The contact surfaces of aluminum alloy with aluminum alloy shall be painted with zinc chromate primer before securing.

C. The surfaces of aluminum alloy parts secured to steel parts shall be protected with a one-part polysulphide sealant, zinc chromate paste, mica insulation joint material or an approved equivalent material that 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.

D. Stainless steel and carbon steel fasteners plated with cadmium or zinc shall be coated with zinc chromate paste 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.

15.6.5 Interior Trim

Where unpainted aluminum is exposed to contact by passengers, 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 inches and a minimum coating weight of 21 milligrams per square inch, or approved equal process.

15.7 ELASTOMERS

15.7.1 General

All elastomeric parts shall be of neoprene, or approved equal, unless otherwise specified. The elastomer shall be compounded and cured to perform satisfactorily in the temperature range specified in Section 2.4.

The elastomers shall have high resistance to ultraviolet radiation, weather, all Authority car washing fluids, and the longest possible life consistent with the other characteristics specified. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease, and acid.

All resilient mounts shall be of natural rubber. Synthetic rubber compounds may be substituted for natural rubber only when approved for a specific application.

15.7.2 Tests

All tests shall be conducted according to the latest revisions of the specified ASTM test procedures, unless otherwise specified. All resilient, natural rubber mounts and elastomeric truck suspension components shall be tested in accordance with the procedures outlined for elastomers in Section 15.25; the results of the testing shall be submitted to the Authority. The performance of only these elastomers will not be bound by the performance requirements for elastomers outlined in Section 15.25.

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 1/2-inch ASTM "dumb bell" type test specimen (or smaller size if the size of the part necessitates) by the methods specified in ASTM-D-3182, D-3183, D-3190, and D-412, the tensile strength shall not be less than 1,500 psi and elongation shall be a minimum 350%. The tensile strength of the elastomer shall not be reduced more than 25% when subjected to accelerated aging by the methods specified in ASTM-D-573, for a period of 96 hours in an air oven at 70°C (158°F).

The ozone resistance of the elastomer shall be tested in accordance with ASTM-D-1149 using an ozone concentration of 100 ppm, an exposure time of 100 hours at 100°F, and a specimen elongation of 20%. The elastomer shall not exhibit any cracks during the test period.

15.7.3 Life Expectancy

For all parts made by vulcanizing an elastomer to metal, any premature failure (less than 5 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.

15.7.4 Metal Parts

Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020 or 1045 hot-rolled steel.

15.7.5 Bonding

The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers 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.

15.7.6 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.

15.7.7 <u>Seals</u>

Glazing strips shall be of neoprene conforming to ASTM-C-542, 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^{o}F and 90^{o}F shall be 70, ± 5.

15.8 GLAZING MATERIALS

15.8.1 <u>Safety Glass</u>

Safety glass shall meet the requirements under Item 1, Table 1 of the latest revision 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."

Laminated safety glass used in the "F" End of the car, including that in the end door, shall be certified as having been tested and having met the FRA 49CFR223 Type I or II test as appropriate for the application.

To prevent particles of glass from striking the Operator, the window in front of the Operator shall incorporate a spall shield as its interior surface. Alternatively, a clear plastic sheet, with an approved abrasion-resistant coating may be installed behind the window and extend from the top of the Operator's console to the top of the window. This plastic sheet shall be hinged or otherwise arranged for easy removal to permit cleaning its forward surface and the interior surface of the window.

15.8.1.1 Type

All safety glass shall be of the laminated sheet type and shall consist of two sheets of glass bonded with an approved interlayer of plasticized polyvinyl butyral resin in the form of a membrane approximately 0.045 inches thick, and resistant to degradation from ultraviolet or visible light and heat.

15.8.1.2 Flatness

When an individual piece 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.

15.8.1.3 Dimension Tolerance

The overall dimensions of individual pieces as supplied shall be held within 0.060-inch of the dimensions ordered.

15.8.1.4 Overlap Tolerance

The overlap of one laminate of the piece 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.

15.8.1.5 Color

The color of the glass shall be as required by Section 3. When new, there shall be no more than ± 4% variation in the color of individual pieces of laminated sheet glass when examined over a white background.

15.8.1.6 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 piece of the same nominal thickness of plate glass when viewed against a north light.

15.8.1.7 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.

15.8.1.8 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 will be no separation between the glass sheets. Lights that contain unbonded areas ("let-go's") shall not be used.

15.8.1.9 Marking

All safety glass shall be marked with proper identification in accordance with ANSI Z26.1, Section 7, and appropriate FRA Type designation. The window light shall be installed so that the identification marking can be read from the inside lower right hand corner.

15.8.2 Plastic Glazing

15.8.2.1 General

This Specification establishes the material requirements, the manufacturing process, properties and quality assurances for abrasion-resistant plastic glazing materials. Plastic glazing shall meet the requirements under Item 4, Table 1 of the latest revision 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." The material shall be selected from General Electric Company "Margard," Rohm and Haas "Tuffak CM-2," or approved equal, meeting FRA 49 CFR Part 223.

15.8.2.2 Applicable Documents

The latest issue of the following documents, in addition to those specified in this Section, shall form a part of this Specification:

A. ASTM-D-673 – Mar Resistance Test.

B. ANSI No. Z26.1 – Item 4, Table 1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code".

C. ASTM-G-23 – Recommended Practice for Operating Light and Water Exposure Apparatus (Carbon Arc Type) for Exposure of Nonmetallic Materials.

D. ASTM-D-1499 – Recommended Practice for Operating Light and Water Exposure Apparatus (Carbon Arc Type) for Exposure of Plastics.

E. ASTM-D-1003 – Recommended Practice for Determining Haze Factor.

F. ASTM-E-162 – Radiant Panel Test For Determining Flame Propagation Index (I_s).

G. FRA 49 CFR Part 223 – Impact Requirements.

H. ASTM-E-662 – Test to Determine Smoke Emission Values (D_s).

15.8.2.3 Material Physical Properties

Plastic materials used in the glazing of side windows and door windows shall meet the following requirements.

15.8.2.3.1 *Strength*

Samples prepared and tested according to FRA 49 CFR Part 223 and Test No. 10, Article 5.10 of ANSI Standard Z26.1, shall not shatter or break when subjected to a falling dart impact of 100 ft.-lbs. The dart tip shall be no more than 1/2-inch radius. Denting or marring of the surface of the tested piece in this test is permissible.

15.8.2.3.2 *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 the tinted passenger side windows shall be 23%, ± 4%.

15.8.2.3.3 *Weathering Test*

The materials shall pass weathering test No. 16 of ANSI Standard Z26.1. An accelerated weathering apparatus of Type D or E in ASTM G 23 shall be used in this test.

15.8.2.3.4 *Color*

The color of the plastic glazing shall be as required by Section 3. The materials 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.

15.8.2.3.5 *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
Mar Resistance	ASTM-D-673	The change in percent haze after 1,600 grams of falling silicone carbide shall be less than 5.
Abrasion Resistance	ANSI Z26.1, Test 17	The change in percent haze shall be less than 5.

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, Test 17. The foregoing test is to be performed for initial product certification.

15.8.2.3.6 ***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 dilute oxalic acid solution (3% by weight), one-half-strength Neleco Products Subway Soil Solvent – Parts 1 and 2, and Electrosol. The exposure time of the test shall be increased to one hour intimate contact with the test chemicals. Any tackiness, crazing or apparent loss of transparency shall be cause for rejection. After immersion, a change in percent haze greater than 5, as measured by Test 17 on ANSI Z26.1, shall be cause for rejection.

To produce the specified one half strength solution of Subway Soil Solvent, mix parts 1 and 2 in the following ratio:

A. Part 1: one gallon (U.S.) liquid-acid solution as received.

B. Part 2: two lbs. of the crystalline and catalyst mix dissolved in 10 gallons (U.S.) of water.

15.8.2.3.7 ***Adhesion of the Coating Materials***

The abrasion resistant coating materials shall retain adhesion to the substrate materials when subjected to a 100 ft.-lb. impact as specified in Section 15.8.2.3.1. The coating must 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 No. 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.

15.8.2.3.8 ***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.

15.8.2.3.9 ***Flatness***

When an individual piece is placed on a truly flat surface, such as a surface plate, the material shall not indicate a bow of more than the length divided by 100.

15.8.2.3.10 ***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.

15.8.2.3.11 ***Optical Quality***

Optical quality of the plastic glazing materials shall be in accordance with Test No. 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 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 piece.

There shall be no detectable cracking of the coating as indicated by fine radial cracks at the point of impact when struck with 2-1/2 ft.-lb. energy from a dart having a 1/2-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.

15.8.2.4 Material Quality

15.8.2.4.1 ***Foreign Material and Inclusion Defects***

Defects occurring in those areas of the lights which shall be covered by the glazing strips shall not be cause for rejection.

In the basic material, there shall be no clusters of bubbles or chain bubbles or bubbles larger than 0.030-inch in diameter. If present, bubbles over 0.020 inch in diameter shall have a minimum separation of 3 inches between bubbles. In a 1-inch diameter circle on the sheet, there shall be a maximum of eight bubbles in the range of 0.020-inch to 0.039-inch. Guidelines for inclusion defects are as follows:

A. Less than 0.020-inch: allowed without population limit to the extent that they do not constitute a severe defect such as clustering.

B. 0.020-inch to 0.039-inch: allowed up to three per ft^2 average over the area of the light.

C. 0.040-inch to 0.050-inch: allowed up to three per ft^2 average over the area of the light.

D. 0.051-inch to 0.065-inch: allowed one per ft^2 average over the area of the light.

E. 0.065-inch to 0.150-inch: allowed one per edge only in the outer 25% of the light.

F. 0.151-inch and above: shall be cause for rejection.

15.8.2.4.2 ***Fibers and Scratches***

Fibers less than 0.125-inch in length are allowable without population limit to the extent that they do not constitute a severe defect such as clustering.

Fibers from 0.125-inch to 1-inch in length and less than 0.032-inch in width are allowable up to one per 12-inch by 12-inch area of the sheet. Fibers over 1-inch in length or more than 0.032-inch in width shall be cause for rejection.

Fine scratches which are detectable only when viewed in bright back lighting are acceptable. Scratches greater than 0.020-inch in width are not allowed. Scratches 0.250-inch to 0.500-inch in length are allowable up to four per square foot area. Scratches 0.501-inch to 1-inch in length are allowable up to one per square foot area.

15.8.2.4.3 ***Apparent Runs***

A. 0.125-inch and under: allowed without population limit to the extent that they do not constitute a severe defect such as clustering.

B. 0.126-inch to 0.250-inch: allowed four per ft^2 average over areas of light but not to the extent that they constitute a severe defect.

C. 0.251-inch to 0.500-inch: allowed one per ft^2, providing they do not constitute a severe defect.

D. 0.501-inch to 1.00-inch: allowed one per edge only in the outer 25% of light area.

E. 1.01-inch or above: shall be cause for rejection.

15.8.2.4.4 *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 the Authority prior to manufacture.

15.8.2.4.5 *Quality Assurance*

The Contractor shall be responsible for the performance of all inspection requirements. Except as otherwise specified, the Contractor may utilize the facilities of its supplier or any approved commercial laboratory.

15.8.2.4.6 *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 strippable from the material and not leave a gummy or sticky residue.

15.8.2.4.7 *Identification*

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 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.

15.8.2.4.8 *Documentation*

The Contractor shall certify that the shipped material complies with the requirements in this Specification.

15.9 FLOOR COVERING

15.9.1 <u>Rubber Floor Covering</u>

Rubber floor covering shall contain 20% (nominal, by weight of compound) Butadiene Styrene rubber, shall be non-staining, non-discoloring, and 100% non-oil extended. Only high quality hard clay shall be used as a filler. No whitening (limestone) shall be used in the compound.

At 68°F, the rubber flooring shall bend 180 degrees around a 3/4-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 Federal Specification SS-T-312.

15.9.1.1 Inspection Criteria

This Section addresses defect items that may be cause for rejection, their allowable limits, and repair methods, where repairs are permitted.

15.9.1.1.1 *Thin-Skinned Blister*

A thin-skinned blister is a blister which, when finger-pushed, will collapse upon itself. Any thin-skinned blisters which exceed the limits listed below shall be cause for rejection of the floor sheet.

A. Maximum Size: 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

B. Maximum Population: 3 blisters in a 12-inch by 12-inch area with only one other blister within 3 feet of this area.

C. 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.

15.9.1.1.2 *Thick-Skinned Blister*

A thick-skinned blister is a blister which, when finger-pushed, will collapse and then return to its original condition.

A. Maximum Size: 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

B. Maximum Population: 3 blisters in a 12-inch by 12-inch area, and only one other blister within 3 feet of this area.

C. Repair Method: no repair authorized.

15.9.1.1.3 *Lump*

A lump is a blister without a void, consisting of solid material.

A. Maximum Size: 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

B. Maximum Population: 3 blisters in a 12-inch by 12-inch area, and only one other blister within 3 feet of this area.

C. Repair Method - no repair authorized.

15.9.1.1.4 *Hole*

A hole is a defect which is 100% through the material. Any holes found in the floor sheet shall be cause for rejection of the sheet.

15.9.1.1.5 *Thin Area*

A thin area is a defect where the sheet is of reduced thickness locally.

A. Maximum Size: 0.030-inch deep at the lowest point, 3 square inches with the longest dimension of 5 inches.

B. Maximum Population: one thin area in a 40-inch by 40-inch area, and no other thin area within 3 feet of this area.

C. Repair Method: rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

15.9.1.2 Color and Marbling Distribution

Color and marbling distribution is an appearance judgment and shall be subject to the approval of the Authority. If the base coloring is not within 5% between production runs, or the marbling is not consistent over the entire surface, the roll shall be rejected.

15.9.2 Carpeting

15.9.2.1 Material

The pile yarn shall be 100% pure virgin wool. The backing, where required, shall be at least 1/8-inch thick foam padding and shall have a weight of at least 38 ounces per square yard.

15.9.2.2 Construction

Carpet shall be level loop pile, four ply wool having a synthetic back and a face weight of at least 56-1/4 ounces per square yard, not including bonding and padding.

The carpet shall be woven through the back and shall be bonded to the padding over its entire area, when padding is required. The carpet shall have a pile height of 0.205 inches, a stitch rate of 10 rows per inch, and a 216 pitch. The carpet shall be constructed to produce less than 3.5 kilovolts of static electricity when tested in accordance with AATCC Test 134.

15.9.2.3 Edge Treatment

The edges shall be latexed to prevent raveling.

15.9.2.4 Color

The color and pattern of the carpet shall match samples, which are available upon request.

15.9.2.5 Protective Treatment

The pile yarn shall be permanently mothproofed. The carpet shall be processed to prevent mildew and other fungi.

15.9.2.6 Carpet Performance

The carpet shall be certified by the contractor to conform to the following requirements:

Characteristic	Test Method	Requirement
Tuft Lock	ASTM-D-1335-1367	3.8 lbs. minimum
Shrinkage	ASTM-D-1335-1367	1% maximum

The Contractor shall advise the Authority on the expected wear over 175,000 cycles, for the “5” index of the National Bureau of Standards Carpet Wear Testing, using the Shiefer Machine.

15.9.2.7 Maintainability

Carpet fabrics shall be cleanable by standard commercial methods suitable for the specific wool material construction, surface effect and color of the fabric identified by this Specification.

15.9.2.8 Environment

A. The carpet shall be capable of maximum performance in the following environment:

1. Temperature Range: 0°F to 140°F
2. Maximum Relative Humidity: 100%

B. The carpet shall be capable of maximum performance after being subjected to the following substances:

1. Rain water
2. Rock salt of the type used to get rid of snow and/or ice.
3. Abrasive dirt, such as the type of sand used to provide traction on icy/slippery surfaces.

The amounts of these substances that the carpet will experience are those encountered during normal operation of the rail cars.

15.10 WOOD AND PANELS

15.10.1 Lumber

Lumber shall be thoroughly air seasoned or kiln dried before using and shall be dressed on all surfaces to full dimensions. Lumber shall be straight-grained, free from dry rot, knots, checks, and other defects that may impair its strength and durability or mar its appearance.

15.10.2 Plymetal

The term "plymetal" as used in this Specification means metal-faced plywood. All plymetal panels shall conform to Military Specification MIL-P-8053, Sections 3.1.2 and 3.1.3 and the following requirements:

Mechanical Properties	Minimum Metal to Wood Average Shear Value or 80% Wood Failure
Dry shear	250 lbf/in^2
Boil shear; 3-hour boil; tested wet at room temperature	150 lbf/in^2
Soak shear; 48-hour soak wet at room temperature	150 lbf/in^2
Creep or cold flow; under static load for 48 hours; at room temperature	250 lbf/in^2

The metal face of the plymetal panel that is faced with melamine shall be constructed in accordance with Section 15.10.6 prior to the melamine-faced metal panel being laminated to the plywood core.

15.10.3 Plywood

All plywood shall be manufactured to conform with the requirements of Grade - Structural I of the National Bureau of Standards Voluntary Product Standard (American Plywood Association) PS 1-83, or approved equal and then stored under cover. Each plywood panel shall be formed from one piece. Scarf or finger jointed panels are not allowed. All plywood shall be sealed with two coats of an epoxy paint, or approved equal on all edges and cutouts as soon as possible after fabrication. All exposed edges of the panels, joints between panels, fastener heads, and openings of panels used in areas accessible to moisture shall be waterproofed and sealed with an approved coating prior to installation in the car. MOD 3

15.10.4 Honeycomb Panels

The term “honeycomb panels” as used in this Specification refers to an assembly of honeycomb material bonded to melamine-faced metal panels or to metal panels. Honeycomb material shall be commercial-grade aluminum honeycomb meeting the requirements of MIL-C-7438G. Bonding shall be sufficient to develop the full strength of the honeycomb material.

15.10.5 Panel Contour Tolerance

Surfaces exposed to passengers shall not deviate from the specified contour by more than 3/32-inch in any 36-inch distance. The slope of any such deviation shall not exceed 3/32-inch in 12 inches.

15.10.6 Melamine-Faced Aluminum

Melamine-faced aluminum panels shall be constructed by laminating melamine to aluminum sheets. The melamine-impregnated papers shall be directly molded to the aluminum sheets at temperatures of no less than 270°F and pressure no less than 1,000 psi. The surface characteristics, after manufacture, shall be no less than that required of type GP (General Purpose) in the NEMA Standards Publication No. LD-3, latest revision. The melamine and the required binder sheets shall be 0.020 inches, ± 0.005-inch thick. The aluminum sheets shall not be less than 0.025-inch in thickness when used as a facing on plywood. The aluminum sheets shall not be less than 0.081-inch in thickness when not laminated to a substrate such as plywood. Aluminum sheets shall be properly cleaned by etching, sanding, or other approved process to ensure full, permanent, adhesion.

The use of contact adhesives to bond the melamine sheets to the aluminum backing is not acceptable.

The bond between the melamine and aluminum sheets shall, as a minimum, meet the following requirements:

A. Internal bond (ASTM-D-952): 2,600 lbf/in^2

B. Flexural strength - (S) (ASTM-D-790)

1. With grain: 26,500 lbf/in^2
2. Crossgrain: 25,300 lbf/in^2

C. Modulus of elasticity - (E) (ASTM-D-790)

1. With grain: 2.8×10^6 lbf/in^2
2. Crossgrain: 3.1×10^6 lbf/in^2

D. Tensile strength (ASTM-D-638)

1. With grain: 22,300 lbf/in^2
2. Crossgrain: 20,300 lbf/in^2

15.11 SEAT CUSHION

15.11.1 General

Seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials. The thickness shall be approved 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.

15.11.2 Physical Properties

Flexible foam shall meet the following physical property criteria when tested without upholstery material:

A. Tensile Strength: 5.0 lbf/in^2 minimum when tested to ASTM-D-3574 Test E
B. Elongation: 70% minimum when tested according to ASTM-D-3574 Test E
C. Compression Set at 50%: 15% maximum when tested according to ASTM-D-1055
D. Flex Fatigue: thickness loss 5% maximum when tested according to ASTM-D-1055
E. Tear Strength: 2.0 lbf/in^2 minimum when tested according to ASTM-D-3574

15.12 NOT USED MOD 3

15.13 FIBERGLASS-REINFORCED PLASTIC

15.13.1 General

Fiberglass-reinforced plastic (FRP) shall be a glass-fiber-reinforced, laminated material, composed of a gel coated surface, fiberglass reinforcement, and a polyester resin. FRP shall withstand, without any physical deformation or structural damage, the environmental conditions in Section 2.4, be resistant to acids, alkalies, and cleaning solutions recommended by the Contractor.

FRP shall be manufactured by either open molding, hand layup, spray layup, or the matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.

FRP parts shall have a greater thickness at attachment points and edges. Exposed sharp edges will 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 material selected to meet the physical properties of this Specification and molding process requirements.

15.13.2.2 Reinforcement

The fiberglass reinforcement shall be mat, fabric woven roving, continuous roving, chopped spun roving, or swirl mat as required to meet the physical properties of this Specification and the molding process requirements. The glass content shall be a minimum of 20% by weight.

15.13.2.3 Gel Coat

The gel coat shall be resistant to scuffing, fire, weather, and cleaning agents. The gel coat shall have a minimum thickness of 0.015 inches. If the surface of the FRP panel is to be painted, a primer gel coat shall be used and the part shall be painted in accordance with Section 15.24. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color selected by the Authority.

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 characteristics of this Specification.

Mineral filler shall not exceed 28% of finished weight for any preformed matched die molding process.

15.13.3 Strength Requirements

Independent laboratory test certificates shall be provided stating that the reinforced plastic material complies with the requirements of the following standards. Test specimens shall be conditioned in accordance with ASTM D 618.

Mechanical Properties	ASTM Test	Open Moldings	Match Die Molding
Tensile Strength	D-638	10,000 lbf/in^2	12,000 lbf/in^2
Compressive Strength	D-695	18,000 lbf/in^2	22,000 lbf/in^2
Flexural Strength	D-790	15,000 lbf/in^2	22,000 lbf/in^2
Impact Strength	D-256	6 ft.-lbs per inch of notch	8 ft.-lbs per inch of notch
Hardness	–	45 Barcol	45 Barcol

15.14 THERMOPLASTIC SHEET

15.14.1 General

Thermoplastic sheet used in the construction of this vehicle shall withstand, without any physical deformation or structural damage, the environmental conditions described in Section 2, and shall be resistant to Authority cleaning solutions. Thermoplastic sheet shall be used as extruded or vacuum-formed.

Thermoplastic sheet shall be homogeneous and extruded from virgin stock which does not include any regrind of vacuum formed parts. The exposed surface of this material shall conform to the color, texture, and gloss specified in Section 3. Only UV stabilized pigments shall be used to create the specified color of the thermoplastic sheet. The color and surface finish of parts manufactured from this material shall be approved prior to the production run of any parts.

15.14.2 Quality

The finished parts shall be free of waves and quilting on both sides. Degraded polymer in the sheet shall not be allowed, and if present, shall be cause for rejection of the piece. Voids, lumps, and contamination shall also be cause for rejection of parts if the defects are larger than 0.010 inch, and the population of these defects is greater than one defect in four square feet.

15.14.3 Strength Requirements

Independent laboratory test certificates shall be provided stating that the thermoplastic sheet complies with the requirements of the following standards. Extruded sheet in the surface finish specified shall be used for testing.

Mechanical Properties	ASTM Method	Value	
Specific Gravity	D-792	1.20 to 1.45	
Tensile Strength	D-638	5,500 lbf/in^2 minimum	
Flexural Strength	D-790	8,000 lbf/in^2 minimum	
Flexural Modulus	D-790	3.3 x 10^5 lbf/in^2	
Hardness Rockwell "R" Scale	D-785	90 to 110	
Heat Shrinkage; 15 minutes at 350°F	–	10% maximum	
Heat Deflection (annealed) at 264 lbf/in^2	D-648	165°F minimum	
Impact Strength, Fabricated Parts; Gardener Dart Drop 1/2-inch diameter ball at 73°F	D5420: 1996 and D5628	160 in-lb. Minimum	MOD 1

15.15 PIPING AND TUBING

15.15.1 General

All piping, valves, fittings, installation methods, and testing shall be in accordance with the Code for Pressure Piping, ANSI B31.1. All joints shall be easily accessible.

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 recleaned and retested until leak-free.

Pipes must 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% 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 specified by AAR Specification No. 2518, Standard S-400, and not with fittings. 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 car loading and deflection, car 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 car 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 car structure. Cantilevered clamps or clamp supports that are weaker than service-proven designs will not be accepted. All clamps shall be of a suitable material for the application.

15.15.2 Air Piping, Tubing, and Fittings

The main reservoir pipe and brake pipe shall conform to ASTM-A-53, Schedule 80 seamless pipe. Type "K" annealed copper tube per Federal Specification WW-T-799 latest revision may also be used, provided it is installed no lower than 2 inches below the floor sheet 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. Where suitable protection in damage-prone areas is not possible or practical, approved steel piping sections shall be provided. 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 7/8-inch O.D.

All air pipes shall be sized in accordance with the function intended and may be either ASTM-A-53 schedule 80 pipe or seamless copper tubing as described previously. All joints for copper tubing shall utilize fittings of wrought copper or non-porous cast brass in accordance with ANSI Standards B16.22 and MOD 1 B16.18: 1994.

All air piping must comply in all respects with the air brake supplier's design and installation requirements. Within 180 days of Contract Award and prior to manufacture of production cars, the Contractor shall provide the Authority 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:

A. All critical line sizes and materials including the main reservoir pipe, the emergency brake pipe, and the brake cylinder piping.

B. The installation details of the above 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.

C. Pipe processing details including welding, brazing, cleaning, and fabrication methods, as required by Section 15.23.

D. Locations of all major air brake control, relay, and emergency venting devices, and the proposed location and volume of all reservoirs.

E. An air consumption analysis justifying the proposed air storage system design.

Where ASTM-A-53 piping is provided, its application shall also comply in all respects to AAR Specification No. 2518, Standard 400, latest revision. Approved copper tube shall also comply with any relevant requirements of AAR Specification No. 2518.

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 hose utilized within the air system shall be in compliance with AAR Specification M-618 latest revision. All hose fittings shall be of the reusable type as manufactured by Stratoflex, or approved equal.

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 10.8.15.

Air piping on the trucks shall be 1/2 inch ASTM A 53 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.

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.

15.15.3 Air Conditioning System Piping, Tubing, and Fittings

Air conditioning refrigerant lines and condensate drain lines shall be of seamless copper tubing, type "K" with wrought copper sweat type fittings. 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, but need not be type "K." 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 psig 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 an 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. 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.

15.15.4 Brazing and Soldering of Piping, Tubing, and Fittings

All brazing and soldering shall comply with the applicable parts of Section 15.23, and the following requirements. Unless specifically approved, all refrigerant piping and air system copper tubing shall be joined using silver solder conforming to Federal Specification QQ-B-654, Class 1 or 3. 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 written procedure prepared for each by the Contractor and approved by the Authority.

15.15.5 Hydraulic Piping, Tubing, and Fittings

All hydraulic pipes, tubing, and fittings shall be sized for the function intended without experiencing a pressure drop of more than 15% from control to function. All exposed tubing, piping, or fittings shall be stainless steel to MIL-T-6845 or MILT-T-8504 specifications. Tubing, piping, or fittings protected from under car exposure may be either stainless steel or carbon steel to SAE J524, SAE J535, or SAE J356 standards. Wall thickness shall be Schedule 80 for truck-mounted piping and sufficient to maintain a safety factor of 6 at the maximum system pressure. Wall thickness in other locations shall be sufficient to maintain a safety factor of 6 at the maximum system pressure.

All joints for tubing or piping shall utilize fittings of the same material as the tubing or piping. Joints shall be welded, brazed, flared to 37 degrees in accordance with SAE J533b, or made with compression fittings, Swage-Lock, or equal. Connections to manifold ports, valve bodies, and other hydraulic system components shall use straight thread fittings with separate O-ring seals. Quick connect couplings shall be of the double shutoff type with valves built into both mating parts of the coupling.

All hose utilized within the hydraulic system shall conform to SAE J517 standard and hose fittings shall conform to SAE J516 standard. All hose shall be rated to withstand four times the maximum operating pressure without bursting. Hose application limits shall conform to SAE J1273, SAE J343, and SAE J1405 standards. Hose shall not be used in locations where the temperature may exceed 200°F. Hose shall be supplied clean and with both ends capped.

There shall be no inaccessible joints. Tubing shall be bent utilizing a bending tool designed specifically for bending of the tubing to be used. All tubing and piping shall be deburred after cutting. All tubing, fittings, and subassemblies shall be cleaned and capped on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.

Truck piping shall not be run on the bottom of truck sides, frames, transom, or bolster.

All cutout cocks shall be designed to automatically depressurize the portion of the system which is being isolated by the cutout cock.

15.16 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.

15.17 WIRE AND CABLE

15.17.1 General

A 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 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.

All applications of shielded cable shall be approved.

The Contractor and each manufacturer of equipment shall, through the Contractor, submit samples, specifications, and qualification test documentation of each size and type of wire and cable specified, for approval, before utilizing said wire and cable.

Only wire or cable shall be used for carrying electrical current. Exceptions are third rail shoes, pantograph carbon strips and other devices specifically designed to be electrical conductors. Where this specification uses wire insulation trade names, the use of an approved equal is acceptable.

15.17.2 Conductors

Wiring shall be sized for the intended load, voltage drop, installation method, and applicable codes.

Maximum wire ampacities shall conform to the National Electric Code (NFPA 70) Table 310-16, 110°C column for wires in raceways or conduit, and Table 310-17, 110°C column for wires in free air. When the free air rating is used, the Contractor shall furnish data to show that the cables will not exceed their rated temperature at the rated current. Where more than three conductors are routed in a raceway or conduit, the ampacities shall be derated as detailed by Note 8 to Tables 310-16 through 310-19. Wire ampacities shall be derated 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 will be submitted for approval.

In no case shall wire smaller than the following sizes be used:

A. Wire which is pulled through conduits or wireways - No. 12 AWG.

B. Wire on electronic units, cards, and card racks - No. 22 AWG.

C. Wire within control compartments - No. 18 AWG.

D. Multi-conductor cables where current is not a factor in wire size selection, such as LED indicator lights or status displays - No. 16 AWG.

E. All other wire, including that which is laid in, rather than pulled through, wireways - No. 14 AWG.

The Authority may approve smaller wire sizes for selected applications.

Trainline wiring, and all associated connections, shall be sized for operation of consists with the maximum number of cars as allowed by Section 2. The maximum voltage drop permitted between the battery or LVPS and any load in the vehicle shall not be greater than 2 V. Voltage drop measurements shall include both the supply and return leads as well as intervening circuit breakers and switches.

Except as otherwise specified, conductors in all electrical wires and cables, including wire and cables in apparatus furnished by subcontractors, shall be of stranded, soft annealed, tinned copper wires in accordance with ASTM B 33. The use of solid wire is not permitted except for approved wire wrap applications.

Stranding and conductor construction for all wires and cables of No. 18 AWG and larger shall be in accordance with AAR Standard S-501 and S-502 (No. 589) NEMA WC3: 1992, as appropriate for the application. MOD 1

Stranding and conductor construction for wires and cables No. 20 AWG and smaller shall be in
MOD 1 | accordance with NEMA WC3: 1992 or shall be 19-strand construction as appropriate for the wire size.

15.17.3 Insulation

15.17.3.1 General Wiring Insulation

The insulation shall be rated at 2,000 VDC in the case of wires carrying a nominal voltage greater than 300 VAC or VDC, and rated at 600 VDC in the case of wires carrying a nominal voltage equal to 300 V or less, AC or DC.

For all general carbody wiring, the insulation shall be a flame retardant, flexible, cross-linked polyolefin material having a continuous temperature rating of 125°C. For wire sizes No. 8 AWG and larger, the insulation material shall be formulated for extra flexibility. In addition, wiring insulation shall meet the following conditions:

A. The smoke, flammability, and toxicity requirements follow:

1. Flammability: For cross-linked polyolefin, use test method ICEA S-66-524, Paragraph 6.12.5. After five applications of 15 seconds each, with a three second rest period between applications, flame shall extinguish in 10 seconds or less. For other insulation materials, use IEEE-383.

2. Smoke Density (Test Method, ASTM E 662: When tested in a National Bureau of Standards Smoke Chamber in accordance with the procedure specified in Section 15.17.6, the Specific Optical Density (Ds) at 4 minutes shall not exceed

a. On a flaming test: 200
b. On a non-flaming test: 75

3. Toxicity: See 15.25.6 for requirements.

B. The insulation shall be in accordance with the requirements of AAR Standard S-501 and the additional special industry requirements in the following list:

1. Insulation Resistance (Test Method ASTM Standard D 470): The minimum value, corrected to a temperature of 15.6°C, shall be 300 megohms for 1000 feet.

2. Heat Distortion – (Test Method ICEA S-66-524, Paragraph 6.4.14) (150°C ±2°C, maximum percent of unaged value):

a. No. 4/0 AWG and smaller: 20%
b. Larger than No. 4/0: 10%

3. Moisture Absorption – Gravimetric Method (ASTM Standard D 470); (70°C, ±2°C, for 168 hours):

a. Maximum milligrams per square inch: 8

4. Moisture Absorption - Electrical Method (ICEA S-66-524): Increase in Capacitance, Maximum Percent:

   a. 1 - 14 Days: 3.0%

   b. 7 - 14 Days: 1.5%

   c. Stability Factor after 14 Days: 1.0%

   d. Alternate to Stability Factor Stability Factor Difference,
   1 -14 Days Maximum: 0.5%

   e. Specific Inductive Capacity
   (1 Day Maximum): 6.0%

   5. Ozone (Test Method, ICEA S-19-81, Paragraph 6.8): After 24 hours exposure to an ozone concentration of 0.03% by volume at 90^{o}C, ±2^{o}C, there shall be no insulation cracks.

6. Tension Set (Test Method ICEA S-66-524, Paragraph 6.4.11.4); (Except that the specimen shall be stretched until the gauge marks are 4 inches apart.): Maximum: 30%

7. Corrosion (Test Method ASTM Standard D 2671-Copper Mirror): The test specimen shall be approximately 0.4 gram of the insulation, cut into small pieces. After a test period of 2 hours at 175^{o} ± 2^{o}C, the removal of more than 5% of the copper film constitutes a failure.

8. Abrasion Resistance (Test Method AAR Standard S-501, Paragraph 5.9.6): Except that minimum cycles to failure is 2,000.

15.17.3.2 Wire Insulation for High Temperature Applications

High temperature insulation shall be in accordance with the following requirements, in addition to the voltage rating specified in Section 15.17.3.1:

A. For wire sizes No. 16 AWG and larger: abrasion resistant Teflon Polytetrafluoroethylene (PTFE) meeting MIL-W-22759/6B, or silicone rubber meeting AAR Standard S-503 (No.59).

B. For wire sizes No. 18 AWG and smaller: abrasion resistant PTFE Teflon meeting MIL-W-22759/6B. When used for interconnecting pieces of apparatus, this type wire shall be in bundles with a protective covering.

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.

15.17.3.3 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 Ethylenetetrafluoroethylene (ETFE) per ASTM D 3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), cross-linked polyolefin per

Section 15.17.3.1 above), or Teflon Polytetrafluorethylene (PTFE) type EE per Military Specification MIL-W-16878/5.

15.17.3.4 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, shall be insulated with Tefzel (ETFE) per ASTM D 3159 MOD 1 and insulation construction per Military Specification MIL-W-22759/16 (AS). When used for this application, these type wires shall be bundled with a protective covering of cross-linked modified polyolefin or similar approved high temperature rated, low smoke generating insulation.

15.17.4 <u>Multi-Conductor Cables</u>

15.17.4.1 General

Multi-conductor cables, where approved, shall be constructed using wiring as described in Section 15.17.2 and 15.17.3. 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.

15.17.4.2 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.

15.17.4.3 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.

15.17.4.4 Shield

The shield, if required, shall consist of either copper braid, concentrically served copper, or aluminum/polyester tape with a drain wire, as is appropriate for the application. The shields shall have the following minimum properties:

A. Copper shield shall be made of either tinned, coated copper strands which conform to ASTM B 33, or silver-coated copper strands which conform to ASTM B 298, as is appropriate for the wire insulation. Shield coverage shall not be less than 85%. Shield strand size and application shall be as recommended by the cable manufacturer for the particular application.

B. 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% of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be a No. 22 AWG 7/30 tinned copper drain wire conforming to ASTM B 33 and B 174.

15.17.4.5 Jackets

The overall jacket of multiconductor cables shall be of flame retardant, cross-linked, modified polyolefin; ETFE Tefzel or TFE Teflon to match the wire insulation and application as approved. Flame retardant, cross-linked, modified polyolefin, compounded for increased cable flexibility, shall be used where necessary, such as for connection to the electric coupler as approved. The jacket shall be extruded and vulcanized over the cabled conductors, and shall be well centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice. The nominal jacket thickness shall be that shown below, with the minimum wall not less than 80% nominal value.

Nominal Sheath Wall Thickness in Inches

Cable Diameter Under Sheath	Modified Polyolefin	Teflon or Tefzel
0.000-0.250	0.045	0.010
0.251-0.500	0.045	0.015
0.501-0.750	0.060	0.021
0.751-1.000	0.080	0.021
1.000-1.500	0.080	0.025
1.501-2.000	0.110	–
2.001-2.500	0.125	–
2.501-3.000	0.140	–

15.17.5 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:

A. Only soft or annealed oxygen-free solid copper conductor shall be used.

B. Wire size shall be No. 28 AWG.

C. A silver conductor coating, with a minimum coating thickness of 40 micro-inches, shall be applied to the wire.

D. 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 135^{o}C maximum conductor temperature.

E. Wrapping shall be "modified" wrap, nominal 7-1/2 turns, including 1-1/2 turns for strain-relief.

15.17.6 Insulation Smoke Test

15.17.6.1 Scope

This test method describes the equipment and the procedure for preparing insulated wire samples from which the specific optical density (D_s) of smoke generated can be determined in the Aminco-NBS Smoke Chamber. This method is used for wire sizes up to and including No. 12 AWG. For wire sizes above No. 12 AWG, the standard procedure outlined in ASTM E 662 shall be used. Equipment calibration, standardization, and operation are to be in accordance with ASTM E 662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials."

15.17.6.2 Apparatus

A. Aminco-NBS Smoke Chamber and Recorder.

B. Aminco 6 tube, 90^{o} burner assembly for flaming mode testing. Burners are all directed in one plane at the sample.

C. Notchless wire frame (Aminco No. 20 AWG wire frame with notches machined off).

D. Aminco troughless wire specimen holder assembly.

E. Air oven.

F. Humidification chamber.

G. Heavy duty aluminum foil (0.001 ± 0.0005 inch)

H. Razor blade.

I. Tape measure.

15.17.6.3 Procedure

A. 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:

$$l = \frac{35}{3.1416 \times d}$$

where: l = sample length in inches
d = diameter of insulated wire in inches

B. Cut and identify a minimum of three samples of the required length.

C. Condition samples prior to testing by predrying in an air oven for 24 hours at 140°F, ±5°F (60°C ±3°C) followed by humidification at 73°F, ±5°F (23°C, ±3°C), and a relative humidity of 50%, ±5%, for a minimum of 24 hours.

D. After conditioning, wind a sample uniformly around the wire frame so that the frame opening is uniformly covered.

E. 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.

F. Place the foil-wrapped wire in a troughless sample holder such that the wire is vertically oriented. Insert millboard backing, spring, and retaining clip.

G. Carefully trim the aluminum foil from the front opening of the sample holder.

H. Adjust wire turns, if necessary, to assure that the sample holder opening is uniformly covered.

I. Perform smoke testing in accordance with ASTM E 662, 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.

J. Report the sample orientation, test conditions, results, and observations made during the test.

15.18 WIRING

15.18.1 General

All car wiring shall be in conformance with Chapter 3 of the National Fire Protection Association's Publication NFPA No. 70, National Electric Code, and the AAR Manual of Standards, Section F S-538, "Wiring Practice and Rolling Stock Standard," except where otherwise specified, and except that all wire shall be as required in this Specification. Circuit protection shall be in conformance with Chapter 2 of NFPA publication No. 70, Article 240.

15.18.2 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 applies:

Wire Size	Maximum Number of Nicked Strands*
Wires smaller than No. 10	None
No. 10 through 1/0	7.4%
Above 1/0 through 1600/24	4.4%
Above 1600/24	Graduated scale

* Definitions:

1. A cutoff strand shall count as two nicked strands.
2. A nick is defined as 25% or more of the strand area damaged, or cut more than one-third of its diameter.
3. Longitudinal scratches in a copper strand are not considered cause for rejection.

15.18.3 Wiring Layout and Installation

15.18.3.1 Wire Harness

The layout of wiring, for both car 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 and tied with a high strength, waxed lacing cord designed not to invade the wire insulation or nylon wire ties. Harnesses shall be installed with identical arrangement and location in each car 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 separable 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 carbuilder practice, will be considered for approval by the Authority.

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, wire trough, conduit, or group of wires between equipment enclosures shall contain a minimum of 10% spares, but no fewer than two spares for each wire size.

15.18.3.2 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:

A. ATC/ATS/Cab Signal circuits
B. High voltage circuits
C. AC circuits
D. Communication circuits
E. Battery voltage level circuits
F. Semiconductor gating voltage level circuits

Wires that are connected in circuits with potentials differing by 50 volts or more shall be separated by a physical barrier. Whenever possible, 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.

15.18.3.3 Wire and Cable Runs

All undercar wiring smaller than No. 6 AWG shall be run in closed wire ducts, conduits, or open 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 carbody 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.

Any wiring run through the floor 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 will 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.

15.18.3.3.1 *Cable Cleating and Support*

All cable and wiring exiting wireways/wire ducts, or that which is not installed in conduit, shall be cleated using fiberglass split-block cleats. The cushioning material shall be fire retardant insulating material with a durometer of 50 to 60 meeting the requirements of Section 15.7. Bolts shall have lock nuts.

No. 6 AWG 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 car movement, touch each other or any other part of the car, except the cleat cushioning material.

Wire and cable runs shall be continuous and unbroken between terminations and shall be supported at not greater than 18-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 will not be permitted, except with express written approval and in accordance with the wire splicing requirements of Section 15.19.9.

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 an access panel at each end of the wire. 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.

15.18.3.3.2 ***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.

No wiring shall be secured directly to the car structure, equipment enclosures, or any metallic surface. Wiring securing devices shall be either completely non-metallic or metallic with a resilient, insulating member between the wiring and the metallic portion of the device.

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 15.19.2. Exterior junction boxes shall be weathertight.

In cases where it is necessary to anchor wires or cables to metallic parts of the car, 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 car 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 re-terminations without applying tension to the wire and without splicing the wire, as follows:

A. No. 10 AWG and smaller: Three re-terminations
B. No. 8 AWG and larger: Two re-terminations

A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.

Wire tying devices shall be of such material and construction that they will 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. 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 will 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 car.

Any wiring needed to calibrate and test car functions shall be a part of the permanent car wiring to enable the Authority to conveniently maintain the equipment. This wiring shall terminate in approved connectors in the respective control groups and cabinets.

The Authority 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.

15.18.4 Insulation Resistance

Insulation resistance to ground at 500 or 1000 VDC, as applicable for each nominal voltage circuit group when measured with a high potential tester, shall give no more than the following leakages, on a vehicle with all circuit breakers closed, and all circuits complete:

Nominal Circuit Voltage	Maximum Leakage Current
Below 90 volts	2 megohms at 500 VDC
90 volts to 300 volts	4 megohms at 1,000 VDC
Above 300 volts	5 megohms at 1,000 VDC

The Contractor shall ensure that these requirements will be met under the most severe conditions of temperature and humidity.

15.18.5 Marking

The Contractor shall devise, and submit for approval, a wire and terminal designation system that shall coordinate all electrical circuits in the car into a unified system. The system shall identify all wiring, including circuit return wiring, and terminals according to their respective circuit function(s) and shall accurately correlate with the car schematic diagrams. Each circuit shall be individually designated from point to point. Common designations for return circuits are not permitted. Alternative designations may be approved for small standard assemblies such as PA amplifiers.

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. All wires shall be marked every 6 inches within 12 inches of the end of the wire and every 12 inches along the entire length 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.

Color coded wires may be approved as an alternative to marking in small standard assemblies such as PA amplifiers. Also, approval may be granted for relief from the marker requirements, on a case by case basis, for electrical panels or around interconnecting jumpers within a panel.

15.18.6 Pulling Compound

Pulling compound shall be non-conductive, non-hygroscopic, non-odorous and shall not attract vermin.

15.18.7 Solder

Solder shall be in accordance with ASTM B 32, Grade 60B. A flux of non-corrosive type shall be applied immediately before soldering.

15.18.8 Tape

Electrical tape shall be polyvinyl chloride 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.

15.19 WIRE AND CABLE CONNECTIONS

15.19.1 General

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.

The Contractor shall submit the proposed design and product line for all connections for approval. Number 6 and smaller type terminal boards and quick-disconnect terminals, other than those stated herein, will only be permitted with approval.

15.19.2 Terminal Boards and Terminal Points

All 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% spares, but not fewer than one spare unless approved. Binding head, screw type terminal boards will be permitted only where approved. All terminal boards shall be in accordance with Military Specification MIL-T-55164A or
MOD 3 approved equal.

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.

Jumpers between terminal board points shall be brass or plated steel. Wire jumpers between adjacent terminals of terminal boards will 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.

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.

15.19.3 Wire Terminations

Terminals and connections used throughout the car 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. The Contractor shall submit the proposed product line for approval. Terminals to be approved shall be tested to Military Specification MIL-T-7928 for temperature rise, voltage drop, vibration, current overload, and corrosion. Test results shall be submitted for approval on a by part number basis. MOD 3

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 No. 10 AWG or smaller shall be of the type which securely grips and holds the insulation of the conductor, unless otherwise approved. Terminals shall be ring lugs in accordance with Military Standard MS-25036, except where otherwise approved for specific applications. MOD 2

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.

15.19.4 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.

15.19.5 Motor Lead Terminals

Traction motor terminals shall be of the glad-hand type or the two bolt type, with crimped or soldered tube type lug.

15.19.6 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. One piece of all cable connectors shall be rigidly mounted.

Where 1/4-turn, bayonet-lock connectors are specified they shall conform to all provisions in MIL-C-5015, or an approved standard, except for the screw coupling requirement.

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. Bolts within the connector shall be long enough to ensure that there is sufficient room to terminate the cable wires within the connector body. 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.

Except as provided above all cable connectors in exterior locations, shall be 1/4-turn, bayonet-lock, quick disconnect type CIR connectors as made by Litton-Veam SPA, or approved equal.

MOD 3 Unless otherwise approved, connectors in high vibration or high motion areas, such as speed sensors and trainline jumpers shall have the wire connections soldered and potted. A watertight jacket shall be molded over the cables and connectors to form a unitized assembly. The contractor shall conduct an approved vibration test on these unitized assemblies.

In waterproof interior locations, the use of non-weatherproof connectors will be allowed as approved. All other connector requirements specified in this section which do not directly apply to weatherproofing shall be met.

15.19.7 Quick-Disconnect Terminals

Approved quick-disconnect terminals shall be utilized to facilitate maintenance and inspection. They shall provide positive terminal engagement and be shock and vibration proof. All terminals shall be provided with insulation equal to that of the wire. No “push-to-fit” (FASTON) type terminals will be permitted unless specifically approved by the Authority.

15.19.8 Grounding Return Connections

15.19.8.1 Grounding

Grounding connections to the carbody and equipment shall be made through copper pads of an adequate area, silver soldered or brazed to the respective carbody and piece of equipment. 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.

All equipment enclosures and shock-mounted equipment shall be grounded with flexible, strap-type, grounding leads bolted between a carbody grounding pad and the equipment’s grounding pad. The ground strap termination method shall apply uniform pressure to the conductive surface and the current density shall not exceed the bonding requirements of Section 15.19.8.2.

The Contractor shall submit, for approval, a complete grounding scheme, which shall indicate the means by which it is proposed to prevent currents from passing through journal, motor, and truck-center bearings. *(CDRL 1504)* 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.

15.19.8.2 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.”

15.19.9 Wire Splicing

Splicing of conductors shall be prohibited except with approval, on a case-by-case basis. Splicing of conductors in conduit will 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, weathertight, 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 unspliced portion by more than 40%. Splices shall be identified in the integrated schematic.

15.20 CONDUIT

15.20.1 Types

All conduit and conduit couplings shall be of an ANSI-approved type. With the exception of truck areas, all conduit shall be of the Aluminum Association's recommended aluminum alloy or galvanized steel. Conduit installed on the trucks or in underfloor areas over the trucks 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.

Rigid aluminum conduit shall consist of seamless, rigid, aluminum alloy conforming to ANSI C-80.5 and to the requirements of Underwriters Laboratory Standard UL-6. All threads shall be covered with an oxidation-inhibiting compound. Aluminum fittings shall be used to assemble aluminum conduit and shall be made to the same grade and alloy as the conduit.

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 B-20.1: 1983 on Pipe Threads. MOD 1

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 Underwriters Laboratory Standard UL-6.

Flexible conduit, if used, shall be watertight and interlocking steel strip-protected, with an approved rust resistive coating.

15.20.2 Size and Fill

Conduit shall be sized such that the sum of the cross-sectional areas of the conductors and their insulation does not exceed 40% of the cross-sectional area of the conduit for three or more conductors. For two conductors, a limit of 31% shall be used, while for a single conductor, a limit of 53% will be permitted. Where conduit having a length not exceeding 24 inches without bends of more than 15^{o} are used between enclosures, a maximum fill of 60% will be permitted.

15.20.3 Installation

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. Suitable approved insulation to prevent electrolysis shall be provided where steel and aluminum are in contact.

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.

15.21 CONDUIT FITTINGS AND JUNCTION BOXES

15.21.1 General

The conduit fittings and junction boxes for car 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 15.21.4.

15.21.2 Boxes

All exterior junction boxes shall be fabricated of steel with a minimum wall thickness of 14 gauge. All exterior junction boxes shall be weatherproof and shall be connected in such a way that drainage from equipment groups will not pass through conduit into the junction boxes. Interiors of all junction boxes shall be primed and then protected with a white, insulating epoxy powder coating as specified in Section 15.24.4.

15.21.3 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.

15.21.4 Covers

All junction box covers shall be 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.

15.22 WIREWAYS

All wireways shall be of rigid steel or aluminum construction with a permanent vinyl coating to minimize the risk of oxidation and rust formation. The trays shall be adequately supported throughout their entire length in an approved manner. There shall be absolutely no sharp edges. The trays shall be completely de-burred 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.

The wireways shall be routed such that they avoid

A. Sources of heat such as propulsion and dynamic brake grid resistors
B. Wheel splash areas
C. Areas along the vehicle where the trays may be subject to foreign object damage.

Wireways shall be located to provide access to the harnesses contained within for maintenance action.

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.

Bends in wireways shall be avoided; however, if they are required, approved protection shall be provided to avoid insulation chafing at the bends.

Wireways will be permitted in approved exterior and ceiling locations only. They will not be permitted in the carbody sidewall area. Only conduit will be permitted in the carbody.

Wireways shall not contain more than 30 current-carrying conductors at any cross-section. The sum of the cross-sectional areas of all conductors contained at any cross-section of a wireway shall not exceed 40% of the interior cross-sectional area of the wireway.

All wire and cable shall be securely fastened within wireways to eliminate movement and resultant chafing.

15.23 WELDING AND BRAZING

15.23.1 General

The Contractor shall be responsible for the quality of its own welding and brazing and that done by its Suppliers and Subcontractors. Cleaning prior to welding shall be in accordance with applicable parts of Section 2, MIL-HDBK-132, “Protective Finishes.”

15.23.2 Structural

All structural welding practices shall be according to requirements of the American Welding Society AWS-D1.1, “Structural Welding Code, Steel”; AWS-D1.2, “Structural Welding Code, Aluminum.” AWS-D1.3, “Structural Welding Code, Sheet Steel”; and the AWS Handbook. Requirements for dynamically loaded structures shall be applied. Cast steel welding shall be according to ASTM A 488/488M “Steel Castings, Welding, Qualification of Procedures and Personnel.” Resistance welding shall be in accordance with MIL-W-6858.

Structural welding of ferritic and austenitic stainless steel shall be governed by ASME Section IX and ASME Section VIII, Part UHA. AISI 201L and 301LN stainless steels shall be treated as P-No. 8, Group-No. 3 category for reference to ASME requirements. 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, Chapter 9, or 50% of the joint strength level calculated from ASME maximum allowable stress values. Higher values shall only be used if qualified by Contractor tests.

15.23.3 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 A 488/488M, or other approved qualifying procedures. Records of welder qualification tests shall be made available for review.

15.23.4 Inspection

The Contractor shall inspect all structural welds according to AWS D1.1. In addition to 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. Subject to the approval of the Authority, the Contractor shall specify a nondestructive inspection sampling rate for all subsequent welds.

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. *(CDRL 1505)* The minimum acceptable inspection plan shall require inspection of one portion of a full penetration weld for every 200 production welds made. The proposed test welds shall be selected from among welds that are most critically loaded as decided by calculations or load test results. With approval, destructive sectioning and metallurgical examination may be substituted for some or all of the required volumetric inspection requirements for production welds.

On the first structure, all ring welds shall be nondestructively inspected by magnetic particle or dye penetrant methods. Sample ring welds shall be sectioned and examined metallographically to determine heat affected zone (HAZ) hardness, which shall not exceed 400 VH (Vickers Hardness). 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 ring weld sample for every 300 production ring welds made.

15.23.5 Post-Weld Cleaning Requirements

All welds exposed to passengers or on sliding contact surfaces of truck frames and bolsters shall be completely cleaned of all spatter.

15.23.6 Contractor Documentation

All welding procedures and documents, including Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR), and Resistance Spot Welding Schedules (RSW), shall be submitted for approval before application. *(CDRL 1506)* Specifications for purchase of welding electrodes, welding wires, and cover gases shall be submitted for approval before their application.

15.23.7 Special Welding

Procedures for structural welding of stainless steel to LAHT, or other combinations of metals or conditions not covered by AWS specifications or codes, shall be submitted for approval. *(CDRL 1507)*

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.

15.23.8 Resistance Welding

Resistance welding of stainless or carbon steels shall be according to MIL-W-6858, Class B for structural applications and Class C for non-structural applications. Contractor-proposed deviations from MIL-W-6858, including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted and approved before application on production hardware.

Design strengths higher than standard certification and production strength requirements shall be qualified according to MIL-W-6858, Figure 11b for one thickness. This requires a test lot size of 180 spot welds. Additional thickness combinations with the same increased strength ratio may be qualified by 25 spot weld shear tests plus three macrosections. Twenty of the 25 shear test specimens may be recorded from production witness tests taken from 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. *(CDRL 1508)*

Surface indentation shall not exceed 20% of material thickness (t) or 0.01 inch, whichever is greater. However, for exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10% 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 indicated, such as by a change in any of the following:

A. Operator
B. Material, material thickness, or combination of thicknesses
C. Electrodes
D. Settings.

15.23.9 Resistance, Spot Weld and Intermittent Weld Spacing

Spacing of resistance and spot welds shall be according to approved structural drawings. Spacing shall not exceed 2 inches plus twice the weld nugget diameter for any structural application, including carbody side sheets. Intermittent fusion-weld spacing pitch shall not exceed five inches for 2-inch (minimum) weld lengths (40% minimum of length welded).

15.23.10 Toughness of Welded Assemblies

The Contractor shall prove all welded steel structures are above the ductile-brittle transition temperature for the specified environmental exposure. Specifically, the weld 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 ft-lbf. of absorbed energy at the lowest specified operating temperature. The Authority shall have the right to require impact tests to verify the specified toughness.

15.23.11 Torch Brazing

All brazing, defined as heating above 840°F, shall follow the recommendations contained in the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who do brazing work shall be qualified in accordance with AWS B2.2-85, Standard for Brazing Procedure and Performance Qualification.

15.23.12 Torch Soldering

All structural (not electrical) soldering, defined as heating below 840^{o}F, shall follow the recommendations contained in the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who do 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. *(CDRL 1509)*

15.24 PAINTS AND COATINGS

15.24.1 General

The exterior portion of the carbody receiving paint shall be painted as required by the Specification and in accordance with the specified color scheme, lettering and numbering. Any austenitic stainless steel portions of the carbody shall not be painted, unless otherwise specified by the Authority 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.

15.24.2 Materials and Preparation

Preparation of the painted surface and application of painting materials for brushing or spraying shall be in accordance with the paint supplier's recommendations. All paint materials shall be used at the consistency recommended by the paint supplier. If thinners are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended. Painting shall be done by experienced labor, using proper equipment under competent supervision.

All painting materials for exterior surfaces visible to the passengers or operating personnel shall be a two-part, high solids, low VOC, polyurethane paint system or approved equal. All paint and filler materials which are to be superimposed to form a finish shall be mutually compatible.

Metal portions of the carbody not constructed of austenitic stainless steel shall, after fabricating, be prepared for painting by grit blasting and immediately thereafter painted with a coat of wash (etch) primer. After application of the wash primer, all metal portions of the car, except the outside skin which will receive the polyurethane paint system, shall be coated with a primer according to Federal Specification TT-P-664. After erection of the framing structure and body sheets, all undercar metal, except stainless steel, shall receive a second primer coat as specified above, plus one coat of charcoal grey alkyd enamel, DuPont Color #6334, per Federal Specification TT-E-527 or approved equal.

The paint manufacturer shall also assure that a continuing supply of touch-up paints in colors used on the car, suitable for spot application by roller or by brush, will continue to be available in the United States.

15.24.3 Exterior Painting

Before painting any car surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed so far as possible by straightening and shall be properly prepared to receive the filler material. These surfaces shall be wash primed following straightening. Any remaining dents or other surface imperfections shall then be filled with an approved epoxy-based 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 1/8-inch.

Exterior austenitic stainless steel shall be cleaned with an approved alkaline cleaning solution, which shall not damage any previously painted surfaces. All hidden aluminum or ferrous materials, except austenitic stainless steel, shall be given one coat of primer and one coat of an approved sealer.

15.24.4 Apparatus and Underfloor Equipment

All underfloor 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 in Section 15.24.3. The interior and exterior surface of all propulsion control equipment enclosures shall be coated with an approved insulating, thermosetting, resin-based, powder coating or approved equal. The interior of the boxes 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. An exterior finish of alkyd enamel shall be provided for equipment control groups. The color shall be as approved by the Authority.

15.24.5 Painting Restrictions

Any equipment or parts of equipment which would be damaged or suffer impaired operation from painting shall not be painted and shall be corrosion resistant. The following parts shall not be painted:

A. General Parts:

1. Conduit and fittings
2. Copper tubing, piping and fittings
3. Wire and cable
4. Power resistors
5. Heat transfer surfaces
6. Electrical insulators
7. Elastomeric portions of air and refrigerant lines
8. Grounding pads.

B. Truck-Related Items:

1. Wheels
2. Axles
3. Elastomeric parts
4. Grease fittings
5. Linkages
6. Threaded parts used for adjustments
7. Electrical equipment
8. Wearing surfaces.

15.24.6 Interior Painting

All exposed interior surfaces, including molding and trim, shall be as specified in Section 3, or powder-coated metal not requiring paint.

Interior surfaces requiring painting shall be coated with an approved thermosetting powder coating. Parts which are to be powder-coated shall be cleaned and prepared in accordance with the recommendations of the powder supplier.

The Contractor and its powder supplier shall supply a touch-up procedure and assure that a continued supply of touch-up paint in the proper colors suitable for spot application will continue to be available in the United States.

15.24.7 Corrosion Protection

Concealed surfaces capable of rusting or oxidation shall be properly cleaned, then primed with a rust inhibiting paint, and painted with an approved finish coat of paint.

Where arc welding is performed on joints between stainless steel and other materials, the joint shall be de-scaled, cleaned, then painted in accordance with Section 15.24.3.

15.24.8 Acoustical Insulation

Acoustical insulating materials shall be applied to properly cleaned underframe, sides, ends, roof and floor sheets, as required in Section 3, to the supplier's recommendations. The materials shall be resistant to dilute acids, alcohols, grease, gasolines, aliphatic oils, and vermin. The material shall be unaffected by sunlight and ozone and shall not become brittle with age. It shall be J.W. Mortell Company's No. 2039 sound deadening compound, Aquaplas No. DL-10, or approved equal.

15.24.9 Trucks

Before installation, the truck shall be cleaned by blowing off with compressed air and solvent-wiped to remove all dirt and grease. All truck components not listed in Section 15.24.5 shall then be sprayed with one coat of primer and one coat of an approved black truck paint (a type that will not conceal cracks that may develop in service) and air dried.

15.24.10 Paint Process Documentation

The Contractor shall prepare a paint coating and application document containing procedures for surface cleaning and preparation, priming, surfacing, and painting for the carbody and all equipment that is painted or powder coated. A detailed paint schedule showing the equipment painted, paint type and manufacturers, recommended thickness, and other pertinent information shall also be included. This document shall be submitted for review and shall be made part of the maintenance manuals.

15.25 FLAMMABILITY AND SMOKE EMISSION REQUIREMENTS

15.25.1 General

All combustible material used in the construction of the car shall satisfy the flammability and smoke emission requirements cited in this Section.

Authority approved, independent laboratory test results indicating successful compliance with these requirements are required for all materials. Test reports older than three years shall not be acceptable.

The Contractor shall be responsible for complete conformance with these standards for itself and its subcontractors and suppliers.

As a minimum, all materials used in the construction of the car shall meet the requirements of this Section and the Urban Mass Transportation Administration's "Recommended Fire Safety Practices for Rail Transit Materials Selection - January 1989" as it appeared in the Federal Register, Volume 54, No. 10 of January 17, 1989, pages 1837 through 1840 inclusive, or the latest issue of that document at the time of bidding, subject to the conditions cited in Section 15.25.3.

A matrix showing the total weight of all materials, where used, flammability and smoke emission test identity, test facility, test requirements, test results, and nature and quantity of the products of combustion shall be submitted by the Contractor during detailed design review. *(CDRL 1510)*

Should the Contractor feel that the quantity of a particular material is such that it would not contribute significantly to a fire, the Contractor may request a waiver from testing for this material. The waiver shall be submitted in writing and shall include the total weight of the material to be used, the location and the distribution of the material in the car, and any previous test reports available. Waivers shall be accompanied by proper justification and will be reviewed on a case-by-case basis.

15.25.2 Combustible Content

The design of the vehicle shall minimize the total combustible material content of the vehicle. Each combustible material shall be specifically identified by supplier's name and type, use in the vehicle, total weight, and heating value in BTU/lb and BTU/hour.

15.25.3 Flammability and Smoke Emission

Materials used in passenger vehicles shall be tested to demonstrate compliance with the requirements set forth in Section 15.25.1.

Requirements for Passenger Vehicle Material Fire Risk Assessment

Function of Material	Test Procedures	Performance Criteria
Seat Cushion	ASTM-D-3675	I_s 25
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 175
Seat Frame	ASTM-E-162	I_s 35
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 175
Seat Shroud	ASTM-E-162	I_s 35
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 175
Upholstery	FAR 25.853	Flame Time: 10 seconds
	(vertical)	Burn Length: 6 inches
	ASTM-E-662	D_s (4.0) (125 uncoated) (250 coated)
Seat Cushion Assembly ("Vandal-guard" type material	ASTM-D-3675	I_s 20
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 200

Function of Material	Test Procedures	Performance Criteria
Ceiling Panel	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 200
Partition Panel	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 200
Windscreen Panel	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 200
HVAC Ducting	ASTM-E-162 ASTM-E-662	I_s 35 D_s (1.5) 100
Light Diffuser and Non-glass Window Glazing	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 100 D_s (1.5) 100 D_s (4.0) 200
Floor Assembly–Structural (see Section 15.25.4)	ASTM-E-119	Pass (with a minimum 15-minute endurance period at AW3 loading
MOD 1		
Flooring (Covering	ASTM-E-648 ASTM-E-662 ASTM-E-662	CRF 0.5 W/cm^2 D_s (1.5) 100 D_s (4.0) 200
Thermal Insulation	ASTM-E-162 ASTM-E-662	I_s 25 D_s (4.0) 200
Acoustical Insulation	ASTM-E-162 ASTM-E-662	I_s 25 D_s (4.0) 200
Elastomers, including articulation section diaphragm	ASTM-C-542 ASTM-E-662 ASTM-E-662	Pass D_s (1.5) 100 D_s (4.0) 200
Exterior Shell, including non-metallic shrouding, equipment box covers, and articulation section panels, where applicable	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 200
Battery Cases	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 200
Wire Insulation	Flammability ASTM-E-662	Per Section 15.17.3.1 D_s (4.0) 200 (flaming) D_s (4.0) 75 (non-flaming) When tested in accordance with Section 15.17.6

Notes:

A. Materials tested for surface flammability shall not exhibit any flaming running or flaming dripping.

B. The surface flammability and smoke emission characteristics shall be demonstrated to be permanent in accordance with one of the following methods:

   1. Washing, if appropriate, according to FED-STD-191A Textile Test Method 5830.

   2. Dry cleaning, if appropriate, to ASTM D 2724.

   3. Materials that cannot be washed or dry cleaned shall be so labeled and shall meet the applicable performance criteria after being cleaned as recommended by the manufacturer.

C. Seat cushion material that is to be tested for surface flammability and smoke emissions shall be first preconditioned in accordance with the procedures in ASTM D 3574, Test I_2, Dynamic Fatigue Test by Roller Shear at Constant Force, Procedure B. After conducting the roller shear test, the same test sample shall be tested for flammability and smoke emission. Test reports for the roller shear test shall be forwarded for review with the flammability and smoke emission test reports.

The following information shall be supplied for all materials tested:

A. Test Description
B. Test Facility
C. Test Results.

15.25.4 <u>Floor Assembly Fire Resistance Testing Criteria</u>

The Contractor shall test the floor assembly in accordance with ASTM E 119 to demonstrate a 15 minute endurance rating. The test procedure, test facility, and test results shall be approved by the Authority prior to the Contractor's procurement of any flooring material necessary for vehicle production.

The following test criteria shall be met:

A. The test specimen shall be a full width vehicle section including side sills or that portion of the wall which extends below the floor. Specimen shall have a minimum exposed area of 100 square feet. 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 11 feet. No fewer than two typical penetrations, spaced at a distance from each other no greater than that which will exist in actual construction, shall be included in the test specimen. The specimen shall include typical floor splice configurations.

B. Test specimen shall be loaded to simulate "crush" passenger loading conditions. Concentrated loads shall be applied to simulate underfloor equipment.

C. Test specimen shall include at least three typical transverse supports.

D. 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.

E. Conditions of acceptance for this test shall be those required for unrestrained assembly.

15.25.5 Not Used

15.25.6 Toxicity

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

Nonstructural materials, except those 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, shall be tested for toxicity using Boeing Specification Support Standard BSS-7239. Materials shall meet the following maximum toxic gas release limits (ppm) as determined per BSS-7239.

A.	Carbon Monoxide (CO)	3500 ppm
B.	Hydrogen Fluoride (HF)	200 ppm
C.	Nitrogen Dioxide (NO_2)	100 ppm
D.	Hydrogen Chloride (HCL)	500 ppm
E.	Hydrogen Cyanide (HCN)	150 ppm
F.	Sulfur Dioxide (SO_2)	100 ppm

The tests are to be run 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.

15.25.7 Electrical Fire Safety

Except when otherwise approved or where more restrictive requirements are imposed by this Specification, electrical equipment shall conform to NFPA 130.

15.26 AIR FILTERS

15.26.1 HVAC and Equipment Ventilation Filters

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.

15.26.2 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:

A. Each air brake control assembly
B. Input and output of each height control valve
C. Coupler controls
D. Door controls
E. Horn.

15.26.3 <u>Low Pressure Air Filters</u>

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 1/2-inch oversize to ensure adequate sealing between the edge of pad and its integral frame.

15.27 ELECTRICAL AND ELECTRONIC DESIGNS

15.27.1 <u>Reliability Standards</u>

All electrical and electronic control systems shall be designed, and components shall be selected, using the MIL Handbook 217F or later revision, as a guide. All devices shall be derated to operate within the "Acceptable" region for electrical stress versus temperature for "Airborne Applications", at ground mobile severity. If there is a conflict between guidelines given elsewhere in this Specification and the "Reliability Design Handbook", the more restrictive condition shall govern. Other service-proven devices may be submitted for approval.

15.27.2 <u>Ability to Repair</u>

All electrical devices including such items as PC boards, relays, contactors, and filters shall be capable of being repaired by the Authority in its electronics laboratory.

Units shall not be sealed, potted, or constructed to prohibit repair by the Authority. Units that must be potted or sealed by design other than lowest level replaceable units (LLRUs) shall have a minimum 10-year warranty.

15.27.3 <u>Hardware</u>

Refer to Section 15.2.2 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.

15.27.4 <u>Wiring</u>

Wire selection, routing and securement shall be accomplished with the goal of having the wire and cable last the life of the carbody. All movement and chafing of wire and cable shall be eliminated. The use of additional wear material(s) to extend life without elimination of the movement, wearing or chafing will not be permitted. Refer to Sections 15.17 through 15.22 for additional wire and wiring requirements.

15.27.5 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".

15.28 SEMICONDUCTOR STANDARDS

15.28.1 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.

15.28.2 Ratings

Discrete semiconductors shall have the following minimum voltage breakdown ratings:

A. Semiconductors, except diodes (see below), operated from the battery supply, or those connected to trainlines, shall have minimum breakdown ratings of four times the maximum achievable circuit voltage. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

B. Diodes operated from the battery supply, used as suppression devices, or connected to trainlines shall have a minimum breakdown rating (PIV) of 1,000 V. Diodes with less than 1,000 V PIV rating may be used if adequate circuit transient protection is also provided.

C. All discrete semiconductors operated from inverters or other isolating devices shall have a minimum breakdown rating of 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 150°C (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% of the maximum continuous current rating or 50% 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, derated to less than 50% 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% below the manufacturer's recommended maximum. In addition, the maximum power shall be limited to 50% of the manufacturer's specified maximum at the maximum operating temperature.

Silicon semiconductors shall be hermetically sealed and rated for operation over the temperature range of -40°C to +85°C. Non-hermetic devices are acceptable to the Authority provided comparable reliability documentation is available upon request.

All Gallium Arsenide and similar optical semi-conductors shall be rated for operation over the temperature range of -40°C to +85°C.

15.28.3 Availability and JEDEC Registration

Except as approved, all semiconductor devices shall be JEDEC registered and numbered.

JEDEC registered devices with house numbers may be used only if a complete cross reference is provided linking each house numbered device with a JEDEC registered device. House labeled devices shall be clearly labeled with the manufacturer's name or logo.

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. 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.

15.28.4 Burn-in

All integrated circuits shall be burned-in and screened for defects to MIL-STD-883, Method 5004, Reliability Class B. Alternative methods, based on a minimum 100 hour burn-in for the completed assembly, will be considered. The burn-in shall 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.

15.28.5 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.

15.29 PRINTED CIRCUIT BOARD STANDARDS

15.29.1 General

Printed circuit boards shall be designed, constructed and inspected to MIL-STD-275, latest revision, unless more stringent requirements are noted here. Traces shall be made as wide as practical, with the minimum width being based on a 10°C temperature rise. Run spacing shall conform with MIL-STD-275, latest revision.

Circuit board material shall be per MIL-P-13949, latest revision, with a minimum thickness of 1/16 inch using type GB or GH base material. Type GE material may be used for boards which have no components whose power dissipation is greater than two watts and when said board is not mounted adjacent to components dissipating greater than two watts. The copper laminate shall be firmly attached to the board and shall be resistant to blistering and peeling when heated with a soldering iron.

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 in^2 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, except where approved otherwise.

15.29.2 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. 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; the first pin on all IC packages shall be identified on the wiring side of the board.

For boards whose component density is greater than 2.25 components per square inch, the Contractor may submit an alternate marking plan for possible approval. Such a plan should include board marking, augmented by layout drawings.

15.29.3 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 will not discolor or damage the board.

15.29.4 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 Authority approval. All other components shall be soldered in place.

Where approved, IC sockets shall comply with MIL-S-83502C and MIL-S-83734, as is applicable for the device, and shall be made of the following materials: MOD 1

A. The bodies shall be molded from diallyl phthalate, PTFE Teflon, or approved equal.

B. 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.

15.29.5 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 coating shall be easily removed with a brush-applied solvent or penetrated by a hot soldering iron when a component must be unsoldered. The coating solvent shall not adversely affect board mounted components.

All IC sockets, connectors, and test points shall be masked when the coating is applied.

15.29.6 Keying

All printed-circuit boards shall be "keyed" to prevent insertion into the wrong socket. Further, circuit boards in safety related control systems, such as propulsion, 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.

15.29.7 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 the Authority prior to commencing design.

Connectors which comply with MIL-C-55302, latest revision, 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 of gold over a minimum of 0.000050-inch of low stress nickel.

All connectors within one panel assembly shall be keyed to prevent damage or malfunction due to incorrect insertion.

Refer to Section 15.17.5 for wire wrap used and connection requirements.

15.29.8 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 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.

15.29.9 Plated-Through Holes

In addition to the general guidelines of the Institute of Printed Circuits (IPC), the following requirements shall be met:

A. Plating Holes: Copper plate shall be a minimum of 0.001-inch minimum average thickness, and 0.003-inch maximum average thickness. Solder plates shall be 0.0003-inch minimum average thickness and 0.0015-inch maximum average thickness.

B. Plated Hole Defects: No more that than three voids per hole will be acceptable. Total area of the voids shall not exceed 10% of the total wall area. The largest void dimension shall not exceed 25% of the core diameter or the board thickness, whichever is smaller. There shall be no pits, voids or cracks at the junction of the hole wall and terminal area to a depth of 1-1/2 times the total copper thickness on the surface.

15.29.10 Multilayer Boards

To ensure repairability, the use of multi-layer PC boards shall be as approved by the Authority and may require additional use of IC sockets.

15.29.11 Enclosures

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.

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.

Enclosure features specified above shall be presented for approval during preliminary design and prior to commencing final design.

15.29.12 Extenders

Printed circuit board extenders (six sets of each type) 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.

15.30 MICROPROCESSOR BASED SYSTEMS

15.30.1 General

The microprocessor based control 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 similar to that available for the Intel 80XXX family of devices.

Should the Contractor elect to use a multi-processor bus architecture, the architecture shall be based on the Intel Multibus, Motorola VME or similar bus used widely in industrial process control equipment. Alternative bus structures may be submitted for Authority approval.

Program code and fixed data shall be stored in PROMs or EPROMs. Either static or dynamic RAM or EEPROM may be used for temporary data storage. All EPROM windows shall be covered with labels that are opaque at the UV erasing wavelengths. Two levels of passwords should be included: one which allows access to data via a PTU for troubleshooting, and the other which allows the software to be modified. This second set of passwords would be more restrictive.

Battery-backed RAM may be used only to store fault information. Batteries shall be sized to retain data for at least six months without charging and shall be located such that leakage cannot damage any control system components. Battery life shall meet the requirements of Section 15.31.10.

At least 30% additional memory space shall be installed and available for future modifications to program code, fixed data space, and temporary data space.

15.30.2 Software

Software may be written in a high or low level language. The language, and its implementation for the selected microprocessor system, shall be commercially available in English.

All software, whether interrupt based or polled, shall always assign the highest priority to safety-related tasks.

Software shall perform the following basic functions:

A. Implement the desired control scheme such that the specified performance is achieved.

B. Monitor all inputs for unsafe, erroneous, or unknown conditions or combinations of conditions.

C. Sample all input conditions 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.

D. Limit all output commands to safe levels regardless of any combination of input conditions.

E. Perform self-diagnostic routines and respond promptly, safely, and predictably to detected faults.

F. 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.

G. Permit thorough interrogation of all input, output, and internal conditions by external diagnostic equipment.

15.30.3 Isolation and Interfacing

The control system shall be powered by dedicated transformer-isolated power supplies driven from the vehicle battery circuit.

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:

A. Protect and isolate the control system from damage due to overvoltage, undervoltage, transients, shorts, and opens.

B. Perform necessary voltage translations.

C. Remove noise and undesired signals.

D. Limit, pre-process, discriminate and format those signals that would otherwise require excessive processor time.

E. Consist of optical isolators, transformer isolators, and other circuits appropriate to the application.

15.30.4 <u>Programming</u>

Programming of microcomputers shall be divided into two classifications subject to Authority approval. The first classification shall be programs which are application independent and can be considered an inherent part of the controlled subsystem. The second classification, application dependent, shall include all programs which are specifically written for the operation and control of the vehicle.

The application-independent programs shall include the inverter or chopper controller, safety-related systems such as the frictionbrake and door controls, the multi-processor bus operating system, dedicated serial bus controllers, and other functions as approved by the Authority. They shall be of an existing design meeting the requirements of service-proven equipment in Section 1. These programs shall be documented by the identification and description of all I/O functions, functional descriptions of the interfaces with all vehicle systems and subsystems, and all information required to ascertain the safe operation of the vehicle in response to any failure. The source code for these programs may be retained by the Contractor.

The application-dependent programs shall include the vehicle logic, subsystem integration, and fault and diagnostic routines related to application-dependent programs. These programs are usually tailored to meet the requirements of this Specification. The development of these programs shall be subject to the requirements of Section 15.30.5. The Contractor shall accept that the Authority may at a future date have a need to change elements of these programs and shall provide the Authority with sufficient information to alter this vehicle software without the Contractor’s assistance.

Unless otherwise specifically approved by the Authority, application-dependent programs shall be programmed in a high level language such as C or PL/M. Compilation of the application dependent programs shall be performed on an IBM-compatible computer. The source code and all necessary files for the linking, locating, and conversion to hexadecimal object code shall be supplied to the Authority on 3.5 in HD IBM-compatible diskettes. The compiler used shall be commercially available.

15.30.5 Software Quality Assurance and Documentation

The Contractor shall comply with the following stipulations concerning software quality and documentation:

A. The Contractor shall submit, for approval, a Software Quality Assurance Plan in accordance with ANSI/IEEE Standard 730-1984. *(CDRL 1511)* For reference, this Standard has the following minimum software documentation requirements:

1. Software Requirements Specification
2. Software Design Description
3. Software Verification and Validation Plan
4. Software Verification and Validation Report
5. User Documentation

B. The Software Design Description (SDD) shall be in accordance with ANSI/IEEE Standard 1016-1987. The final Software Design Description shall include details required by ATA A652, through all levels to Level 6. Level 4 may be omitted for application independent software as defined in Section 15.30.4. The levels defined in ATA No. 102 are summarized below only for information: MOD 1

1. Level 1 – Computer description and operation
2. Level 2 – Software architecture, basic program and functions
3. Level 3 – Detailed flow information
4. Level 4 – Annotated compiler/assembly listing
5. Level 5 – Detailed memory map and listing
6. Level 6 – Input/output port map

At its option, the Authority will participate in both the Software Requirements and the Preliminary Design Review, as defined by IEEE 730-1: 1995. Following these reviews, the Contractor shall submit, for approval, the Software Requirements Specification and the Software Design Description. All subsequent changes to these documents shall also be submitted and approved prior to implementation. MOD 1

15.31 ELECTRICAL DEVICES AND HARDWARE

15.31.1 General

All electrical devices shall be transit industry-proven. Electrical connections shall use either captive screws or captive nuts, with crimped ring-type terminals.

15.31.2 Contactors and Relays

15.31.2.1 General

Unless otherwise approved, all contactors and relays shall meet or exceed the requirements of MIL-R-6106, MIL-R-5757 or IEC947-4 as applicable, with the following two qualifications: MOD 3

A. 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.

B. 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.

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.

Unless specifically approved on a case basis, there shall be a maximum of no more than 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 manufacturers 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. The Authority reserves the right to review and approve the design and selection of all contactors and relays.

Contactor tip replacement shall not exceed 10% of the total number of tips at 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 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 will 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.

15.31.2.2 Vital Relays

Vital biased neutral relays shall meet the requirements established by AAR Communication and Signal Division's Signal Manual of Recommended Practice, Part 6.2.1, Recommended Design Criteria for Tractive-Armature, Direct-Current Neutral Relay, where the requirements of the AAR Specification do not conflict with any requirements specified below.

Vital DC relays, except as specified below, shall be plug-in, biased neutral relays with a nominal operating voltage of 28 volts. They shall be rack mounted and shall be furnished with transparent covers which will not support combustion. The design of the relay covers and of the cabinet in which several relays are mounted shall permit viewing the relays without disassembly or other mechanical manipulation to determine whether each relay is picked up or dropped out. These relays shall be capable of operating continuously and successfully without resultant damage with a minimum voltage range of 18 volts to 42 volts applied to their operating circuits.

All biased neutral relays used for the ATC equipment shall be identical and interchangeable. All front contacts of each such relay shall be silver-to-metalized carbon which meet the requirements of Part 6.5.1.G, Paragraphs 1 through 10, of the AAR Communication and Signal Division's Signal Manual cited above. Each such relay shall also have a minimum of two silver-to metalized carbon back contacts unless otherwise approved by the Authority. In reviewing any proposed alternate back contact composition, the Authority will evaluate the composition, the overall relay characteristics, and the circuit applications of the contacts. It shall be the Contractor's responsibility to perform any tests required by the Authority and to provide all data requested by the Authority. In evaluating proposed alternates, should an alternate back contact composition be approved and later found to be unacceptable due to relay characteristics and/or circuit application, the Contractor shall supply relays as specified at no additional cost to the Authority.

Biased neutral vital relays shall be designed so that their armatures will not pick up with the permanent magnet de-magnetized. These relays shall also be designed so that their armatures will not pick up when no current is applied to coils due to an interruption of the normal magnetic circuit. Biased neutral vital relays shall be designed so that up to at least 50 times working energization applied for 2 seconds at both normal and reverse polarity will not affect their operating characteristics by more than 2 percent, and will not pick up their armatures on reverse polarity.

Arc suppression for vital relay coil(s) shall be built into the relay or into its plugboard.

Decoder output relays shall be identical to other biased neutral relays except they may have a different coil resistance, different operating values and six dependent front-back contacts. The front contacts shall be silver-to-metalized carbon.

When three DC vital or non-vital relays, suppressed as specified herein, are connected in parallel and operated from 24 volts, a vital relay front or back contact that breaks this load shall be capable of at least 5 million operations at this load without the contact resistance, measured with a 10 mA current, exceeding 5 ohms.

15.31.3 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 the Authority's service environment. The design and selection of all switches shall be subject to review and approval.

There shall be a maximum of two 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.

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 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, as approved by the Authority.

15.31.4 Circuit Breakers

15.31.4.1 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 overcurrent or shunt trip elements.

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.

MOD 1 All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI C37.13 and IEEE C37.14: 1992.

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.

15.31.4.2 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 manipulable in all positions.

15.31.4.3 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:

A. General Use: Westinghouse Series C, Quicklag C frame, Heinemann Series AM or approved equal, front connection or approved access arrangement, and approved labeling

B. Fast Operation: Airpax type IMLK, dust sealed, magnetic breaker, or Airpax type UP, hermetically sealed, magnetic breaker, or an approved equal.

15.31.5 <u>Fuses</u>

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:

A. To protect solid state equipment from catastrophic damage
B. Where current or voltage levels prohibit circuit breakers

Fuses shall be used in car heater circuits only with the approval of the Authority.

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 750 volt circuits shall be rated for no less than 1,000 volts.

High voltage fuses shall be mounted in totally enclosed, dead front, fuseholders, 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.

Unless explicitly noted otherwise in this Specification, all fuse compartments shall have a spare fuse of identical size and rating for each "in-circuit" fuse, and shall be mounted next to the respective "in-circuit" fuse with the fuse holder clearly marked "SPARE FUSE"." The spare fuse holder shall not be enclosed and shall not consist of any loose parts.

15.31.6 Bus Bars

Bus bars are to be fabricated from OFE (Oxygen Free Electronic) or ETP (Electrolytic Tough Pitch) copper (CDA 101). The bus bar conductivity shall be 100% IACS. All bus bar joints shall be silver or tin plated.

Current densities, other than at joints, shall not exceed 1575 amperes per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 30^{o}C. Current densities in joints shall not exceed 600 amperes 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 busbar 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 or other approved means. Tape is not acceptable. Bus bars that are behind insulating panels, and those cases where there are suitable warning labels and maintenance procedures that prohibit opening the equipment case when energized, are exempt from this requirement.

15.31.7 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 20 years. Filter capacitors shall have high ripple current rating for long life.

Capacitors shall be derated 20% 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 85^{o}C.

Except for braking power resistors, all resistors shall be derated 50% for power dissipation. Other power resistor applications may be submitted for approval of lower derating, on a case-by-case basis.

15.31.8 Transformers and Inductors

Transformers and inductors shall be derated 10% for current.

15.31.9 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 No. 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 will not be permitted.

15.31.10 Battery Backup Circuits

Where individual electronic circuits require their own battery, the following conditions apply:

A. The batteries shall be rechargeable nickel-cadmium with a built-in charger or non-rechargeable lithium, unless otherwise approved by the Authority.

B. If a nickel-cadmium battery is used, the charge time vs. discharge time must be approved, for the specific application. In no case shall the battery life-span be less than five years.

C. If a lithium battery is used, the calculated life-span and the assumptions for that calculation must be approved for the specific application. In no case shall the life span be less than five years.

D. In order to properly assess the impact of distributed battery backup systems, the Contractor shall provide a complete list of battery locations, battery type, estimated lifespan, discharge time, and the impact of battery discharge failure. Approvals of items above may be affected by this total vehicle evaluation.

SECTION 16
NOISE AND VIBRATION

TABLE OF CONTENTS

Section **Page**

SECTION 16
NOISE AND VIBRATION

16.1 GENERAL

The Contractor shall ensure that the car and equipment are designed and built so that the noise and vibration limits specified in this section are not exceeded. The vehicle design shall incorporate features to attenuate equipment noise or vibration that otherwise would not meet the noise- and vibration-level limits specified. Particular attention shall be given in the design of all equipment to ensure minimum generation of noise and vibration, and in the design of the vehicle for attenuation of airborne noise and structure-borne vibration along the paths from source to passengers.

Unless otherwise stated, noise herein means sound pressure level and sound (noise) level as defined in ANSI S1.4-1983, Specification for Sound Level Meters. All noise levels listed are in decibels referenced to 20 micro-newtons per square meter (0.0002 microbar) as measured on the "A" scale or the "C" scale of a Type 2 standard sound level meter, abbreviated dBA and dBC, respectively, as defined in ANSI S1.4-1983, Specification for Sound Level Meters. Unless otherwise specified, the "slow" meter scale shall be used.

Except as noted, the noise limits specified are based on measurements taken in essentially a free-field environment such as outdoors, away from any reflective surfaces other than a ballast-and-tie trackbed and the adjacent ground. Interior noise criteria apply to measurements taken in a complete but empty car.

Sound transmission losses specified for carbody floors, walls, and ceilings refer to sound insulation values obtained by measurement procedures outlined in ASTM E90 or ASTM E336, Recommended Practices, except that octave band rather than 1/3-octave band measurements are specified.

For tests and measurements the Contractor shall use a Type 2 sound level meter meeting the requirements of ANSI S1.4-1983, Specification for Sound Level Meters. Where octave band or 1/3-octave band measurements are specified, the Contractor shall use an analyzer meeting the requirements for Class II Filters as given in ANSI S1.11-1986, Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets.

16.2 AUDIBLE NOISE CRITERIA

16.2.1 <u>Equipment Noise Prior to Installation on Car</u>

16.2.1.1 Traction Motors

The noise produced by each traction motor shall not exceed 93 dBA at 15 feet from the center of the motor, in any direction, while operating at all speeds from 0 mph to the equivalent of 75 mph car speed and at all loads up to the equivalent of maximum dynamic braking in both directions. The average of eight readings taken in the horizontal plane passing through the output shaft of the motor, circumferentially around the motor both parallel and perpendicular to the output shaft and diagonally at 45 degrees thereto, at a distance of 15 feet from the geometric center of the motor shall not exceed 89 dBA.

16.2.1.2 Propulsion System Gearing

The noise produced by each propulsion system gear box shall not exceed 85 dBA at 15 feet from the geometric center of each gear box, in any direction, and with gears rotating in either direction at all speeds from 0 mph to the equivalent of 75 mph car speed and at all loads up to the equivalent of maximum dynamic braking.

16.2.1.3 Auxiliary Equipment

The noise produced by the individual operation of all noise-generating pieces of apparatus including, but not limited to, air conditioning compressors, condenser fans, and evaporators; static converters, inverters, air compressors, hydraulic pumps, and air-exhausting valves; brake discs and blowers; but excluding traction motors and gear boxes, shall not exceed 68 dBA at 15 feet in any direction from the center of the equipment while it is operating at normal conditions. All duct work, baffles, or appurtenances that form a part of the installed assembly shall be included as part of the equipment for noise tests.

16.2.2 Equipment Noise after Installation on Car

16.2.2.1 Traction Motors and Gearing

The noise produced by the traction motors and gear boxes of a complete truck, mounted under the carbody, with all wheels spinning under no-load conditions, at all speeds from 0 mph to the equivalent of 75 mph car speed, shall not exceed 92 dBA (88 dBA at 60 mph) when measured at a distance of 15 feet from the center of the truck on the horizontal plane passing through the axles.

16.2.2.2 Friction Brakes

The noise produced by full or partial application of friction brakes at low speeds, 0 to 15 mph, shall not exceed 75 dBA at 15 feet from the car centerline on the horizontal plane passing through the axles.

16.2.3 Effect of Pure Tones

Noise level limits set forth in this specification shall be reduced by 3 dBA if significant pure tones in the range from 300 Hz to 4,000 Hz are present in the noise. Pure-tone noise shall be considered significant in this context if any 1/3-octave band sound pressure level is 5 dB, or more, higher than the average of the two adjacent 1/3 octaves containing no pure tone or “tonal” noise.

16.2.4 Car Interior Noise Levels

16.2.4.1 Auxiliary Equipment Noise with Car Stopped

With all auxiliary equipment operating at maximum capacity, including propulsion system cooling blowers if installed, the sound pressure levels measured 4-1/2 feet above the floor, at all points along the car centerline, shall not exceed the limits tabulated below:

Condition	Measurement Location	Sound Pressure Level
All auxiliary equipment operating simultaneously	Low ceiling area, not less than 2 feet from end walls	69 dBA
	High ceiling area, not less than 2 feet from the low ceiling areas	66 dBA
Each auxiliary system or unit operating on its own	Low ceiling area, not less than 2 feet from end walls	67 dBA
	High ceiling area, not less than 2 feet from the low ceiling areas	64 dBA

16.2.4.2 Car Moving on Ballasted Track

When the completely assembled and operating vehicle is moving at all speeds up to 70 mph on tangent, at-grade, ballast-and-tie track with clean, smooth rail with all vehicle systems operating simultaneously at normal conditions and with the vehicle operating in any specified mode of acceleration, deceleration, or coasting, the noise level in the car interior (without passenger load) shall not exceed 72 dBA at any point along the centerline of the car at 4-1/2 feet above the floor and not less than 2 feet from the end walls of the car. In areas immediately above trucks the maximum noise level 4-1/2 feet above the floor and 2 feet from the side doors shall not exceed 75 dBA.

16.2.4.3 Car Moving in Subway

When the completely assembled and operating vehicle is moving at speeds up to 60 mph in box-section subway without sound absorption and with clean, smooth rail and with all vehicle systems operating simultaneously at normal conditions and with the vehicle operating without passenger load, in any specified mode of acceleration, deceleration, or coasting, the noise level in the car interior shall not exceed 74 dBA at any point along the car centerline at 4-1/2 feet above the floor and not less than 2 feet from the car end walls. In areas immediately above the trucks, the maximum noise level 4-1/2 feet above the floor and 2 feet from the side doors shall not exceed 76.5 dBA.

16.2.5 Door Operation Noise

Noise produced by operation of all the side doors on one side of the car shall not exceed 75 dBA, on the fast meter scale, at all points in the car one foot or more from the doors or door pockets and between 3 feet and 6 feet above the floor.

16.2.6 Carbody Sound Insulation

The sound transmission loss of the car floor, wall, and ceiling assemblies in completed form shall be adequate to achieve the interior noise level limits specified in Section 16.2.4. The average sound transmission loss of each characteristic section of the carbody should be not less than that specified in the following table:

Sound Transmission Losses By Octave Bands

Octave Band Center Frequency	Entire Floor	Ceiling and Roof	Walls Including Windows But Excluding Doors	Door Areas With Doors and Weatherstripping Installed	Door Panel Including Window
250 Hz	27 dB	23 dB	23 dB	15 dB	19 dB
500 Hz	35 dB	31 dB	31 dB	23 dB	27 dB
1,000 Hz	38 dB	35 dB	34 dB	26 dB	30 dB
2,000 Hz	40 dB	35 dB	34 dB	26 dB	30 dB

It shall be the Contractor's responsibility to perform the necessary calculations and preliminary tests during the design and development of the car as required to determine that the sound insulation of the completed car will meet the requirements specified in Section 16.2.4. The design must include provisions for controlling sound energy transmitted into the car through all weak areas such as apertures, door seals, air ducts, openings for wiring and air ducts, and grilles.

16.2.7 <u>Miscellaneous Equipment</u>

All equipment shall be designed to eliminate rattling and resonance at all speeds up to 10% above maximum running speed by the use of damping, gasketing, resilient mounts or similar methods. Included in this requirement but not limiting the generality thereof are such accessories as:

A. Windows
B. Seats
C. Wiring
D. Piping
E. Ventilating ducts
F. Ventilating grilles
G. Doors
H. Lining panels
I. Cab door
J. Cab walls
K. Lighting fixtures and covers
L. Stanchions
M. Handholds
N. Fire extinguishers
O. Partitions
P. Polycarbonate dividers
Q. Truck-mounted equipment
R. Windscreens

Noise generated by fluorescent lamps, fixtures, and ballasts, installed in the car and energized at rated voltage, shall not exceed 40 dBA when measured 1-foot from each lighting fixture with all lights operating simultaneously at normal conditions.

Noise generated by the car public address system in the standby condition shall not exceed 45 dBA when measured 12 inches away from any loudspeaker with PA auxiliary equipment energized and operating and with the car electrical systems energized. Testing for this limitation may require an indirect test of loudspeaker acoustic sensitivity and electrical noise at the loudspeaker terminals.

16.2.8 <u>Car Exterior Noise Levels</u>

16.2.8.1 Car Stopped on At-Grade, Ballast-and-Tie Track

With the car stopped and all vehicle systems operating simultaneously at normal conditions, the noise level measured 50 feet horizontally from the centerline of the track on the horizontal plane passing through the axles shall not exceed 61 dBA at any point along the length of the car on either side. This requirement is intended to supplement Section 16.2.4.1 to discourage concentrations of noise-producing apparatus.

16.2.8.2 Car Stopped in Subway Station

When a two-car train is stopped at a subway station platform and all vehicle auxiliary systems are operating simultaneously at normal conditions, the noise level at all points along the platform, parallel to the cars, 6 feet from the edge of the platform and 5-1/4 feet above the platform surface shall not exceed 68 dBA

16.2.8.3 Car Moving on At-Grade, Ballast-and-Tie Track

When a two-car train is moving on level, tangent, at-grade, ballast-and-tie track with clean, smooth rail at all speeds from 0 mph to 75 mph, and while accelerating or braking, with all vehicle systems operating simultaneously at normal conditions, the noise level measured on either side, at 50 feet from track centerline on the horizontal plane passing through the axles, shall not exceed 86 dBA.

16.2.9 Auxiliary Equipment

The noise produced by the individual operation of all equipment and operating systems, except traction motors and gearing, shall not exceed 68 dBA at 15 feet from the car centerline, on either side and on the horizontal plane passing through the shaft or equipment centerline, while the equipment is operating at normal conditions with the car at rest. The equipment must be complete, installed on the car, and all components of each system operating during tests for noise level.

16.3 VIBRATION CRITERIA

Equipment and auxiliaries mounted anywhere on the car, carbody, or trucks shall not cause vertical or horizontal vibrations anywhere on the car floor, walls, ceiling panels, stanchions, handholds, or seat frames in excess of 0.10 inch peak-to-peak amplitude, for the frequency range from 0 to 1.4 Hz, in excess of 0.01g peak acceleration for the frequency range from 1.4 Hz to 20 Hz, and in excess of 0.03 inch per second peak vibration velocity for the frequency range above 20 Hz. It shall be the Contractor's responsibility to perform the necessary calculations and preliminary tests during the design and development of the car as required to substantiate that the vibration isolating mountings for the equipment are appropriate to achieve vibration levels of the completed cars in accordance with the defined limits.

The first traction motor and one traction motor out of each lot of up to 100 motors, selected at random, shall receive a vibration test. The motor, detached and supported on resilient mounting providing at least 1/4-inch static deflection, shall not exceed 0.0015-inch peak-to-peak displacement anywhere on the motor while the motor is rotating at any and all speeds between 50% and 100% of maximum normal operating speed.

16.4 NOISE AND VIBRATION TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 1.8.

16.4.1 Noise Tests

16.4.1.1 Test Conditions

Conformance with the specifications is to be based on measurements taken in essentially a free-field environment such as outdoors, away from any reflecting surfaces other than the ground on which the car is resting, except for tests in subways. Except for subway tests, all measurements shall be made at locations where reflected sound, such as reflections from nearby walls, floor, or other equipment, will not influence the directly radiated sound from the equipment measured by more than 2 dB. All measurements shall be made with an ambient sound level in the vicinity of the test measurement locations of 10 dB or more below the noise produced by the equipment being measured, when evaluated using the same weighting or octave band. Where auxiliary methods of driving or loading equipment such as motors or dynamometers are required, these devices shall be temporarily enclosed or baffled to eliminate their effect on the equipment noise being measured. For equipment noise measurements with the car stationary or on jacks, the car shall be located outdoors on a ballast-and-tie, at-grade trackbed in an area free of barriers, third rail coverboards, or other sources of interference. Carbody section transmission loss measurements may be performed outdoors or indoors. Car interior and exterior noise level tests with the car moving shall be done at a section of clean, smooth rail both on a ballast-and-tie at-grade track with no sound barriers or third rail coverboard on the measurement side and in a box-section subway without sound absorption on the walls.

16.4.1.2 Equipment Noise Test Procedures

Using sound level meter and analysis equipment as specified in Section 16.1, the Contractor shall measure the sound level produced by equipment in the operating mode at the distances and directions specified and using the scales and frequency ranges specified in Section 16.2.

16.4.1.3 In-Vehicle Noise Test Procedures

Using sound level meter and analysis equipment as specified in Section 16.1, the Contractor shall measure the sound levels inside the vehicle with all equipment energized and all components operating except the propulsion motors; shall measure the noise levels inside the vehicle with each individual equipment system energized; and shall measure the sound levels inside with the vehicle moving at speeds up to 70 mph on ballast-and-tie at-grade track and at speeds up to 60 mph in box-section subway. The sound readings shall be obtained at sufficient locations along the car centerline to determine that the specified noise level limits are not exceeded at any point along the center of the car.

16.4.1.4 Tests of First "A" Car and "B" Car Sets of Equipment

Noise level measurements shall be performed on the first car sets of equipment before and after installation on the car to verify that the noise generated is within the limits specified in Section 16.2. The tests shall include measurements to determine the noise levels produced by the traction motors and propulsion system gearing for one car and the noise levels produced by the compressor, motors, blowers, brakes and other noise generating components of the first two cars.

16.4.1.5 Tests of First Completed "A" Car and "B" Car

Noise level tests shall be performed on the first completed car to verify performance within the limits specified in Sections 16.2.5 and 16.2.7. Noise level tests shall be performed on the first completed "A" car and "B" car to verify performance within the limits indicated in Sections 16.2.2, 16.2.3, 16.2.4, and 16.2.8. These tests shall include measurements to determine the exterior noise levels from the vehicle equipment and the complete vehicle both stopped and moving, and the car interior noise levels from the vehicle equipment and with the car moving in accordance with the requirements and conditions specified in Section 16.2.

16.4.1.6 Vehicle Body Diagnostic Transmission Loss Tests

In the event that tests of the car interior noise indicate noise levels in excess of the limits specified in Section 16.2.4 the supplier shall, using the procedures outlined in ASTM E336-71, "Recommended Practice for Measurement of Airborne Sound Insulation in Buildings." perform diagnostic tests to ascertain the sound insulation value of each section of the completed carbody. The purpose of the tests is to determine the appropriate or necessary modifications to correct the car interior noise levels. Evaluation of the carbody sound insulation shall be done using one or a combination of the following procedures:

A. With the car located outdoors on the ballast-and-tie, at-grade trackbed or indoors in a space where reflected sound from nearby walls or floor will not influence the sound radiated from the carbody by more than 2 dB, the Contractor shall, using portable loud speakers in a manner approved by the Authority, create a random noise of constant level, for the frequency range encompassing the 250 Hz to 2,000 Hz center frequency octave bands, with sufficient Sound Pressure Level (SPL) inside the car that the noise transmitted through the carbody is at least 10 dB higher than the outside ambient SPL in each octave band and with sufficient diffusion or distribution that the sound level in the car is uniform within 3 dB along the length of the car. (Achieving a uniform sound field over the car floor may require removal of the seats.) Using this procedure the carbody section sound insulation can be evaluated by using a sound level meter and octave band analyzer to measure the space average SPL inside the car in the 250, 500, 1,000 and 2,000 Hz center frequency octave bands and by also measuring the exterior SPL for each of these octave bands at a distance of 12 inches from all car surfaces at a sufficient number of locations to determine the average noise reduction for each characteristic body section, such as the walls, roof, and doors. The measurements may be used to identify the influence of any sound leakage such as at ducts, seals, or openings and the influence of flanking sound transmission paths at locations such as the floor-to-wall juncture and to identify any components which are deficient in sound insulation value. The difference between the interior space average SPL and the average exterior SPL at each section is the Noise Reduction provided by the carbody section. Noise Reduction measured in this manner is 6 dB greater than the transmission loss.

The measurements must be corrected to transmission loss in accordance with procedures given in ASTM E336-71 in order to determine comparison with the appropriate minimum sound insulation of each carbody section required to achieve the interior sound levels specified in Section 16.2.4.

B. With the car located near highly reflective surfaces, such as over a maintenance and inspection pit, the transmission loss may be measured in accordance with the two-room reverberant sound field methods indicated in ASTM E336-71. To create a satisfactory reverberant condition outside the car, and to define the boundaries of the space beneath the car for testing car floor transmission loss, temporary baffles or barriers shall be placed between the carbody exterior and the reflecting surfaces, such as between the carbody exterior walls at the floor level and the edges of a maintenance pit. The temporary baffles both define the space exterior to the car and prevent flanking paths outside the car from influencing the measurements, for example, by preventing sound transmission through the car walls or doors from bypassing the floor during a test of the floor.

16.4.2 <u>Vibration Tests</u>

The Contractor shall measure and record vibration amplitudes of the floor, stanchions, seat frames, walls and ceiling panels in the vicinity of each operating or energized car component. The measurements shall include the measurement of peak-to-peak amplitude, the measurement of peak acceleration for the frequency range from 1.4 to 20 Hz and the measurement of the peak vibration velocity for the frequency range from 20 Hz to 250 Hz.

The vibration of each traction motor shall be measured in accordance with the requirements of Section 16.3.