WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
6000 SERIES RAPID TRANSIT CARS
TECHNICAL SPECIFICATIONS
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SECTION 1
GENERAL INFORMATION AND SUBMITTAL REQUIREMENTS

1.1 SCOPE

1.1.1 General

This Specification is for the complete design, manufacture, delivery and testing of rapid transit cars for 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 compatible in all respects with the Authority's existing cars.

1.1.3 Design Options

In certain places throughout the specification, the requirements are written to afford the Contractor some latitude in design or implementation so that the Contractor may make use of existing equipment or procedures in order to minimize project costs or schedule. In any situation where design options are offered to the Contractor or where the Contractor proposes a different approach than the preferred method described in the specification, a detailed description of the proposed approach shall be submitted for review and approval by the Authority. WMATA retains the sole right to accept or reject an alternative approach proposed by the Contractor.

1.2 DESIGN DOCUMENTATION AND OTHER DELIVERABLES

1.2.1 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, to the extent that such documentation exists and is readily available. 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 that 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.

A006 The design life of the car and its components shall be consistent with a useful life of 40 years, with the cars undergoing a mid-life overhaul after approximately 20 years.

1.2.2 Design Specifications and Standards

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.

1.2.3 Contract Data Requirements

1.2.3.1 General

The Contractor shall comply with the Specification requirements for the submission of schedules, reports, plans, certificates, drawings, manuals, training curriculum, software, parts lists 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. Exhibit 1-1 contains a consolidated listing of the CDRL lists provided at the end of each section.

Each item of data submitted to the Authority shall be identified on the first page of the document by the applicable CDRL number. In addition, the Contractor shall include the relevant CDRL number and/or Technical Provision number in the subject line of the transmittal letter, fax, or e-mail. Cover letters, faxes and e-mails shall include a transmittal number. All hand-delivered submittals shall also include a cover letter with a transmittal number. Electronic submission of information is preferred. Fax and hardcopy submittal methods may also be used. Contractor submissions shall be submitted to the
A006 WMATA Program Manager and to other recipients identified by WMATA.

The Contractor shall designate a single point of contact responsible for providing answers to questions about submittals. The Contractor shall provide the name, telephone number and e-mail address of that person at the start of the project.

As part of the monthly status report (see Section 2.1.3.2), the Contractor shall provide a list of submittals in CDRL number sequence showing the date submitted, transmittal number and status. When data contained in a CDRL item has changed, the Contractor shall provide a new CDRL submission to WMATA. Whenever the estimated completion date of a CDRL shown on a schedule has been exceeded, a revised estimated completion date shall be provided to WMATA.

1.2.3.2 Alternate Schedule

The Authority may permit changes to the specified submittal due dates of CDRL items if the Contractor can demonstrate that the specified dates are not consistent with its normal sequence of work. The Contractor shall propose an alternate CDRL schedule for the Authority's review, and shall submit this proposed alternate along with the Master Program Schedule (see Section 2.1.2.1). All changes from the CDRL schedule included herein shall be uniquely identified and highlighted in the Contractor's proposed alternate.

1.2.4 Drawings

1.2.4.1 General Requirements

The Contractor shall submit a drawing list in an Authority-approved electronic format 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. ***(CDRL 101)*** The drawing list shall indicate those drawings to be submitted for approval and those to be submitted for information and/or reference only. The list shall also identify the number of sheets per drawing, the current revision number of the drawing, the Contractor's transmittal number, date of transmittal, and the current approval status for each drawing. As part of the initial drawing list submittal (CDRL 101), the Contractor shall describe the primary drawing numbering system, including the significance of characters. A006

Exhibit 1-1
Contract Data Requirements List (CDRL)

CDRL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****	
SECTION 1. GENERAL INFORMATION AND SUBMITTAL REQUIREMENTS							
101	Drawing List	1.2.4.1	PDR-60	3	1/Periodically	Yes	
102	Detail Drawings	1.2.4.1	Note 1	3	1	Note 1	
103	Car Arrangement Drawings	1.2.4.2	CDR-30	4	1	Yes	A002
104	Dynamic Outline Calculations	1.2.4.3	CDR-30	3	1	Yes	
105	As-Built Drawings	1.2.4.4	Note 2	Note 19	1	Yes	
106	Operator's Cab Mock-up	1.2.5.1	PDR	1	1	Yes	
107	Underfloor Equipment Mock-up	1.2.5.2	FDR	1	1	Yes	
108	Production Prototype of Each Type of Seat	1.2.5.3	FDR	1	1	Yes	
109	Decorative Material Samples	1.2.5.4	FDR-30 + car delivery	2	1	Yes	
110	Car History Books	1.2.7	Note 3	1 per married pair	A/R	Yes	
SECTION 2. MANAGEMENT PROGRAM							
201	Program Management Plan	2.1.1	45	3	1/Every 3 months A/R	Yes	
202	Master Program Schedule	2.1.2.1	60	3	1/Monthly	Yes	
203	Production/Delivery and Acceptance Schedule	2.1.2.2	120	3	1/Periodically	Yes	
204	Minutes of Monthly Progress Review Meetings	2.1.3.1	A/R	3	Monthly		
205	Monthly Progress Reports	2.1.3.2	30	3	Monthly		
206	CDR Package(s)	2.2.1	CDR-30	6	1	Yes	
207	Identification of All Interfaces	2.2.1	CDR-30	6	1	Yes	
208	PDR Package(s)	2.2.2	PDR-30	6	1	Yes	
209	FDR Package(s)	2.2.3	FDR-30	6	1	Yes	
210	Systems Engineering Plan	2.3.2	90	3	1	Yes	
211	Configuration Management Plan	2.4.2	CDR-30	3	1	Yes	
212	Description of Serial Numbers	2.4.3.1	FDR-30	3	1	Yes	
213	Engineering Change Proposals	2.4.6	A/R	8	A/R	Yes	
214	Description of Proposed Bar Code System	2.4.3.2	FDR-30	3	1	Yes	
215	Video Conferencing Hardware	2.1.5	30	1	1	Yes	A009
SECTION 3. TEST PROGRAM							
301	Master Test Plan	3.2.1	150	3	1/Periodically	Yes	
302	Test Procedures	3.2.2	Note 8	3	1	Yes	
303	Test Reports	3.2.3	Note 9	3	1	Yes	

	CDRL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****
	304	Test Status Log	3.2.4	FDR-30	3	1/Monthly	
	305	Car Weighing Procedure	3.4.1	Note 11	3	1	Yes
A009	306	Operational Characteristics Analysis Plan	3.4.8.1	CDR-60	3	1	Yes
	SECTION 4. TRAINING PROGRAM						
	401	Manuals Program Plan	4.1.2	60	3	1	Yes
	402	Manuals Style Guide	4.1.3	80	3	1	Yes
	403	Manuals and Parts Catalogs Table of Contents and Samples	4.1.4	120	3	1	Yes
	404	Draft Manuals and Catalogs	4.1.7	See 4.1.7	See 4.1.7	1	Yes
	405	Final Draft Manuals and Parts Catalogs	4.1.7	See 4.1.7	See 4.1.7	1	Yes
	406	Final Published Manuals and Parts Catalogs	4.1.7	See 4.1.7	See 4.1.7	1	Yes
	407	Updates to Manuals and Parts Catalogs	4.1.7.3	See 4.1.7.3	See 4.1.7.3	A/R	Yes
A008	408	*Intentionally Left Blank*					
	409	Instructor and Student Guides	4.2.1	Note 6	A/R	1	Yes
	410	Training Plan and Summary Level Schedule	4.2.3	120	3	1	Yes
	411	Training Course Outlines	4.2.4	Note 20	3	1	Yes
	412	Training Lesson Plans	4.2.4	Note 6	3	1	Yes
	413	Training Aids	4.2.5	Note 6	A/R	1	Yes
	414	Instructor Resumé and Qualifications	4.2.6.1	Note 20	3	1	Yes
	415	Student Test and Evaluation Results	4.2.6.3	A/R	A/R	A/R	Yes
	SECTION 5. SYSTEMS ASSURANCE						
	501	Quality Assurance Program Plan	5.1.2	60	3	1/Periodically	Yes
	502	Inspection and Test Plan	5.1.2	PDR-30	3	1/Periodically	Yes
	503	Quality Assurance Manuals	5.1.2	60	3	1/ Periodically	Yes
	504	Sample Quality Assurance Reports	5.1.3.5	PDR-30	3	1	Yes
	505	Statistical Quality Control Inspection List	5.1.3.7.5	PDR-30	3	1	Yes
	506	FAI Packages	5.1.3.7.8	Note 10	3	1	Yes
	507	Audit Checklists and Reports	5.1.4.1	Note 7	3	A/R	Yes
	508	Reliability Assessment Response Report	5.2.6	Note 13	3	See Section 5.2.6	
	509	Reliability Test Report	5.2.7.1	Note 12	3	Monthly	
	510	Maintainability Analysis	5.2.9.1	PDR-30	3	1/Every 90 days A/R	Yes
	511	System Safety Program Plan	5.4.2	PDR-30	3	1/ Periodically	Yes
	512	Preliminary Hazard Analysis	5.4.5	PDR-30	3	1/ Periodically	Yes
	513	Failure Mode and Effects Analysis	5.4.6.1	PDR-30	3	1/Every 60 days A/R	Yes
	514	Operating & Support Hazard Analysis	5.4.6.2	PDR-30	3	A/R	Yes
	515	Fault Tree Analysis	5.4.6.3	A/R	3	A/R	Yes
	516	Weight Control Report	5.1.3.1	60	3	Monthly	Yes
	517	Design and Development Review Report	5.1.3.1	A/R	3	A/R	Yes
A009	518	Design Verification and Validation Report	5.1.3.1	A/R	3	A/R	Yes
	519	Preliminary Systems Reliability Assessment	5.2.2	PDR-30	3	1	Yes
	SECTION 6. SYSTEMS SUPPORT						
	601	Warranty Plan	6.3.1	60	3	1/ Periodically	Yes
	SECTION 7. PERFORMANCE REQUIREMENTS						
	701	EMC/EMI Control Plan	7.6.2	60	3	1/ Periodically	Yes
	SECTION 8. CARBODY						
	801	Preliminary and Final Stress Analysis of Carbody, Underframe and Equipment Supports	8.3.2.3	PDR-30	3	1	Yes
	802	Repair Procedure for Lining Material	8.6.12	FDR-30	3	1	Yes
	803	Crashworthiness Design Data	8.3.2.2	PDR-30	3	1	Yes
	804	Cab End Contour Details	8.3.9	FDR-30	3	1	Yes
	805	Grill Design for Seat Enclosures	8.11.3	FDR-30	3	1	Yes
	806	Heat Transfer Analysis	8.12.2	Note 18	3	1	Yes

CDRL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****	
SECTION 9. COUPLER, DRAWBAR AND DRAFT GEAR							
901	Finite Element Structural Analysis of Coupler Hook	9.1.2	PDR-30	3	1	Yes	
902	Finite Element Analysis of the Drawbar	9.1.2	PDR-30	3	1	Yes	
903	Finite Element Analysis of the Anchor Assembly	9.1.2	PDR-30	3	1	Yes	
SECTION 10. MISCELLANEOUS CARBODY ITEMS							
None							
SECTION 11. DOOR OPERATION AND CONTROL							A005
1101	Documentation on Door Diagnostic System	11.7	PDR-30	3	1	Yes	
SECTION 12. HEATING, VENTILATING AND COOLING							
1201	HVAC System Fault Indications	12.5.1	PDR-30	3	1	Yes	
1202	Functional Block Diagram of DAM	12.7	PDR-30	3	1	Yes	
1203	Air Grille Details	12.3.3	FDR-30	3	1	Yes	
1204	Potential Failures Affecting Both HVAC Systems Concurrently	12.1	PDR-30	3	1	Yes	A003
SECTION 13. LIGHTING							
None							
SECTION 14. POWER SUPPLY AND MISCELLANEOUS ELECTRICAL APPARATUS							
1401	Initial Analysis of Auxiliary Inverter Loads	14.1.3.2	PDR-30	3	1	Yes	
1402	Self-Tests of Auxiliary Power System	14.1.3.5	PDR-30	3	1	Yes	A005
1403	Details of Load Management System	14.1.3.6	PDR-30	3	1	Yes	A008
1404	Final Analysis of Auxiliary Inverter Loads	14.1.3.2	FDR-30	3	A/R	Yes	
1405	Data on Design/Functionality of Diagnostic System	14.1.3.9	PDR-30	3	1	Yes	
1406	List of Faults & Functional Description of Fault Logic	14.1.3.9	PDR-30	3	1	Yes	
1407	List of Triggering Faults & Functional Description of Trace Recording System	14.1.3.9	PDR-30	3	1	Yes	
1408	Plan for Battery System Electrical Compatibility	14.2	60	4	1	Yes	
1409	Load Analysis of LVPS and Description of Operating Characteristics	14.3.1	PDR-30	3	1	Yes	
1410	Design and Installation of Power Converter	14.3.8	PDR-30	3	1	Yes	
SECTION 15. PROPULSION AND BRAKING SYSTEM							
1501	Performance Data Adjustment Calculations	15.1.3	Note 9	2	1	Yes	
1502	Information on Vacuum Pressure Impregnation Process for Motor Stator Coils	15.3.6	PDR-30	3	1	Yes	
1503	Electrical Protection System Design Details	15.1.5	PDR-30	3	1	Yes	
1504	Duty Cycle Calculations	15.2.3	PDR-30	3	1	Yes	
1505	Traction Motor Ventilation System Design Details	15.3.7	PDR-30	3	1	Yes	
1506	Information on Motor and Rotor Balancing Methods	15.3.12	PDR-30	3	1	Yes	
SECTION 16. FRICTION BRAKES							
1601	Performance Calculations	16.1.4	PDR-30	3	1	Yes	
1602	Description of DAM	16.2	PDR-30	3	1	Yes	
1603	Friction Brake and Propulsion Integration Plan	16.1.2	PDR-30	3	A/R	Yes	
1604	Compressor Air Dryer Efficiency Procedure	16.4.4.1.4	PDR-30	3	1	Yes	A008
SECTION 17. TRUCKS							
1701	Truck Dynamic Analysis	17.2.8	PDR-30	3	1	Yes	
1702	Truck Swiveling Index	17.2.8.7	PDR-30	3	1	Yes	
1703	List of Truck Construction Procedures	17.9	PDR-30	3	1/Perodically	Yes	
1704	Track Force Calculations and Test Procedures	17.2.8.5	PDR-30	3	1	Yes	
1705	Corrosion Protection Plan for Truck Frame	17.2.12	PDR-30	3	1	Yes	

CDRL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****
1706	Stress Analysis	17.4	PDR-30	3	1	Yes
1707	List of Critical Areas and Welds	17.5.2	PDR-60	3	1	Yes
1708	Truck Inspection and Acceptance Plan	17.5.2	60	3	1	Yes
1709	Truck Pressing Acceptance / Rejection Limits	17.9.1	FDR-30	3	1	Yes
SECTION 18. AUTOMATIC TRAIN CONTROL						
A003 1801	Vital Software Validation Report	18.2.6.7	CDR-30	3	1	Yes
1802	Not Used					
1803	Design Test Plan	18.10.2	60	3	1	Yes
1804	Design Test Procedures	18.10.2	FDR-30	3	1	Yes
1805	Factory Test Plan	18.10.3	60	3	1	Yes
1806	Factory Test Procedures	18.10.3	FDR-30	3	1	Yes
1807	Installation & Testing Plan	18.10.4.1	60	3	1	Yes
1808	System Test Procedures	18.10.4.2	FDR-30	3	1	Yes
1809	Static & Dynamic Test Plan	18.10.5.1	60	3	1	Yes
1810	Static & Dynamic Test Procedures	18.10.5.1	FDR-30	3	1	Yes
1811	Safety Analysis of ATC System	18.2.6.5	PDR-30	3	1	Yes
SECTION 19. COMMUNICATIONS						
1901	Factory Test Plan	19.10.1	60	3	1	Yes
1902	Factory Test Procedure	19.10.1	FDR-30	3	1	Yes
1903	Field Test Plan	19.10.3.2	60	3	1	Yes
1904	Field Test Procedure	19.10.3.2	FDR-30	3	1	Yes
1905	FCC Certification of Transmitters	19.10.3.2	FDR-30	3	1	Yes
SECTION 20. VEHICLE MONITORING SYSTEM						
2001	System Block Diagram	20.1	PDR-30	3	1	Yes
2002	Fault Tree	20.1	A/R	3	1	Yes
2003	List of All VCU Signals	20.2.1	PDR-30	3	1	Yes
2004	Recommended Shut-Down Conditions and Implementation Techniques	20.2.4	PDR-30	3	1	Yes
2005	Final List of Command and Operating Data To Be Recorded by the VCU	20.3	FDR-30	3	1	Yes
2006	List of Fault Messages	20.9	PDR-30	3	1	Yes
SECTION 21. SPECIAL TOOLS, TEST AND DIAGNOSTIC APPARATUS						
2101	Portable Test Devices and Required Documentation	21.2.1	A/R	A/R	1	Yes
2102	List Of Bench Testers	21.3.1	90	3	1/Every 90 days	Yes
2103	Bench Testers and Required Documentation	21.3.1	A/R	A/R	1	Yes
2104	List of Special Tools	21.4	120	3	1/Every 60 days	Yes
2105	Special Tools & Required Documentation	21.4	A/R	A/R	1	Yes
SECTION 22. MATERIALS AND WORKMANSHIP						
2201	Test And Inspection Plan for Stainless Steel In Weld Applications	22.3.4	PDR-30	3	1	Yes
2202	Test And Inspection Plan for Structural Steel Applications	22.4.2	PDR-30	3	1	Yes
2203	Sampling Frequency of Radiographic Inspections	22.5.3.2	PDR-30	3	1	Yes
2204	Grounding Scheme	22.18.8.1	PDR-30	3	1	Yes
2205	Sampling Plan for Full Penetration Weld Inspections	22.22.4	FDR-30	3	1	Yes
2206	Contractor's Welding Procedures	22.22.6	FDR-30	3	1	Yes
2207	Special Welding Procedures for Stainless Steel	22.22.7	FDR-30	3	1	Yes
2208	Welding Settings, Shear Strength and Diameter Records	22.22.8	FDR-30	3	1	Yes
2209	Torch Soldering Test Samples	22.22.12	FDR-30	3	1	Yes
2210	Flammability and Smoke Emission Test	22.24.1	PDR-30	3	1	Yes

CDRL NO.	TITLE	REFERENCE SECTION	DUE DATE*	QUANTITY (Sets)**	FREQUENCY*** (Initial/Subsequent Submittal)	APPROVAL REQUIRED ****
	Results					
2211	Software Assurance Plan	22.29.5	CDR-30	3	1/As-Required	Yes
2212	Air Brake Supplier Approval of Contractor's Piping	22.14.2	PDR-30	3	1	Yes
SECTION 23. NOISE AND VIBRATION						
None						

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 above are the number of copies/sets to be submitted to the Authority. In addition to these copies, three copies of each data deliverable, including the transmittal letter, will also 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. Test procedures shall be identified by the number "302" followed by a dash and the CDRL number assigned to the specific test, as found in Exhibit 3-1. For example "302-T851" corresponds to the test procedure for the carbody watertightness test.
Note 9: Test date +30 days. Test reports shall be identified by the number "303" followed by a dash and the CDRL number assigned to the specific test, as found in Exhibit 3-1. For example "303-T851" corresponds to the test report for the carbody watertightness test.
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.
Note 16: Commencement of training –90 days
Note 17: Conclusion of each training Course
Note 18: Start of final assembly –30 days
Note 19: Two (2) sets of legible aperture cards and twenty (20) sets on CD-Rom disks as described in Section 1.2.4.4
Note 20: At least 90 days prior to the commencement of training

The Contractor shall submit, for the Authority's review and approval, detailed 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, operation, overall assembly aspects, and interfaces. Detailed parts drawings need not be furnished unless required by the Authority to enable 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. Information on drawings shall be provided in black on a white background. All drawing titles and file names shall be provided in English. Drawings shall be submitted on CD ROM disks in
A006 AutoCAD 2000, or an otherwise Authority-approved format. A minimum of three copies shall be provided of all drawing submittals.

All dimensions on drawings shall be expressed in the English system; all drawing titles and 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 transit and railroad industries within the United States. Drawings shall be made to either the first-angle or third-angle projection system.

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 drawing number of the next higher subassembly or assembly. This requirement does not apply to standard hardware, electrical or electronic components. No more than five sizes of drawings shall be used, with 36-inches by 72-inches being the largest drawing size permissible.

Whenever a material or process is identified on a drawing by the Contractor's own specification number, the drawing shall also provide 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 22.27, 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. As part of the Monthly Progress Report, the Contractor shall submit a revised drawing list (CDRL 101) whenever drawings are changed, added or deleted.

Drawings on which any changes have been made, even though fewer than five in number, 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 revised drawing.

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.

1.2.4.2 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 arrangement drawings shall be dimensioned, and all key points shall be located by dimensions from the longitudinal centerline, the pulling face of the "F" end coupler, and the top of rail. All arrangement drawings shall be to a scale of 1:25 or larger except for cross-sections, which shall be to a scale of 1:10 or larger.

Arrangement drawings shall be included on the drawing list (CDRL 101). After approval by the Authority, arrangement drawings shall be revised no less frequently than monthly so as to continually represent the as-designed or as-built configuration of the cars.

1.2.4.3 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 within the limiting dynamic outline given in Contract Drawing 97936-017. ***(CDRL 104)*** Supporting calculations shall also be provided. These drawings shall be included on the drawing list (CDRL 101).

1.2.4.4 "As-Built" Drawings

The Contractor shall furnish, prior to acceptance of the last car, two sets of legible aperture cards and twenty (20) sets on CD-ROM discs ***(CDRL 105)***. The electronic media shall conform to the following requirements: A006

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.

A006

Every Engineering Change, deviation, Material Review Board (MRB) repair, or similar variance affecting form, fit, or function shall be incorporated in the affected drawing whenever such variance applies to five or more cars, and the drawing shall be clearly labeled with the car numbers (Authority's) to which each configuration applies. Those variances applying to fewer than five cars may either be incorporated in the affected drawings or, as an alternative, be supplied separately, with a list of applicable variances included in each relevant Car History Book, 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, the Contractor 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 25 years. The Contractor 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 20 years, the Contractor shall provide, at current market price for similar drawings, any prints required by the Authority.

1.2.4.5 Use of Terminology of Existing Cars

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 used for that 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 request by the Contractor, the Authority will provide sample documentation (e.g., manuals, schematics, and other drawings) demonstrating names and symbols used for components and devices on the existing cars.

1.2.5 Engineering Mock-ups and Materials

1.2.5.1 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. ***(CDRL 106)*** 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. After Authority approval, it shall remain intact, and shall be kept up-to-date to reflect approved design and configuration changes, until the pilot cars are completed.

1.2.5.2 Underfloor Equipment

The Contractor shall construct a full-scale mock-up of the underfloor equipment, showing all boxes, enclosures, piping, and conduit on all equipment; and also showing space necessary for removal of equipment, opening of doors, and access for maintenance. **(*CDRL 107)*** The mock-up shall be reviewed and approved by the Authority before further production.

1.2.5.3 Seat

Seats shall be provided in accordance with Section 8.11 and the Contract Drawings. Because of the difficulty of depicting the shape and comfort of a 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. ***(CDRL 108)*** Drawings and prototype seat assemblies shall be submitted to the Authority for approval prior to production of the seats. Seat drawings shall be shown on the drawing list (CDRL 101), and shall be included as part of the drawing submittal requirements (CDRL 102). 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 for installation on a car.

1.2.5.4 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. ***(CDRL 109)*** In addition, two complete sets of all such materials shall be delivered to the Authority with the delivery of the first car (CDRL 109). 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.

1.2.6 Pilot Cars

The "Pilot" cars are the two "A" and two "B" cars that are the most advanced in the production line and are the first to be delivered to the Authority's site for acceptance testing. 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. The Authority will make major inspections of each Pilot Car at the following seven stages of completion (or process control points), which are not necessarily in order: A002

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.

The Authority may perform additional inspections of the pilot cars as it elects during Pilot Car construction. The Contractor shall provide at least 7 days' notice to the Authority 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 is given by the Authority to incorporate them at an effective point later than the first car. This provision 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.

1.2.7 Car History Books

The Contractor shall provide a loose-leaf history book for each married pair of cars. ***(CDRL 110)*** This binder shall contain the following information for each car of the pair, provided in the following order unless otherwise directed by the Authority, with labeled dividers between each section:

A. Car numbers (Contractor's number and Authority's number), type, and class

B. Serial numbers of all serially numbered apparatus listed in Section 2.4.3.1

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 name, and manufacturing dates for wheels, axles and journal bearings and results of inspections and tests specified in Section 17.10.

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

G. Mill reports applying to materials used on the car

A006 H. Other equipment or material certifications, as specified in this Technical Specification

I. List of all changes applicable to that car but not applicable to all cars

J. 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

K. 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 the car is 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. Books shall be readily available for inspection by WMATA representatives.

1.3 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 101	Drawing List
CDRL 102	Detail Drawings
CDRL 103	Car Arrangement Drawings
CDRL 104	Dynamic Outline Calculations
CDRL 105	As-Built Drawings
CDRL 106	Operator's Cab Mock-Up
CDRL 107	Underfloor Equipment Mock-Up
CDRL 108	Production Prototype of Each Seat Type
CDRL 109	Decorative Material Samples
CDRL 110	Car History Books

1.4 REFERENCED STANDARDS

The following standards are referenced in this section:

AAR M-101	Axles – Carbon Steel, Heat Treated

AAR M-107 Wheels, Carbon Steel

SECTION 2
MANAGEMENT PROGRAM

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SECTION 2
MANAGEMENT PROGRAM

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 progress of the contractual effort.

2.1. PROGRAM MANAGEMENT

The Contractor shall designate a Project Manager and establish an organization to provide effective management of this transit vehicle procurement program. The organization shall be highly responsive to the needs of the Authority as required in this Specification.

2.1.1 Program Management Plan

The Contractor shall develop, and shall submit to the Authority for approval, a Program Management Plan (PMP). The Management Plan shall be updated every 3 months or more frequently if significant changes A006
occur. ***(CDRL 201)*** If, in WMATA's sole judgement, one or more changes have occurred that are significant enough to warrant updating the PMP in advance of the six month cycle, The Contractor shall submit an updated PMP within 21 days of receipt of a request for an update. The Management Plan shall include, but shall not necessarily be limited to:

A. An organizational chart including a definition of the responsibilities and qualifications, including experience and duration associated with the proposed position, of all personnel therein. A006

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 provided by subsuppliers.

E. Periodic design reviews conducted to assess the degree of completion of technical efforts related to major milestones. Conceptual Design Reviews (CDRs), Preliminary Design Reviews (PDRs), Final Design Reviews (FDRs), and First Article Inspections (FAIs) shall be broken out separately in the Management Plan and on schedules.

F. Supplier audits.

G. Reference to other CDRL plans used to implement the PMP, such as training, systems engineering, configuration management plan, electromagnetic interference/electromagnetic compatibility (EMI/EMC) control and test plans, quality assurance plans, safety plans, software plans and test plans.

H. Details about the means to be used to produce, review, revise and deliver manuals, training, as-builts and other documentation, including managing subcontractor responsibilities in these areas.

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.

2.1.2 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.

2.1.2.1 Master Program Schedule

The Contractor shall supply a master program schedule (MPS). ***(CDRL 202)*** The program schedule shall identify all contractual milestones including deliverables per CDRL, 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 MPS shall be prepared using Project 98 or other approved software and shall be submitted electronically.

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, delivery of major and/or critical materials and components for assembly of the pilot cars, final assembly, factory test, delivery, and final acceptance of pilot cars.

The Contractor shall revise the MPS monthly to reflect actual completion dates and revised estimated completion dates, corrections or task additions.

2.1.2.2 Production, Delivery and Acceptance Schedule

The Contractor shall submit a detailed baseline production schedule. ***(CDRL 203)*** 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 schedule shall show factory acceptance test (FAT) schedules, design qualification test (DQT) schedules, and acceptance schedules by car or married pair number.

2.1.3 Progress Reviews and Reports

2.1.3.1 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 Contractor shall provide minutes of monthly progress review meetings to the Authority for review and concurrence. ***(CDRL 204)*** The minutes shall track outstanding action items and indicate who has primary responsibility for the action.

2.1.3.2 Monthly Progress Update Reports

During the performance of this contract, the Contractor shall submit monthly progress reports ***(CDRL 205)*** containing detailed information in narrative form on the following:

A. Work completed as of the reporting date
B. Work in progress as of the reporting date
C. Major problems (e.g., delays incurred) and action items
D. Status of outstanding action items
E. Progress against the approved master program schedule
F. Technical performance variations from the Specification requirements
G. Engineering Change Proposal (ECP) status
H. Organizational changes
I. Subcontractor program progress
J. CDRL submission status by document serial number and date for one-time submissions A002
K. Recurring CDRL item list showing document serial number, date and status.

To the extent possible, information in the report should be shown in CDRL and MPS sequence. 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 shall 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 2-1 for an example.)

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. The MPS shall be updated to reflect the new estimated completion dates.

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, retrofits, anomalies, 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.

2.1.4 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.

A009 ### 2.1.5 Video Conferencing

Whenever practical, Progress Review Meetings shall be conducted through the use of video conferencing equipment. This equipment shall be provided by the Contractor and delivered to a site designated by the Authority ***(CDRL 215)***. At a minimum, the equipment should include:

- (1) Digital video camera with tri-pod capable of remote-controlled pan, tilt, zoom, etc. from across the WAN or Internet
- (1) Television monitor, 32" minimum screen size
- Any other necessary hardware to facilitate video conferencing

If the Contractor currently utilizes video conferencing, then the equipment provided under this contract shall be fully compatible with and of equal quality to the existing equipment used by the Contractor. If the Contractor does not currently utilize video conferencing, then compatible equipment must also be installed at the Contractor's Program Management Office (at the Contractor's expense).

Hardware specifications shall be submitted to the Authority for review and approval prior to Contractor's procurement of the equipment.

2.2 DESIGN REVIEWS

A009 Three formal design review meetings shall be held, at a site approved by the Authority, to assess and summarize progress of design. These 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. These review packages shall be received by the Authority no later than 15 working days before the scheduled design review. Failure to provide the package for the allotted review time shall cause a postponement of both the design review and the milestone payment. The Contractor shall prepare and distribute minutes of review meetings.

Review meetings shall include the review of the design and functionality of bench test equipment and portable test devices, including any related custom software. CDR, PDR, and FDR document package
A007 submittals shall include adequate information to support the review of the bench test equipment and portable test devices. Failure to provide such information may result in a delay of the applicable design review meeting until such information is provided.

Exhibit 2-1
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	[illegible]				
P02	Pre-Bid											
P03	BAFO											
P04	NTP											
MANUFACTURING/PRODUCTION												
M01	Design Review	120	0	100	[illegible]	[illegible]	[illegible]	08/01/97				
M02	Preproduction											
M03	First Article											
M04	Testing											
M05	Production											
DELIVERY												

2.2.1 Conceptual Design Review (CDR)

The purpose of the CDR is to provide early agreement on the Contractor's approach to 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, to eliminate ambiguities, and to 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 their 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. ***(CDRL 206)*** The CDR package(s) shall include:

A. A narrative descriptions of each major subsystem as proposed by the Contractor and subsupplier(s). This may be an elaboration, confirmation, 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 vehicle, including worst-case conditions of wear and failures (see Section 1, CDRL 104).

C. Updated car arrangement drawings (see Section 1, CDRL 103)

D. Identification of all interfaces between the major systems and subsystems. ***(CDRL 207)***

A007 E. A narrative description of each bench test unit and portable test device. Where portable test devices consist of laptops with custom software, a description of the various custom software applications shall be provided, including minimum system requirements to operate the software.

2.2.2 Preliminary Design Review (PDR)

A formal PDR shall be conducted to summarize progress made on and the 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 or packages addressing the following topics as a minimum ***(CDRL 208)***:

A. Interior layout

B. Underfloor layout

C. Detailed functional descriptions of 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 and configuration control descriptions for microprocessor-based or other programmable equipment

F. List of trainlines and proposed coupler pin arrangement

G. Heat load calculations for the heating, ventilating, and cooling (HVAC) subsystem, including psychometric charts for each control condition

H. Data verifying that the propulsion equipment 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. Failure modes and effects analysis A003

K. List of special tools required for each subsystem

L. Detailed functional descriptions of the bench testers and portable test devices, including detailed descriptions of the software design and configuration control methods. A007

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

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

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

P. Details of the passenger door system

Q. Specifications for seating

R. Side window and windshield specifications

A002

2.2.3 Final Design Review (FDR)

The FDR shall be conducted incrementally as the detailed design of each subsystem is completed 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 or packages addressing the following topics as a minimum ***(CDRL 209)***:

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.

A006 G. Upon request by the Authority, component data sheets shall be made available for review

A007 H. Assembly drawings for all bench testers and portable test devices, other than laptops or other commercially-available portable test devices. Software documentation consisting of structured data flow diagrams to the lowest level of decomposition, with software module descriptions in structured narrative format for all bench testers and portable test devices.

2.3 SYSTEMS ENGINEERING

2.3.1 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.

2.3.2 Systems Engineering Plan

The Contractor shall prepare, and shall submit to the Authority for approval, a Systems Engineering Plan. ***(CDRL 210)*** The Systems Engineering Plan may be submitted as part of the Program Management Plan. It shall describe the organization and process by which the Contractor proposes to:

A. Transform Specification requirements into a description of system and subsystem configuration and performance parameters 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.

2.4 CONFIGURATION MANAGEMENT

2.4.1 General

The Contractor shall prepare configuration records to acceptable commercial standards, as specified or approved by WMATA, and shall 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 subsuppliers' equipment incorporated in the vehicle design complies with all requirements specified in this section.

2.4.2 Configuration Management Plan

The Contractor shall prepare and submit a Configuration Management Plan. ***(CDRL 211)*** This plan shall identify how the Contractor intends to meet the configuration management requirements.

2.4.3 Configuration Records

The Contractor's configuration records shall be prepared to acceptable commercial standards, as specified or approved by WMATA. They shall define the approved configuration of equipment under development, test or production, or in operational use, and shall include 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, software, test procedures, test reports 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 down to the lowest level of repair or replacement that are 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. Two copies shall be submitted to the Authority at the time of vehicle delivery.

2.4.3.1 Serial Numbers

Serial numbers of equipment shall be provided in the relevant Car History Books (see Section 1.2.6). 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 (excluding 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 that are customarily numbered serially.

A description of the serial numbers for each of the items listed above shall be submitted to the Authority at least 3 months prior to acceptance of the first pair of cars. ***(CDRL 212)*** The description may identify a block of numbers from which the serial numbers will be drawn or, as a minimum, the number of characters in the serial number and whether numerals, letters, or a combination thereof will be used. Existing serialization programs of the Contractor or 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.

2.4.3.2 Bar Codes

A002

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 of bar codes shall be chosen to provide ease of reading without requiring the removal the component from the car, wherever possible. The medium used for the bar code shall be approved by the Authority ***(CDRL 214)***.

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 and spare parts shall be bar-coded to facilitate electronic scan recording of maintenance actions.

2.4.4 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.

2.4.5 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.

The Contractor shall identify and number all proposed changes and indicate whether those changes are believed to be Class I or Class II. WMATA will make the final determination of whether the ECP is Class I or Class II.

2.4.6 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 before any implementation action is taken. ***(CDRL 213)*** The Contractor shall provide to the Authority eight copies of the ECP, accompanied by all technical documentation, cost A006 information, production cut-over point, and impact on schedule necessary to fully evaluate the change, to the Authority. The Contractor shall be responsible for classifying and controlling all changes that it originates, as well as all changes originating from its subcontractors. The Contractor shall take any action, or bear any costs, necessary to correct problems in the product or documentation arising from the Contractor's misclassification.

The Contractor shall immediately notify the Authority of all Class I changes that affect safety, either 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.

2.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

	CDRL 201	Program Management Plan
	CDRL 202	Master Program Schedule
	CDRL 203	Production/Delivery and Acceptance Schedule
	CDRL 204	Minutes of Monthly Progress Review Meetings
	CDRL 205	Monthly Progress Reports
	CDRL 206	CDR Package(s)
	CDRL 207	Identification of Interfaces
	CDRL 208	PDR Package(s)
	CDRL 209	FDR Package(s)
	CDRL 210	Systems Engineering Plan
	CDRL 211	Configuration Management Plan
	CDRL 212	Description of Serial Numbers
	CDRL 213	Engineering Change Proposals
A002	CDRL 214	Description of Proposed Bar Code System
A009	CDRL 215	Video Conferencing Hardware

2.6 REFERENCED STANDARDS

No standards are referenced in this section.

SECTION 3
TEST PROGRAM

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SECTION 3
TEST PROGRAM

3.1 GENERAL

The complete car and its apparatus shall be subjected to a comprehensive test program to substantiate design and performance requirements, and to determine compliance with reliability and maintainability requirements. Test plans, procedures, and reports shall meet the requirements of Section 3.2 and shall be subject to review and approval by the Authority. Design qualification, factory acceptance, and on-site acceptance testing on all items is required. Exhibit 3-1 is a reference listing of tests required throughout this Specification that the Contractor must perform (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 ensuring 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 5.1). 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, or because of design changes necessary to meet the specification requirements, the Contractor shall make the necessary A006 corrections and, at the Authority's option, the test shall be re-run in its entirety at the Contractor's expense. If further corrections or modifications affecting the item under test are instituted, the Contractor shall perform a complete retest at its expense to demonstrate compliance with Specification requirements.

The Authority will, at its option, witness all tests. The Contractor shall give at least 2 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.

3.2 TEST DOCUMENTATION

3.2.1 Master Test Plan

The Contractor shall submit to the Authority, for approval, a Master Test Plan covering all tests and adjustments required by this Specification. ***(CDRL 301)*** 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 supplier or subcontractor plants, all Contractor 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.

Exhibit 3-1
Design Qualification, Factory Acceptance, and On-Site Acceptance Test Requirements Reference List

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

	System	Required Test	Reference Section(s)	Test Type	CDRL
	General Testing	Weight Test	3.4.1	FAT	CDRL T351
		Misc. Apparatus Tests	3.4.2	FAT	CDRL T352
		Wiring Continuity Test	3.4.3	FAT	CDRL T353
A002		Ground Insulation Test	3.4.3	FAT	CDRL T354
		High Potential Test	3.4.3	FAT	CDRL T355
		Factory Trainline Test	3.4.5	FAT	CDRL T356
		Multiple Configuration Trainline Tests	3.4.5	DQT	CDRL T357
		Car Compatibility Test	3.4.6	DQT	CDRL T358
		Electromagnetic Compatibility Test	3.4.7	DQT	CDRL T359
A009		Operational Characteristics Analysis Report	3.4.8.2	DQT	CDRL T360
		AC Auxiliary Motors Type Tests	3.4.9	DQT	CDRL T361
		Truck Weight Tests	3.4.1	DQT	CDRL T362
A008		Lateral and End-to-End Imbalance Tests	3.4.1	DQT	CDRL T363
	Carbody	Watertightness Test	8.15.1	FAT	CDRL T851
		Carbody Compression Test	8.15.2	DQT	CDRL T852
		Vertical Load Test	8.15.2	DQT	CDRL T853
		Coupler Anchor Compression Test	8.15.2	DQT	CDRL T854
		Diagonal Jacking	8.15.2	DQT	CDRL T855
		End Window Ease of Replacement Demonstration	8.9.3	DQT	CDRL T856
A008		Seat Strength Tests	8.11.9	DQT	CDRL T857
	Couplers	Structural Strength in Buff Test	9.1.2	DQT	CDRL T951
		Structural Strength in Draft Test	9.1.2	DQT	CDRL T952
		Coupler Step Strength Test	9.1.2	DQT	CDRL T953
		Centering Ability Test	9.1.3	DQT	CDRL T954
		Gathering Range Test	9.1.3	DQT	CDRL T955
		Shear Pin Device Release Test	9.3.2	DQT	CDRL T956
		Compatibility Test	9.6.1	DQT	CDRL T957
		Electrical Equipment Watertightness Test	9.6.5	DQT	CDRL T958
	Doors	Functional	11.10	FAT	CDRL T1151
A003		1.5 Million Cycle Test	11.10	DQT	CDRL T1152
	HVAC	Air Conditioner Qualification Test	12.8.1.1	DQT	CDRL T1251
		Air Conditioner Functional Test	12.8.1.2	FAT	CDRL T1252
		Air Diffuser Test	12.8.1.3	DQT	CDRL T1253
		Heating System Qualification Test	12.8.2.1	DQT	CDRL T1254
		Heat Transfer Test	12.8.2.2	DQT	CDRL T1255
		Heating System Functional Test	12.8.2.3	FAT	CDRL T1256
		Defroster Test	12.8.2.4	FAT	CDRL T1257
	Lighting	Light Intensity Test	13.1.2	DQT	CDRL T1351
	Miscellaneous Electrical	Auxiliary Inverter Functional Test	14.1.3.10	FAT	CDRL T1451
		Battery Capacity Test	14.2.6	FAT	CDRL T1452
		Battery Functional Test	14.2.6	OAT	CDRL T1453

System	Required Test	Reference Section(s)	Test Type	CDRL	
	LVPS Type Test	14.3.8	DQT	CDRL T1454	
	Auxiliary Circuit Functional Test	14.6.1.5	FAT	CDRL T1455	
	Third Rail Shoe Functional Test	14.7.5	OAT	CDRL T1456	
	Under-Voltage Trip Test	14.2	DQT	CDRL T1457	A005
Propulsion	VPI Verification Test	15.3.6	DQT	CDRL T1551	
	Traction Motor Type Test	15.8.3.1	DQT	CDRL T1552	A003
	Combined Systems Test	15.8.3.3	DQT	CDRL T1553	A008
	Ambient Temperature Test	15.8.4	DQT	CDRL T1554	
	Noise Tests	15.8.4	DQT	CDRL T1555	
	Shock and Vibration Tests	15.8.4	DQT	CDRL T1556	
	Gear Unit 100-Hour Test	15.8.4	DQT	CDRL T1557	
	Dynamic Brake Resistance	15.8.4	DQT	CDRL T1558	
	Traction Motor Factory Acceptance Tests	15.8.7	FAT	CDRL T1559	
	Propulsion System Factory Acceptance Tests	15.8.7	FAT	CDRL T1560	
	Duty Cycle Confirmation Test	15.8.8.4	DQT	CDRL T1561	A003
Friction Brakes	Pressure Test	16.6.3.1	DQT	CDRL T1651	
	Brake Rate Characteristics Test	16.6.3.2	DQT	CDRL T1652	
	Brake Unit Fatigue Test	16.6.3.3	DQT	CDRL T1653	
	System Capacity Test	16.6.3.4	DQT	CDRL T1654	
	Brake Endurance Test	16.6.3.5	DQT	CDRL T1655	
	Ambient Temperature Test	16.6.4	DQT	CDRL T1656	
	Noise Tests	16.6.4	DQT	CDRL T1657	
	Shock and Vibration Tests	16.6.4	DQT	CDRL T1658	
	Brake System Performance Test	16.6.7.1	FAT	CDRL T1659	
	Brake System Functional Test	16.6.7.2	FAT	CDRL T1660	
	Hand Brake Test	16.6.7.3	FAT	CDRL T1661	
	Car Performance Test	16.6.8.1	OAT	CDRL T1662	
	Drift Test	16.6.8.2	OAT	CDRL T1663	
	Slip-slide Test	16.6.8.3	OAT	CDRL T1664	
	Friction Brake Only Round Trip Test	16.1.3	DQT	CDRL T1665	A008
Trucks	Static Load Test	17.10.1	DQT	CDRL T1751	
	Overload Test	17.10.2	DQT	CDRL T1752	
	Fatigue Test	17.10.3	DQT	CDRL T1753	
	Primary Suspension Test	17.10.4	DQT	CDRL T1754	
	Equalization Test	17.10.5	DQT	CDRL T1755	
	Stability Test	17.10.6	DQT	CDRL T1756	
	Ride Quality Test	17.10.7	DQT	CDRL T1757	
	Truck Frame Magnetic Partical Inspection	17.5.2	FAT	CDRL T1758	
	Truck Frame Radiographic Inspection	17.5.2	FAT	CDRL T1759	
	Axle Inspection	17.7	FAT	CDRL T1760	
	Wheelset Press Records	17.9.1	FAT	CDRL T1761	
ATC	Development Tests	18.10.2.1	DQT	CDRL T1851	
	Compatibility Tests	18.10.2.2	DQT	CDRL T1852	
	Qualification Tests	18.10.2.3	DQT	CDRL T1853	
	Factory Acceptance Test	18.10.3	FAT	CDRL T1854	
	System Test	18.10.4.2	OAT	CDRL T1855	
	Static Test	18.10.5.2	OAT	CDRL T1856	
	Dynamic Test	18.10.5.3	OAT	CDRL T1857	
	Qualification Demonstration Tests	18.10.6	OAT	CDRL T1858	

System	Required Test	Reference Section(s)	Test Type	CDRL
Communications	Factory Acceptance Test	19.10.1	FAT	CDRL T1951
	Installation Test	19.10.2	FAT	CDRL T1952
	Qualification Test	19.10.3	OAT	CDRL T1953
Vehicle Monitoring System	VMS Qualification Tests	20.12	DQT	CDRL T2051
	VMS Factory Acceptance Tests	20.12	FAT	CDRL T2052
	VMS Performance Tests	20.12	OAT	CDRL T2053
	VMS Vehicle Level Tests	20.12	OAT	CDRL T2054
	VMS Reliability Test	20.12	OAT	CDRL T2055
Materials and Workmanship	Elastomeric Tests	22.7.2	DQT	CDRL T2251
	Plastic Materials Weathering Tests	22.8.2.3.3	DQT	CDRL T2252
	Plastic Materials Abrasion Resistance Tests	22.8.2.3.5	DQT	CDRL T2253
	Plastic Materials Chemical Resistance Tests	22.8.2.3.6	DQT	CDRL T2254
	Plastic Materials Adhesion of Coating Materials Tests	22.8.2.3.7	DQT	CDRL T2255
	Plastic Materials Optical Quality Tests	22.8.2.3.11	DQT	CDRL T2256
	Carpeting Construction – Static Electricity Tests	22.9.2.2	DQT	CDRL T2257
	Carpet Performance Tests	22.9.2.6	DQT	CDRL T2258
	FRP Strength Tests	22.12.3	DQT	CDRL T2259
	Piping Pressure Tests	22.14.1	DQT	CDRL T2260
	Insulation Smoke Tests	22.16.6	FAT	CDRL T2261
	Flammability and Smoke Emissions Tests	22.24.3	DQT	CDRL T2262
	Floor Assembly Fire Test	22.24.4	DQT	CDRL T2263
	Toxicity Tests	22.24.6	DQT	CDRL T2264
Noise and Vibration	Equipment Noise Test - Pre-Installation	23.2.1	FAT	CDRL T2351
	Equipment Noise Test - Post-Installation	23.2.2	OAT	CDRL T2352
	Car Interior Noise Levels	23.2.4	OAT	CDRL T2353
	Door Operation Noise	23.2.5	OAT	CDRL T2354
	Car Body Sound Insulation	23.2.6	OAT	CDRL T2355
	Miscellaneous Equipment	23.2.7	OAT	CDRL T2356
	Car Exterior Noise Levels	23.2.8	OAT	CDRL T2357
	Auxiliary Equipment	23.2.9	OAT	CDRL T2358
	Noise Test	23.4.1	OAT	CDRL T2359
	Vibration Tests	23.4.2	OAT	CDRL T2360

3.2.2 Test Procedures

The Contractor shall prepare a test procedure for each test identified in the Master Test Plan described in Section 3.2.1. ***(CDRL 302)*** Each test procedure shall, as a minimum, include the items shown in Exhibit 3-2, Test Procedure Requirements. The Contractor shall submit test procedures at least 60 days in advance of the test commencement date. Test procedures must be approved by the Authority prior to the start of any test.

A. Format. The Contractor shall use Exhibit 3-2 as a guide for developing a standardized format for all test procedures and data sheets. The Contractor's standard test procedures shall provide all information and data identified in Exhibit 3-2.

B. Data Sheets. The test procedure shall contain data sheets for the recording of test results, which shall be included in the test report after 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 3-2, to certify that the test has been witnessed by the Contractor/subcontractor's quality control representative and that the data have been 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; such witnessing shall not constitute the Authority's approval of test results.

3.2.3 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 303)*** 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 to do so. For example, any specific software, information about the product,

Exhibit 3-2
Test Procedure Requirements

"Cover Page"

Test Procedure No. *ST-PS-001* (1)	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 1 of X**	*Rev. B* *Approved 5/1/03*

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
6000 SERIES RAPID TRANSIT CARS

CONTRACT XXX.XXX

TEST PROCEDURE

PROPULSION SYSTEM TEST

Specification Section Reference
Technical Provisions xx.xx

Prepared by ______________________________
(signature)

____
(printed name and title)

____
(date)

Reviewed/Approved by (2) ______________________________
(signature)

____
(printed name and title)

____
(date)

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

Exhibit 3-2
Test Procedure Requirements (Continued)

"Revision Page"

Test Procedure No. *ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 2 of X**	*Rev. B* / *Approved 5/1/03*

Rev. Level	**Description of Modification**	**Date Approved**

This page shall provide a description of modifications (additions, corrections, etc.) made to the procedure. For example:

A	Basic/initial version.	4/3/03
B	Microprocessor software modification, Sections 1, 3, 5 affected in this procedure	5/1/03

"Table of Contents"

Test Procedure No. *ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 3 of X**	*Rev. B* / *Approved 5/1/03*

The Table of Contents shall list each section of the test procedure by section number, title, and page number. For example:

Exhibit 3-2
Test Procedure Requirements (Continued)

"Instructions"

Test Procedure No. *ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 4 of X**	*Rev. B* *Approved 5/1/03*

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 3-2
Test Procedure Requirements (Continued)

"Instructions"

Test Procedure No. *ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 5 of X**	*Rev. B* *Approved 5/1/03*

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 3.2.3.

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:

Record actions taken on any discrepancy.

"Data Sheet"

Test Procedure No. *ST-PS-001*	**Test Procedure** *PROPULSION SYSTEM TEST*	**Pg. 6 of X**	*Rev. B* *Approved 5/1/03*

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 3-2
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 5/1/03*

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)

manufacturer, and software version shall be included. If 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.

3.2.4 Status Log

The Contractor shall use Exhibit 3-3, Sample Test Status Log, as a guide in preparing and maintaining a running record of the status of all test procedures. The Status Log shall include as a minimum the data fields shown in Exhibit 3-3 for each test procedure.

The database/matrix shall be kept up to date, and clear copies shall be provided to the Authority on a monthly basis after submission of the first test procedure for approval. ***(CDRL 304)***

Exhibit 3-3
Sample Test Status Log

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

6000 SERIES RAPID TRANSIT CARS
CONTRACT NO. TC-6000/TGB

Test Type (1)	**Test Name**	**Procedure No.**	**Rev. Level** (2)	**Status**	**Contractor's Letter No.**	**Date Submitted**	**WMATA Letter No.**	**Disposition Date**	**Remarks** (3)
ST	*Propulsion System Test*	*ST-PS-001*	*B*	Approved					
ST	*Friction Brake Test*	*ST-FB-002*	*C*	Conditionally Approved					

Notes:

(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.

(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.

(3): Remarks shall be inserted in Column 10 as appropriate. The identity and the date of the latest approved version shall be included, if the revision level being reported in Column 4 has not been acted on by the Authority.

3.3 FACILITIES FOR TESTING

3.3.1 Contractor Facilities for Testing

A002 Prior to shipment of vehicles to the Authority's site, each married pair shall be functionally and dynamically tested while operating under its own power. Such tests shall be performed in manual operating mode on an electrified test track sufficiently sized and equipped to allow safe acceleration and braking to and from speeds of at least 30 mph.

These tests shall demonstrate that the vehicles' systems operate in compliance with the Specifications. The Contractor shall prepare and submit a detailed test description and procedure for this test to the Authority for approval.

The pre-shipment vehicle dynamic testing shall be incorporated into the Master Test Plan (CDRL 301).

3.3.2 Authority Facilities for Testing

A002

The Authority will make available to the Contractor a track of adequate length for tests 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 trains simultaneously will be available to the Contractor from 01:00 AM to 04:30 AM. on weekdays and from 03:00 AM to 07:00 AM on Saturdays and Sundays,
A002 exclusive of holidays observed by the Authority. The Authority has a limited amount of time available on its system for performing tests. Times for testing are subject to change at any time.

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.

3.4 MISCELLANEOUS VEHICLE TESTS

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

3.4.1 Weight Test

A002
A008 The Contractor shall weigh each car at the time of shipment ***(CDRL T351)***. The weight of each end of the car shall be provided separately. A weighing device that provides a permanent record of the weight to the nearest hundred pounds shall be used, and the weight tickets shall be submitted to the Authority and copies thereof included in Car History Books.

A006

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 120 days. If the device is mechanical, it shall be calibrated immediately prior to weighing the first car and annually thereafter. The Contractor shall submit the car weighing procedure, including a description of the equipment to be used, to the Authority for approval before the first car is weighed. ***(CDRL 305)***

The Contractor shall separately weigh both trucks of the first car, and of another car approximately three-fourths through the production, using weighing devices as described above ***(CDRL T362)***. A008

Additionally, the first car and another car approximately three-fourths through the production shall be weighed to verify compliance with the lateral and end-to-end balance requirements of Section 7.3 ***(CDRL T363)***.

3.4.2 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 shall be furnished to the Authority ***(CDRL T352)***. A002 Tests shall be in accordance with the requirements of IEEE. 11 and IEEE 112 for rotating machinery and IEEE 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.

3.4.3 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 ***(CDRL T353)***. A002

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 ***(CDRL T354)***. A002 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 car shipment, but the testing at the Contractor's plant will not supersede the test to be conducted immediately prior to acceptance. This test must demonstrate compliance with the requirements of Section 22.17.

C. Make a high-potential ground insulation test in accordance with IEEE 11 for power circuits and IEEE 16 for control circuits ***(CDRL T355)***. A002

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.

3.4.4 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 Section16.6.8.1. The signals specified shall be recorded simultaneously for each car. A006

A. The Contractor shall perform an acceptance test of each married pair of cars upon their delivery at the Authority's property. This testing shall include ground insulation tests as required in Section 3.4.3, functional testing of all apparatus and controls, field test of all communications system apparatus as required by Section 19.9, and static tests of the ATC equipment to demonstrate compliance with the requirements of Section 18.

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 15.1, 15.5 and 15.8 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 the performance tests specified in Section 15.8.8. The relationship between performance characteristics of empty and loaded cars shall be developed based on the performance tests conducted as required by Section 15.8.8, 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 correction of all known defects by the
A006 Contractor, including complete re-test if necessary or required by the Authority, and following up to 30 days of additional testing by the Authority as described in Section 3.1, the cars will be accepted by the Authority.

3.4.5 Trainline Tests

A. The Contractor shall verify the accuracy of the car's trainline connections by the use of a test panel that 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
A002 controls are operated (e.g., master controller, door controller, and PA equipment) ***(CDRL T356)***. 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-
A002 B Car, and A Car-to-B Car configuration **(CDRL T357)**. 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.

3.4.6 Car Compatibility Tests

The qualification test program shall include complete functional tests of the first four pairs delivered to
A002 the Authority's property ***(CDRL T358)***. 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

3.4.7 Electromagnetic Compatibility Test

One pair of cars shall be tested by the methods referenced in Section 7.6 for compliance with specified requirements and for compatibility with the Authority's power distribution and train control, signal, and
A002 communication systems ***(CDRL T359)***. The test shall be conducted on the Authority's tracks.

A002
3.4.8 Operational Characteristics Analysis

Prior to Conceptual Design Review (CDR), the Contractor shall acquaint himself with all aspects of the existing fleet and system interfaces by conducting an Operational Characteristics Analysis. The

Authority will support this activity by providing one married-pair of each unique configuration in the inventory, for testing in the yard, and access to any of the five (5) mainlines. However, no more than one trainline of maximum length will be taken out of service at any one time. These cars include:

- ROHR cars rehabilitated with GTO AC propulsion (1000 Series)
- Breda 2000 / 3000 cars with Cam Controller
- Breda 2000 / 3000 cars rehabilitated with IGBT AC propulsion
- Breda 4000 cars with DC chopper
- CAF cars with IGBT AC propulsion (5000 Series)

Note: Each car type listed has many other dissimilar though compatible sub-systems besides the example stated (propulsion) including: Doors; Friction Brakes; ATC; Auxiliary Electrical, etc.

To ensure that the data collected is fully representative of system operation, some testing will be allowed during busy (peak) periods between revenue service trains. This is to allow the Contractor experience with effects such as a receptive line and ATC System operation with close headways. Since doors will not be operated on the platform side on a test train and are therefore not subjected to passenger interaction, the Contractor will need to observe such operation and devise a similar scheme for testing operational scenarios, if necessary. The majority of testing will be restricted to 'off-peak' hours or evenings to avoid disrupting revenue service operations unnecessarily. Therefore it is essential that the Contractor identify before hand, which tests have to be conducted during peak hours as opposed to those tests that can be performed at any time.

The Conceptual Design Review, and each incremental sub-system design review meeting between the Authority and Contractor shall include the relevant items identified in the Operational Characteristics Analysis, as well as the Contractor's action item or progress.

3.4.8.1 Test Plan and Procedures

A002

Following contract award, the Contractor shall review all sections of the Technical Specification and formulate a series of tests on these existing cars that will remove any ambiguity about how the interfaces should perform to meet these compatibility requirements ***(CDRL 306)***. No sub-system that has an interface with another system, whether on the cars or to the wayside, shall be considered to have 'Design Approval' until issues identified in this Test Plan have been incorporated into design reviews and have been resolved to the Authority's satisfaction.

Sufficient detail shall be provided in the plan and associated test procedures to facilitate efficient installation of instrumentation, data collection and analysis by the Contractor. Detailed planning of this activity is essential at the earliest opportunity in order that the relevant parameters can be disseminated to the sub-suppliers and included in the design process.

After the Test Plan and Test Procedures have received Authority approval, the Contractor must demonstrate that the test equipment including: transducers, cables, connectors and recording devices, etc. is available before any cars will be removed from revenue service for this activity.

A schedule shall be included in the Test Plan showing each activity from start to finish, enabling the Authority to work around the cars removed from service for a pre-determined period of time. In order to limit the testing period and subsequent loss of cars from revenue service, multiple sub-system data from multiple cars shall be collected concurrently, limited only by the consist / platform length to the greatest extent possible. That does not mean that single married-pair testing will not be allowed, but there must be a justification. Particular emphasis shall be placed upon those interfaces where the chosen sub-suppliers have not provided the interfaces previously at WMATA or if the previous responsibility for certain functions has been different.

Approval by the Authority of any or all of the Test Plan and Test Procedures shall not relieve the Contractor of the responsibility for the compatibility requirements between the new cars of this contract and existing cars / wayside interfaces in all respects. If during testing the Contractor finds a situation more arduous than the Technical Specification; the Contractor shall design for the worst-case condition encountered and under no circumstances shall the design be any less restrictive than the Technical Specification.

Each test procedure shall be in sufficient detail to concisely explain the purpose and methodology to be used to collect / analyze data in each particular sub-system whereas the Test Plan shall delineate how the various Test Procedures are utilized to collect data from various sub-systems and from multiple cars simultaneously. The initial condition of all the various cut-out switches and bypasses shall be clearly defined i.e. is dynamic brake cut-in or cut-out, is regeneration enabled or inhibited, are the cars at tare weight or loaded with ballast, etc.

A002 ***3.4.8.2 Operational Characteristics Analysis Reports***

Results of the tests conducted in the Operational Characteristics Analysis should be conveyed in reports
A009 submitted to the Authority ***(CDRL T360)***, and are due no later than 30 days prior to the Conceptual Design Review Meeting. The Authority does not plan to approve these reports, but may, however, provide comments to the Contractor.

A002 **3.4.9 AC Auxiliary Motor Type Tests**

One motor of each type shall be type tested in accordance with IEEE 112, NEMA MG 1, or IEC 60349 to demonstrate compliance with these Provisions and the required duty cycle, including audible noise ***(CDRL T361)***.

3.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 301	Master Test Plan
CDRL 302	Test Procedures
CDRL 303	Test Reports
CDRL 304	Test Status Log
CDRL 305	Car Weighing Procedure
CDRL 306	Operational Characteristics Analysis Plan
CDRL T351	Weight Test
CDRL T352	Misc. Apparatus Test
CDRL T353	Wiring Continuity Test

CDRL T354	Ground Insulation Test
CDRL T355	High Potential Test
CDRL T356	Factory Trainline Test
CDRL T357	Multiple Configuration Trainline Tests
CDRL T358	Car Compatibility Test
CDRL T359	Electromagnetic Compatibility Test
CDRL T360	Operational Characteristics Analysis Reports
CDRL T361	AC Auxiliary Motors Type Tests
CDRL T362	Truck Weight Tests A008
CDRL T363	Lateral and End-to-End Imbalance Tests

3.6 REFERENCED STANDARDS

The following standards are referenced in this section:

IEEE 11	Rotating and Electrical Machinery for Rail and Road Vehicles
IEEE 112	Test Procedure for Polyphase Induction Motors and Generators
IEEE 16	Electric Control Apparatus, Land Transport
AAR	AAR Mechanical Division Manual of Standards, Section F-304

SECTION 4
USER MANUALS AND TRAINING PROGRAM

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SECTION 4
TRAINING PROGRAM

4.1 MANUALS AND CATALOGS

4.1.1 General

Manuals and Illustrated Parts Catalogs are an integral part of any maintenance activity. Consequently, the Contractor shall develop manuals for this Contract following a very strict and systematic process, and shall submit them to the Authority for review and approval. The manuals shall be developed using various reliability and maintainability analyses required for this Contract.

In addition to the printed versions of the manuals, the Contractor shall supply electronic versions of all manuals and shall supply the associated support system to allow the Authority to maintain the manuals once the Contract is completed.

Unless specifically stated otherwise, the use of the word “manual(s)” shall mean any and all manuals and catalogs specified anywhere in this Technical Specification.

4.1.2 Manuals Program Plan

The Contractor shall prepare and submit to the Authority for review and approval a Manuals Program Plan within 12 weeks after Notice to Proceed ***(CDRL 401)***. The purpose of the Plan is to identify all of the elements associated with the development of manuals for this Contract. At a minimum, the Plan shall include:

a. A description of the process the Contractor intends to follow to develop the manuals.

b. The schedule for manuals development.

c. An organizational chart showing the person with primary responsibility for development, along with all persons, departments, or vendors who will be working on the manuals.

d. The methods to be used to assure that the manuals reflect the reliability and maintainability analyses upon which they are based.

e. The revision tracking methodology to be used in the manuals.

f. The Contractor’s approaches to using styles and developing a Style Guide.

g. The quality program to be used to assure the accuracy and completeness of the manuals.

h. The audit and sign-off sheets that shall be used during manuals development.

4.1.3 Manuals Style Guide

Within 16 weeks after Notice to Proceed (NTP), the Contractor shall submit to the Authority for review and approval a Style Guide, including an electronic version, and format for each of the manuals required under this Contract ***(CDRL 402)***.

The Contractor shall use the Style Guide to develop all required manuals. All Suppliers shall use the same Style Guide for the development of their manuals, or their portions of the manuals, for use on this Contract.

4.1.4 Outlines

Within 24 weeks after NTP, the Contractor shall submit to the Authority for review and approval, tables of contents and samples for each type of manual and for the Illustrated Parts Catalog in accordance with the Style Guide ***(CDRL 403)***.

4.1.5 Design and Format

Manuals shall be designed for continuous, long-term service in a maintenance shop environment. The publications shall be complete, modern, thoroughly organized, and authentic, and shall contain no extraneous material such as advertisements or irrelevant information.

Manuals and catalogs shall be produced in the same format as the manuals in use for the Authority's existing vehicles. A complete correlation between in-use documentation is required; 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 the manuals and catalogs, except for emphasis.

Each manual shall contain the following general information:

a. Title Page – This includes the Contract name and number, name of the Contractor, date, and revision of the submittal.

b. Revision Tracking – This includes a listing and revision number of all pages, as well as a list of each revision, date of revision, and associated explanation of the revision.

c. Table of Contents – This includes a list of all sections, a list of all figures, and a list of all tables. A Table of Contents shall be provided at the beginning of each manual.

d. Index – This includes all relevant terms and page locations.

e. Each manual shall have language permitting the reproduction contents for training purposes.

Each manual section shall be subdivided, to the extent required by the subject matter, into the following topics:

a. General description and operation of the subsystem
b. Block diagram
c. Signal flow diagrams
d. Functional schematics
e. Functional wiring and piping diagrams
f. Troubleshooting techniques
g. Microcomputer software
h. Lubrication and cleaning, including frequency, methods and trade identifications of recommended materials; component location and description
i. Inspection and maintenance standards including wear limits, settings and tolerances
j. Installation and removal
k. Test and evaluation procedures

4.1.5.1 Paper and Binding

Each page of all final manuals, including drawings and figures, shall be printed on approved high-grade paper with a reinforced binding edge and oversized punched holes for binding in loose-leaf form.

Pages shall be printed on both sides. Sides of pages intentionally left blank shall be so noted. Diagrams and illustrations shall be either 8.5 x 11 in. (216 x 279 mm) or 11 x 17 in. (279 x 432 mm), as approved, and shall be bound to the central binder.

Pocket-size manuals, where applicable, shall be 4-1/4 inches wide, 7 inches high, and not more than 1-1/4 inches thick. They shall be bound along either dimension, as long as the contents are not obscured, 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. Manuals with 8-1/2 x 11-inch size pages may be divided into Volume 1, Volume 2, etc., if the required material cannot be accommodated within the maximum allowed binder thickness. Adequate cross-references and table of contents shall be provided in each manual and catalog.

All covers shall be approximately 1/16-inch thick and resistant to oil, moisture, and wear to a high degree, commensurate with their intended use. 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. The use of halftone illustrations is thus precluded; line drawings are required for all illustrations.

4.1.5.2 Indexing

Manual sections shall be indexed with heavy-duty, 90 lb minimum, white index dividers, having white, rounded corner tabs. Tabs shall be laminated, and have bold, black printing with capital lettering on both sides. Indexing of the pocket-sized Operator's Manuals may be abbreviated, as required, to achieve condensation without impairing legibility.

All sections shall be subdivided to the extent required by the subject matter.

4.1.5.3 Figures

Figures, including diagrams, drawings, and illustrations, shall be labeled as figures. Folding pages will be permitted (11 x 17 inches, "Z"-folded) where the information to be conveyed cannot be presented clearly on single pages.

Figures shall not be loose or in pockets.

4.1.6 Functional Requirements

The car shall be treated as a whole and not as a grouping of disassociated parts. The manuals shall be organized logically with subsystems and elements considered in descending order of importance.

All material shall be indexed with and Authority-approved standard numbering system in accordance with the Authority-approved outline. All statements must be clear and accurate, with no possibility of incorrect implications or inferences. Simple declarative statements shall be employed to convey instructions.

Safety-related notes, cautions, warnings, special procedures, or other information needed to maintain safe conditions shall be highlighted and included in all manuals. Block diagrams shall be used to facilitate the description of assemblies and the relationship of components, assemblies, and subsystems. Photographs shall not be used in the manuals.

The publications shall consist of 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. Operation and Maintenance Manuals – Portable Test Equipment and Bench Test Devices (8-1/2 x 11-inch pages)
f. Parts Catalog – Portable Test Equipment and Bench Test Devices (8-1/2 x 11-inch pages)

If microcomputers are used, the Contractor shall provide in separate binders five sets of software documentation conforming to the requirements of Section 22.29. This documentation 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 the functions of such assemblies shall be explained and the appropriate values shall be noted for each external test point. Procedures appropriate to the replacement of sealed assemblies, 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. These revisions shall be kept current during the warranty period. Manual and catalog revisions shall be supplied to the Authority before or coincident with the arrival of the altered parts or components.

4.1.6.1 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, gauges, 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.

4.1.6.2 Running Maintenance and Servicing Manual

The Running Maintenance and Servicing Manual shall provide the maintenance technicians with all of the information required for on-car running maintenance and adjustment, lubrication, inspection, and on-line trouble diagnosis of each system, including such data as troubleshooting guides and schematics for the car and each of its systems. Information on how to utilize any laptop-based test program shall also be included.

4.1.6.3 Heavy Repair Maintenance Manual

The Heavy Repair Maintenance Manual shall contain a detailed analysis of each component of the car so that maintainers can effectively service, inspect, maintain, adjust, troubleshoot, repair, replace, and overhaul the component. The Heavy Repair Maintenance Manual shall also include, in a separate section, all information needed for periodic inspection and servicing requirements, including lubrication, inspection, adjustment, removal, repair, installation and overhaul (if applicable) of all apparatus.

Information on ATC system hardware and software and the Radio system hardware and software shall be replicated and provided in additional, separately-bound manuals, with the same requirements as above, and shall contain the same general information, as described in Section 4.1.5.

4.1.6.4 Parts Catalog

The Illustrated Parts Catalog shall enumerate and describe every component with its related parts, including the supplier's number and commercial equivalents. A separate column shall be provided for insertion of the Authority's stock numbers 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 higher assembly.

Information on ATC system and Radio system components shall be replicated and provided in additional, a separately-bound parts catalogs, with the same requirements as above, and shall contain the same general information, as described in Section 4.1.5.

4.1.6.5 Operation and Maintenance Manuals – Portable Test Equipment and Bench Test Devices

Operation and Maintenance manuals for test devices shall include the requirements of Section 21.1 and shall be presented in the format required by Section 4.1.5.

4.1.6.6 Parts Catalog - Portable Test Equipment and Bench Test Devices

Parts Catalogs for test devices shall include the requirements of Section 21.1 and shall be presented in the format required by Section 4.1.6.4.

4.1.7 Submission Schedule and Quantities

The Contractor may submit draft manuals to the Authority for review on a chapter-by-chapter basis; however, each manual must be submitted as a complete unit before receiving Authority approval. The Contractor shall submit draft manuals ***(CDRL 404)***, final draft manuals ***(CDRL 405)*** and final published manuals ***(CDRL 406)*** in accordance with the following schedule and quantities:

		Draft Manuals		Final Draft Manuals		Final Published Manuals	
		Quantity	Due Date[1]	Quantity	Due Date[1]	Quantity	Due Date
a.	**Train Operator's Instruction Manual**	30	-60 days	30	+60 days	650	Note 2
b.	**Running Maintenance and Servicing Manual**	30	-60 days	30	+60 days	80	Note 2
c.	**Heavy Repair Maintenance Manual**	30	+30 days	30	+150 days	80	Note 2
d.	**Illustrated Parts Catalog**	30	-30 days	30	+90 days	80	Note 2
e.	**Operation and Maintenance Manual – Portable Test Equipment and Bench Test Devices**	30	-60 days	30	+60 days	20	Note 2
f.	**Illustrated Parts Catalog – Portable Test Equipment and Bench Test Devices**	30	-30 days	30	+90 days	20	Note 2

In addition to the above manuals, the Contractor shall replicate the sections discussing the Carborne ATC Equipment and the Radio Equipment, and shall deliver additional bound copies of these sections as follows:

		Final Draft Manuals		Final Published Manuals	
		Quantity	Due Date[1]	Quantity	Due Date
g.	**Carborne ATC Maintenance Manual**	30	+60 days	50	Note 2
h.	**Carborne ATC Parts Catalog**	30	+90 days	50	Note 2
i.	**Radio Maintenance Manual, for FCC Licensed Personnel**	20	+60 days	20	Note 2
j.	**Radio Parts Catalog**	20	+90 days	20	Note 2

Note 1: Due dates shown in number of days (-) before or (+) after scheduled Acceptance of the first vehicle.

Note 2: Final Published Manuals must be submitted before the scheduled completion of the Contractor Reliability Monitoring Period, described in Section 5.2.7, or no later than 12 months after Acceptance of the first vehicle, whichever occurs first.

The Contractor shall supply revisions to the Authority, as applicable, every 3 months until the end of the Authority Reliability Assessment Period described in Section 5.2.6. A new revision sheet shall be provided for each manual showing the date of any changes made since the previous submittal and the pages that are affected. When no changes are required for a 3-month period, the Contractor shall provide only a new revision sheet showing the new period of validity.

4.1.7.1 Draft Manuals and Parts Catalogs

The intent of the Draft Manuals and Parts Catalogs is to allow the Authority to review and provide feedback on the substance of the manuals with enough time for necessary modifications to be made to support the Authority's Maintenance Training Program. As such, the Draft Manuals and Parts Catalogs shall be complete and thorough, and shall be prepared as if they were the final versions. The Draft Manuals and Parts Catalogs shall reflect the current state of the vehicles at the time of publishing, and shall be a culmination of the discussions of the various manuals status meetings held with the Authority, as described in Section 4.1.10.

Draft Manuals and Parts Catalogs shall be provided in both printed and electronic formats.

4.1.7.2 Final Draft Manuals and Parts Catalogs

The Final Draft Manuals and Parts Catalogs shall incorporate the necessary revisions as a result of the Authority's review of the Draft Manuals and Parts Catalogs, and shall incorporate any vehicle modifications realized at the time of submittal. The intent of the Final Draft Manuals is to provide an interim comprehensive set of documentation, which has incorporated the necessary Authority comments, and which will support the Authority's Training and Maintenance efforts until the Final Published Manuals and Parts Catalogs are available.

Final Draft Manuals and Parts Catalogs shall be provided in both printed and electronic formats.

4.1.7.3 Final Published Manuals and Parts Catalogs

Final Published Manuals shall incorporate any and all revisions or modifications realized during the Contractor's Reliability Monitoring Period.

Final Published Manuals and Parts Catalogs shall be provided in both printed and electronic formats.

Additionally, the Contractor shall provide, in both printed and electronic format, any necessary revisions through the end of the Authority's Reliability Assessment Program ***(CDRL 407)***.

4.1.8 Interactive Electronic Technical Manuals A009

The Authority is in the process of selecting an Interactive Electronic Technical Manual (IETM) provider for the existing WMATA fleet. The Contractor will be required to author an IETM for the 6000 series that will be in a fully compatible format.

4.1.9 Revisions

Manual revisions shall be recorded on a control list in the front of each manual. The list shall be issued with each revision and shall show the date of each revision and the page reference.

Revisions related to field alteration of subsystems or assemblies shall be issued with the associated service bulletin before the arrival of the components or retrofit packages.

The Contractor shall provide an electronic copy of all manuals on CD-ROM with each delivery of the paper copies. Additionally, a new CD-ROM shall be provided with each revision, including those related to field alteration of subsystems and assemblies. A final CD-ROM shall be provided with the submittal of the final manuals.

4.1.10 In-Process Reviews

The Contractor shall conduct in-process reviews of the manuals and all aspects of the manual development process during this Contract. The first review shall be conducted within 24 weeks after NTP. Subsequent review dates shall be coordinated with the Authority, but in no case shall they be held less than quarterly, or once every 12 weeks. During these reviews, the Contractor shall:

- Present the status of the manuals program versus the Contract document requirements, including action items status from previous reviews.
- Present all completed manuals chapters or portions thereof for Authority review.
- Present the results of any audits.
- Present any issues related to the development of the manuals to be addressed by the Authority.
- At the Authority's request, make available for interview those persons who are developing the manuals.
- Record minutes to be published after the review, including any action items.

These reviews shall be conducted at the location to be selected by the Authority. An agenda and materials to be presented during the review shall be submitted to the Authority prior to the review date.

4.1.11 Audits

The Contractor shall conduct periodic audits to assure that the manuals accurately reflect equipment design and the reliability and maintainability analyses upon which they are based. The results of these audits shall be presented at the in-process review meetings.

4.1.12 Contractor Internal Review and Approval

All manuals shall be reviewed by the appropriate Contractor engineering personnel, manuals department head and/or the person responsible for manuals on this Contract, and program management personnel for accuracy and completeness before submittal to the Authority. In addition, each document submitted to the Authority shall be accompanied by a sign-off sheet that includes the signatures (and date of signing) of all persons who conducted the review attesting to the accuracy and completeness of the submitted manuals.

4.1.13 Use of Suppliers

If the Contractor utilizes a Supplier to develop the manuals, all requirements of this Contract shall remain in effect and continue to be the sole responsibility of the Contractor. In addition, the Contractor shall manage the efforts of the Supplier and participate in any and all meetings and in-process reviews related to manuals.

4.2 USER EDUCATION

4.2.1 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 curriculum shall emphasize the differences between these cars and the Authority's existing rolling stock and equipment. 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.

The curriculum material shall be accurate, complete, and of professional quality. Instructor and Student Guides ***(CDRL 409)*** shall be provided for each course, as well as the training aids as specified in Section 4.2.5. The Maintenance Manuals and Parts Catalogs shall be incorporated into the classroom discussion, but shall not serve as the Student Guides.

The training program shall be conducted at the Authority's facilities in Washington, D.C. and shall 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 paper copies of training materials, 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 testing and evaluation to determine the proficiency of the students. Testing shall consist of written tests, utilizing a multiple choice format with four possible answers.

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

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.

4.2.2 Objectives

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

The primary objective of the Operations Training Program shall be to provide Train Operators and Operations Supervisors with proficiency in the operation of the transit car.

4.2.3 Training Plan

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

The Contractor shall submit a Training Plan and Summary Level Schedule ***(CDRL 410)*** that identifies milestones for submitting course outlines, lesson plans, instructor/student guides, and training aids; for providing mock-ups/simulators; for conducting classes; and for administering written and practical tests. The training plan shall identify each module of instruction and the general topics to be taught, and shall indicate the order in which modules will be conducted. The Authority will provide samples of how training materials should be organized, and of 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.

4.2.3.1 Operations Training

Topics to be covered in the Operations Training Program shall include, but not be limited to, the following:

A. Car specifications, controls and indicators

B. Car systems (e.g., propulsion, friction brake, electrical, truck and coupler assemblies, door control, HVAC, lighting and communications)

C. Car operations (i.e., actual operation of the car in maintenance yards and on the revenue railroad)

D. Troubleshooting procedures and recovery operations.

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

4.2.3.2 Maintenance Training

Topics to be covered in the Maintenance Training Program shall include, but not be limited to:

A. Carbody
B. Car logic control
C. Destination signs
D. Propulsion
E. Friction brake
F. Pneumatics
G. Primary power
H. Auxiliary power
I. Trucks and suspension
J. Coupler and draft gear
K. Door control
L. Heating, ventilation and cooling
M. Lighting
N. Automatic Train Control
O. Communications

Authority employees shall be exposed to the depth of detail that is necessary for the performance of troubleshooting, preventive (scheduled) maintenance, 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/electronic, and mechanical. To enable student participation during the demonstration and performance of maintenance functions, each course shall be separated into these two classifications.

4.2.4 Training Courses

The Contractor shall submit course outlines for each course at least 90 days prior to the anticipated start date of each course. ***(CDRL 411)*** Lesson plans shall be submitted for each course at least 60 days prior to the anticipated start date of each course. ***(CDRL 412)*** The Contractor shall provide detailed schedule data for the proposed courses (see CDRL 410*)*. This information shall be grouped by type of course and separately indicated for each individual course proposed.

A qualified instructor shall be assigned to each group of students during training. The training shall provide in-depth understanding of vehicle assembly, subsystem installation and operation, subsystem integration, and vehicle verification testing. Additionally, students shall observe demonstrations of proper maintenance practices and shall be instructed in the requirements for and use of proper tools (e.g., special tools), the importance of proper torquing and sealing procedures, and the most efficient way to perform maintenance.

Hands-on instruction in both the maintenance and the operation of the car shall be presented by instructors having thorough experience in maintenance services or operations, as the case may require. Instructors shall have their subject matter properly organized prior to commencement of the class.

Classes shall be scheduled on the basis of a 40-hour work week, 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. The length of practical application periods is not fixed.

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

Operator Training courses 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 the instruction and to request changes to enhance the effectiveness of the training.

4.2.5 Training Aids

The Contractor shall supply the following training aids for both the Operation and the Maintenance Training classes ***(CDRL 413)***:

A. The Contractor shall provide Student Guides that highlight the classroom material to be covered, and emphasize important concepts or maintenance issues. Copies of any transparencies for which the subject matter could not otherwise be found in the Manuals (i.e. viewgraphs showing simplified schematics for purposes of emphasizing a concept) shall be included in the Student Guides. Whenever possible, actual Manuals sections should be referenced as having been used during the classroom discussion. The Student Guides shall have all pages numbered and such numbering must be reflected on the corresponding transparencies to aid with locating the subject material during classroom discussions.

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

C. The Contractor shall furnish IBM PC-compatible computer-driven video displays for use during the propulsion, friction brake, and automatic train control electrical maintenance course. The video display shall include, but not be limited to, an animated schematic of the propulsion primary motor circuit, the friction brake pneumatic circuit, and signal paths for the automatic train control system ATP, ATO, and ATS subsystems. The animated schematic shall:

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

    2. Accurately display system configurations 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.

4. Accurately display, on screen, propulsion system operating parameter values for all propulsion, friction brake, and ATC modes and configurations. The parameters displayed on screen shall include, but not be limited to, line currents, motor currents, motor voltages, motor RPMs, brake cylinder pressures, brake pipe pressures, 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, friction brake, and ATC systems, shall be included in the display.

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

The display shall allow the user to simulate common propulsion, friction brake, and ATC system faults including, but not limited to, low or high line voltage, high and low brake pipe and brake cylinder pressures, semiconductor faults, relay and contactor failures, tachometer failures, over-temperature conditions, compressor failures, loss of cab signals, and over-speed conditions. The display shall then immediately show the actual effect that those faults would have on the propulsion, friction brake, and ATC systems.

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

D. The Contractor shall supply a minimum of ten interactive training videos covering all major subsystems plus subsystem interfaces in DVD format. Each DVD video shall be divided into segments that are 10 to 20 minutes in length. An interactive menu shall be included at the start of the DVD that allows the user to select a specific segment to review. Segments shall include, but not be limited to: operation of propulsion, friction brake, ATC, door, and communications equipment, including the use of the portable test equipment and/or laptop-based troubleshooting equipment.

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, a key shall be provided to permit precise identification.

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 participants to clearly see the material.

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 the master reproducible of each audio-visual aid.

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 is the result of neglect by the Authority. Lesson plans shall be updated as required during the course of instruction.

The following listing gives the numbers of personnel to be instructed:

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

4.2.6 Classroom Instruction

4.2.6.1 Instructor Qualifications

All instructors provided by the Contractor shall be fully capable of transmitting in-depth technical information that can be understood by participants. Instructors must be fluent in English. The Contractor shall provide to the Authority for approval a detailed resume and statement of qualifications for each instructor. ***(CDRL 414)***

The Authority will recognize the instructor as qualified when he or she:

A. 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, its 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.

4.2.6.2 Class Size

Class size will generally be from 5 to10 employees, depending on the nature of the course being taught. The Contractor shall supervise all classes.

4.2.6.3 Instructional Format/Materials

All maintenance and operations courses shall include a combination of classroom and hands-on instruction. Manuals and other training 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.

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. Written tests shall be multiple choice format, with four possible answers. Student test and evaluation results shall be provided to the Authority at the end of each training course. ***(CDRL 415)***

4.2.7 Factory Training

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 a 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.

4.2.8 Training Bulletins

If warranty work done on cars necessitates a change in maintenance or operation that may require modifying manuals or course content, the Contractor shall issue training bulletins to reflect the necessary changes.

4.2.9 Authority-Provided Resources

The Authority will make available, upon proper notice and at no cost to the Contractor, shop or lead track space for vehicles used for instructional purposes, and will arrange for road operation as well as the furnishing of power, dispatching, and operational supervision as necessary. All vehicles used for conducting training must be supplied by the Contractor, and shall be made available at the most updated configuration. Vehicles that have already been accepted by the Authority shall not be made available for training purposes.

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.

4.3 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 401	Manuals Program Plan
CDRL 402	Manuals Style Guide
CDRL 403	Manuals and Parts Catalogs Table of Contents and Samples
CDRL 404	Draft Manuals and Parts Catalogs
CDRL 405	Final Draft Manuals and Parts Catalogs
CDRL 406	Final Published Manuals and Parts Catalogs
CDRL 407	Updates to Manuals and Parts Catalogs
CDRL 408	Electronic Documentation Support System
CDRL 409	Instructor and Student Guides
CDRL 410	Training Plan and Summary Level Schedule
CDRL 411	Training Course Outlines
CDRL 412	Training Lesson Plans
CDRL 413	Training Aids
CDRL 414	Instructor Resumé and Qualifications
CDRL 415	Student Test and Evaluation Results

4.4 REFERENCED STANDARDS

No standards are referenced in this section.

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SYSTEMS ASSURANCE

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SECTION 5
SYSTEMS ASSURANCE

5.1 QUALITY ASSURANCE PROGRAM

5.1.1 General

The Contractor shall be responsible for providing a quality product to the Authority under this Contract. To this end, the Contractor shall plan and establish a quality assurance program which shall be maintained throughout the duration 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 and execute in the performance of the Contract to ensure that the design, materials, processes, and workmanship are furnished in conformance with Specification requirements, and that the 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 quality assurance program; and conducting regular quality program audits. Required tests and adjustments are specified in Section 3.

5.1.2 Quality Assurance Program Plan

The Contractor shall submit a Quality Assurance Program Plan, specific to this Contract, to the Authority for approval. ***(CDRL 501)*** The submittal shall provide objective technical evidence of the adequacy of the Contractor's quality assurance program to assure product compliance; either through the presentation of historical records or the examination of operations in progress. The Contractor's Quality Assurance Program Plan shall include all applicable elements of and ensure compliance with FTA Quality Assurance and Quality Control Guidelines (FTA-MA-06-0189-92-1, March 1992). These guidelines have been established based on the ISO 9001 standards for quality management systems.

The Quality Assurance Program Plan shall describe in detail the type of activities that are planned in order to achieve the required quality. It shall also identify quality hold points where quality reviews of A006
the products will take place. Work cannot proceed beyond those points unless WMATA is satisfied with the quality of the work or product. The plan shall include a company policy statement that clearly defines the authority and role of quality assurance function within the Contractor's organization, particularly with regard to schedules and cost.

The Quality Assurance Program Plan will be evaluated by the Authority, and shall be revised by the Contractor as directed by WMATA or deemed necessary by the Contractor and approved by WMATA to achieve conformance with the Specification requirements for the quality assurance program. The Authority may visit Contractor and subcontractor facilities, prior to approval of the Quality Assurance Program Plan, assess the effectiveness of the quality assurance program If deficiencies are noted during the assessment of the program, the Contractor shall take and document corrective action as a condition of having the Quality Assurance Program Plan approved.

The Contractor shall maintain a quality assurance program with established quality control functions 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 5.1.4 to determine implementation status during the performance of the Contract.

The quality assurance program shall include an inspection and test plan. ***(CDRL 502)*** The inspection and test plan shall include a narrative description of the manufacturing and inspection process for major
A008 equipment and shall identify where critical manufacturing activities will be performed. In addition, the
A006 inspection and test plan shall include major manufacturing and inspection milestones on a schedule, and shall be incorporated into CDRL 202 “Master Program Schedule. 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 implement and maintain its quality program. The Quality Assurance Manual shall contain a comprehensive collection of all forms to be used to document quality control activities that assure the compliance of material, processes, personnel and products with applicable standards and specifications. The Quality Assurance Manuals of the Contractor and subcontractors shall be submitted and revised until they receive the Authority’s approval. ***(CDRL 503)*** 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.

5.1.3 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 Contractor shall appoint a dedicated QA Manager who has appropriate training, experience and qualifications to oversee the QA process, and the authority to accept or reject work and stop work, if necessary. The individual proposed for this position shall be approved by WMATA before starting work on the project. The QA function shall be independent of the production function The QA Manager should report to an officer or top level manager within the Contractor's organization, not to the Contractor's Project Manager for this project. The management responsibility for the quality assurance function shall be set forth in the Contractor’s policy statement, and organization charts shall be submitted to show individuals in the Contractor's organization and all subcontractor's organizations involved in the QA function. .

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

5.1.3.1 Design Control

The following design control activities shall be undertaken as part of the quality assurance program:

A. Conduct planning activities as needed to determine: (1) each stage of the design and
A006 development process; (2) review, verification, and validation activities that are appropriate to each design and development stage; and (3) responsibilities and authorities for design and development. The Contractor shall manage the interfaces among the groups involved in design and development to ensure effective communication and clear assignment of responsibility.

B. Control of design and development inputs and changes thereto, to assure that Specification design requirements are correctly translated into the drawings and specifications used for procurement, manufacturing, and testing. These inputs shall include: (1) functional and performance requirements, (2) applicable statutory and regulatory requirements, (3) information derived from previous designs (where applicable), and (4) other requirements essential for design and development. Inputs shall be reviewed for adequacy. Requirements shall be complete, unambiguous, and consistent with each other. A006

C. Control of design and development outputs, to ensure consistency and compliance with established inputs. These outputs shall be provided in a format that facilitates verification against the corresponding design and development input. Outputs shall be approved by the Contractor prior to release to the Authority, and by the Authority prior to release for production. Design and development outputs shall: (1) meet the corresponding input requirements; (2) provide appropriate information for purchasing, production, and service; (3) contain or reference product acceptance criteria; and (4) specify the characteristics of the product that are essential for its safe and proper use. A006

D. Implementation of design and development reviews. The Contractor shall establish a program of systematic reviews of design and development activities and work products. These reviews shall be conducted at suitable stages of the design and development process and in accordance with established protocols. These reviews shall be performed to evaluate the ability of the results of design and development activities to meet established requirements and to identify any problems and propose necessary corrective actions. The Contractor shall generate and maintain records of these reviews and any resulting actions ***(CDRL 517)***. A006 A009

E. Verification and validation of design and development outputs. The Contractor shall conduct verification activities to ensure that input requirements have been met, and validation to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use. The Contractor shall generate and maintain records of verification and validation activities and any resulting actions ***(CDRL 518)***. A006 A009

F. 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.

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

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

I. Establishment of procedures for identifying and documenting design and development changes. The Contractor shall ensure that such changes are reviewed, verified, and validated at the same level as the original, and approved before implementation. Design and development changes are subject to the same approval level as the original. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered. The Contractor shall generate and maintain A006 A008 records of change control activities and any resulting actions. A matrix of all changes shall be established and kept current.

J. Establishment of procedures for monitoring of vehicle weight. Total weight of the car and
A002 allowable imbalance shall be closely monitored. The Contractor shall provide a monthly report presenting the current total car weight and center of gravity, to verify compliance with Section 7.3 ***(CDRL 516)***.

5.1.3.2 Materials Control

Quality assurance activities in the area of materials control shall include:

A. Control of purchased material, equipment, and services to ensure 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 Material Review Board (MRB), as described below, and shall be properly dispositioned to the satisfaction of the Authority.

D. The Contractor shall establish an MRB 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. Records of all MRB's shall include the investigation, disposition, corrective
A008 action and follow up actions (when applicable). These records must be kept on file and are subject to the Authority's review. All MRB recommendations for "repair" and "use as is" of nonconforming materials shall be subject to Authority approval. The Contractor shall inspect all reworked material and either reject the material or certify it as conforming. At no time shall nonconforming material be installed for rework or replacement at a later time without exceptional approval by 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 weekly 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 and cars affected by the non-conformity.

The Contractor shall submit an MRB plan for approval as part of the Quality Assurance Program Plan outlined in Section 5.1.2.

5.1.3.3 Manufacturing and Process Control

Control of manufacturing and production processes shall be accomplished through the use of a manufacturing process control plan. The Contractor shall submit a complete manufacturing process control plan as part of the Quality Assurance Program Plan. This plan shall be compatible with the approved inspection plan and shall be 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. A008

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.

In addition, the following quality assurance activities shall be taken to control manufacturing and production processes:

A. Control of production and service provision, to include as applicable the following: (1) the availability of information that describes the characteristics of the product or component such as visual aids and/or boundary samples, (2) the availability of work instructions, (3) the use of suitable equipment, (4) the availability and use of appropriate monitoring and measuring devices, (5) the implementation of monitoring and measurement, and (6) the implementation of release, delivery, and post-delivery activities. A006 A008

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, painting, welding, heat treating, and non-destructive testing are accomplished using personnel and procedures qualified in accordance with industry codes and standards or Specification requirements. A008

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 correct non-conforming conditions and preclude their recurrence. A006

E. Control of all work instructions, procedures, and their revisions to assure that manufacturing and processes are performed in accordance with Specification requirements, including ensuring that work is performed in the proper sequence. A006

F Control of materials and equipment used during production and inspection activities, including all required calibration and maintenance activities. A006

G. Validation of processes for production and service provision where the resulting output cannot be verified by subsequent monitoring or measurement. This includes any processes where deficiencies become apparent only after the product is in use or the service has been delivered. The Contractor shall demonstrate the ability of these processes to achieve planned results. The Contractor shall establish protocols for these processes including the following: (1) defined criteria for review and approval of the processes, (2) approval of equipment and qualification of personnel, (3) use of specific methods and procedures, (4) record keeping requirements, and (5) revalidation, if necessary. A006

A006 H. Determination, provision, and maintenance of the infrastructure and work environment needed to achieve conformity to Specification requirements. Infrastructure includes, as applicable, the following: (1) buildings, workspace, and associated utilities; (2) process equipment (including hardware and software); and (3) supporting services.

5.1.3.4 Testing

Quality assurance activities in the area of testing shall include:

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 3.

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.

5.1.3.5 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.

A006 Changes to documents and data shall be reviewed and approved by the same functions/organizations that performed the original review and approval, unless specifically designated otherwise. The designated function/organization shall have access to pertinent background information upon which to base their review and approval. Where practical, the nature of the change shall be identified in the document or appropriate attachments.

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:

A008 A. Results of examinations (Contractor's and Authority's)
B. Inspection results (Contractor's and Authority's)
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 504)*** 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."

The Contractor shall include any additional categories or sorts that are required as a result of the Authority's review. Reports shall be generated from these various sorts as required by the Authority.

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.

5.1.3.6 Quality Assurance Procedures

Procedures shall be developed in the following areas to assure effective implementation of the quality assurance activities discussed in Sections 5.1.3.1 through 5.1.3.5 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 recordkeeping

K. Shipping inspection

L. Selection of qualified procurement sources

M. Evaluation of subcontractor quality assurance programs

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.

5.1.3.7 Quality Control Functions

5.1.3.7.1 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 reserves the right to make inspections of items, completed or in-progress, with or in addition to the Contractor's inspection. This shall in no way remove, lessen or take the place of the Contractor's obligation to conduct thorough inspections. 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.

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.

5.1.3.7.2 Scheduling Inspections

A008 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. All notices for scheduled inspections shall be addressed to the Project Manager. 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.

5.1.3.7.3 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 the Special Provisions. The facilities shall enable convenient inspection of materials, work, and equipment, and shall include provisions for separate office space, desks, locker facilities, and file cabinets. Copies of all drawings A008
(electronic and paper), diagrams, schedules, changes, deviations, and data shall also be furnished. Data shall be sufficient 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.

5.1.3.7.4 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 for review and approval. Sampling procedures which determine Acceptable Quality Levels (AQL) and Average Outgoing Quality Levels (AOQL) shall be performed under ASQC Z1.4, ANSI/ASQC Z1.9, or other approved plans.

5.1.3.7.5 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-105 guidelines. Results shall be documented. A list of parts and material to be inspected by SQC shall be presented to the Authority for approval. ***(CDRL 505)***

5.1.3.7.6 Inspection Status

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

5.1.3.7.7 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 shall be performed to Specification drawing and purchase order requirements. Material certifications and test reports shall be retained by the Contractor.

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5.1.3.7.8 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 include 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 506)*** 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 such are 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 shall evaluate component and system maintainability where possible. The FAI shall establish the quality of workmanship for the balance of like components. The quality level shall be established jointly by the Authority and the Contractor.

No FAI shall 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 shall be performed only on components built using approved production processes, tooling, and manpower.

FAIs shall 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.
A002 J. Interior Liners

K. Car Interior Appointments

The following shall be provided for each FAI:

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

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

C. Completed inspection forms that controlled and accepted in-process work

D. Completed test documents which reflect that unit has passed

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

F. The inspection article displayed on a stand or table

G. Tools and labor to take mechanical or electrical measurements

H. Tools and labor for disassembly and removal of covers

I. Tools and labor for functional testing.

5.1.3.7.9 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 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. All of the Contractor's deficiencies shall be reworked and/or dispositioned prior to requesting an inspection by the A008
Authority. The acceptance status of reinspected articles 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.

5.1.3.7.10 Hold-Point Inspection

The Contractor shall establish hold points in the manufacturing process, as part of the inspection and test plan (Section 5.1.2) 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.

5.1.3.7.11 Source Inspection

A008 The Contractor shall provide qualified source inspectors for the purpose of conducting inspections of subcontractor components and materials at Subcontractor plants.

A008 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 Authority may elect not to attend the source inspection, however the Contractor's source inspectors shall attend as scheduled and perform the inspections. 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.

A008 Additional items may be added to the source list by the Authority, depending upon product history.

5.1.3.7.12 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.

5.1.3.7.13 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.

5.1.4 Quality Assurance Audits

5.1.4.1 General

The Authority will audit the Contractor's quality assurance and quality control activities as frequently as it deems necessary to determine compliance with the approved Quality Assurance Program Plan. The audit will be conducted to the schedule in Section 5.1.4.2. 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 subcontractors according to the referenced schedule, and shall provide reports of the audits to the Authority. Audits shall be performed to approved checklists by personnel other than those who performed the work. Audits shall report on the degree of compliance with approved quality assurance procedures listed in Section 5.1.3.6. ***(CDRL 507)***. Audit follow-ups A008
will be ongoing until all subcontractors are working to a fully compliant quality system.

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.

5.1.4.2 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.

5.1.4.3 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. Additional audits of subcontractors may be directed by WMATA, at its discretion. If it deems necessary, WMATA may conduct its own audits of subcontractors.

5.1.4.4 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

A008 C. The Contractor shall submit a formal written response to the Authority within 15 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. In advance of the full formal response to the report, the Contractor shall correct deficiencies and provide interim responses in compliance with the timetable for any such requirements specified in the audit report.

5.2 RELIABILITY, AVAILABILITY & MAINTAINABILITY

5.2.1 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. <u>Mileage, Operating</u>. 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. <u>System</u>. 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. <u>Components and Subsystems</u>. 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. Where Secondary failures occur, it shall be the responsibility of the Contractor to prove that protection measures provided integral to the apparatus in which the secondary failure occurred were adequate. In general it will not be acceptable for Primary Failure in a component, subsystem or system to lead to failure in other components, sub-systems or systems unless those items are provided specifically to prevent more serious or costly damage. Secondary Failures shall be counted as chargeable failures until proven otherwise to the satisfaction of the Authority.

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.

5. In complex systems the occurrence of repeated transient failures is evidence of systems that are not fully integrated. The operational impact of transient failures is unacceptable to the Authority. Therefore multiple occurrences of a transient failure, one where a failure is reported but no fault is found during investigation, will be classified as a single Chargeable Failure.

6. Loss of function resulting from the required resetting of circuit breakers, or similar re-initialization of systems, including the restarting of systems incorporating software. A009

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. <u>Indeterminable Failure</u>. 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.

A failure classified as an Indeterminable Failure will be reclassified as a Chargeable Failure following multiple occurrences of the failure. The Authority will determine reclassification of transient failures.

N. <u>Failures per Million Miles (FPMM)</u>. The FPMM of an item is the ratio of the total number of chargeable failures to the total mileage, in millions, of the Test Fleet. The Test Fleet's mileage shall be accumulated on a calendar monthly basis. The Test Fleet's monthly mileage shall be derived from actual mileage records as recorded by the Authority for the cars.

A009 O. <u>Multiple Occurrences</u>. Multiple occurrence will be deemed to have taken place following the third report of a transient failure within a rolling three month period.

P. <u>Mean Time To Repair (MTTR)</u>. Average time required to bring system from a failed state to an operational state. MTTR is calculated considering the diagnostic, repair (or replacement) and retest times only. The MTTR does not include logistic delay time (assumes maintenance personnel and spares are available to effect repair).

Q. Availability. The probability that a car will be in an operational state. The Availability is calculated from the percentage time in operational state (up time) compared to the total operational time (up time and down time). The up time is calculated from the Mean Time Between Failures (MTBF) (derived from the Failures Per Million Miles). The total time comprises MTBF, Mean Time To Repair (MTTR) and Mean Preventive Maintenance Time (MPMT), as follows: A009

$$\text{Availability} = \text{MTBF} / (\text{MTBF} + \text{MTTR} + \text{MPMT})$$

5.2.2 General Requirements

The Contractor shall make every effort to design and construct all equipment furnished under this contract to provide failure-free operation, achieve high levels of availability and ensure ease of maintenance. The reliability failures shall not exceed the values allowed by Exhibit 5-1. 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. The Availability and Maintainability requirements shall be agreed with the Authority and shall then form part of the contractual requirements between the Contractor and the Authority.

The Contractor shall make use of all reasonable means to ensure that the level of reliability, availability and maintainability provided by the vehicles supplied under this contract comply with the at least the minimum requirements of the Authority.

The contractor shall provide a preliminary assessment of systems reliability prior to PDR ***(CDRL 519)***. This reliability assessment shall include sufficient information and data to demonstrate that preliminary system designs are consistent with the requirements listed in Exhibit 5-1. Empirical data and engineering calculations shall be delivered to support any assertions pertaining to the anticipated reliability of these systems. A009

Where appropriate the Contractor shall make use of results of analyses required by related sections of the specification, such as safety Failure Modes and Effects Analysis, Fault Tree Analysis, etc. If required to provide evidence of their achievement of the contractual requirements the Contractor shall propose such additional analyses as are appropriate (Reliability Block Diagrams, Maintainability Analyses, etc). The Contractor shall inform the Authority prior to commencing such analyses, and shall take due account of comments raised by the Authority. The Authority will inform the Contractor if it considers analyses will not provide the assurance claimed by the Contractor.

5.2.3 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 69,000 miles per car. A006

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.

5.2.4 System Failure Limit Requirements

The Maximum Allowable Failures per Million Miles for each of the systems, subsystems and/or components is shown in Exhibit 5-1. 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 5.2.6.

5.2.5 Authority Reliability Analyses

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.

5.2.6 Authority 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
A009 evaluation of the performance of each system. Any option cars will be evaluated using identical criteria, but treated as a separate assessment program.

Exhibit 5-1
System Reliability Requirements in Failures per Million Miles (FPMM)

System/ Subsystem	Maximum Allowable Failures Per Million Miles
Propulsion	15
Brake	10
Door	10
Coupler	1
A009 Communications	6
ATC	6
Auxiliary Power	3
700 Volt Power	2
Heating Ventilation and Air Conditioning	5
Destination Signs/Graphics	2
Lighting	2
Truck	3
Traction Motor	1.5
Propulsion Logic	6

HVAC Control	2
Friction Brake Controls	4
Friction Brake Pneumatic/Hydraulic System	4
Converter	2
Radio	2
ATP	2
ATO	2
ATS	1
Door Operator	2
Door Control	3

Note: For car components and systems not covered in Exhibit 5-1, the cumulative fleet defect rate in any 12 consecutive month period shall not exceed 10% of the overall failure rate. Any components within system with failure rate requirements specified in Exhibit 5-1 shall not contribute more than 10%. The assignment of components shared by two or more systems will be determined by the Authority.

Within 60 days after the receipt of this report, the Contractor shall provide a formal reliability assessment response report ***(CDRL 508)***, 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. A009

5.2.7 Contractor Reliability Monitoring

The Contractor shall implement and maintain a closed loop system for identifying and analyzing failures and their causes, determining and implementing corrective actions. The reporting system shall comply with the minimum requirements of MIL-STD 2155, Failure Reporting Analysis and Corrective Action (FRACAS). The Contractor shall provide to the Authority monthly summaries of failure data and corrective actions, when the project enters the Reliability Test phase the output from the FRACAS shall be combined with the Reliability Test Report as detailed in Section 5.2.7.1. The Authority shall review the information supplied and where appropriate require additional justification or corrective action to provide increased confidence in the system's abilities to meet the reliability requirements.

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.

A009 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 5-1 have passed the reliability test according to the test criteria. The car shall enter the reliability test group either three months or 10,000 miles after acceptance, whichever is later.

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
A009 frequently with the mutual consent of both parties. Problems with claims that cannot be resolved at the meetings shall be referred to the Contracting Officer for final decision.

5.2.7.1 Contractor Reliability Test Report

It is the responsibility of the Contractor to submit a monthly reliability test report to the Authority, summarizing the Reliability Test status. ***(CDRL 509)*** 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.

5.2.7.2 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 necessary to bring the vehicle and systems into conformance with these reliability requirements. 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 requirements. In the event that the requirements are not attained, the Authority will make whatever repairs it deems are necessary, at the Contractor's expense, in order to achieve the reliability requirements.

5.2.8 Availability Requirements

The Contractor shall identify an availability target for the complete vehicle. The availability target will be subject to approval by the Authority, but shall reflect the level of service expected by the Authority. The Availability Target shall be greater than 0.98.

The Availability requirement agreed by the Authority shall be subject to monitoring throughout the Reliability Test Period, within the Reliability Monitoring System. The Availability monitoring shall be reviewed to consider the direct impact of failures on the service provided by the Authority and to monitor the effectiveness of the maintenance documentation. Failure to achieve the targets shall lead to modification of maintenance manuals, additional training or possible design action.

The results of the Availability monitoring shall be reported within the monthly Reliability Test Report.

5.2.9 Maintainability Requirements

5.2.9.1 General Requirements

The Contractor shall design and construct the equipment furnished under this contract to ensure ease of maintenance. The maintenance periods and resources required shall not exceed those available as defined within the Authorities Heavy Maintenance Manual Section 15.

A maintainability analysis for all systems on the car shall be submitted to the Authority. ***(CDRL 510)*** 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 (for example, 10,000 miles, semiannually and annually), the task frequency, the time required, skill levels and the necessary support equipment. The maintenance intervals shown in the maintainability analysis shall match those actually used by WMATA for their existing maintenance schedule. 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.

5.2.9.2 Accessibility

All subsystems and components serviced as part of periodic preventive maintenance shall be readily accessible for service and inspection.

Components requiring more frequent maintenance, repair or replacement shall be readily accessible without the need for special to type tools or equipment. 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 (such as topping off of fluids or adjusting of parts) be provided more frequently than at 10,000 mile intervals, except where permission has been given by the Authority for a shorter interval. However, the service manuals should include provisions for inspections on a more frequent basis, including daily, 30-day and 60-day inspections as needed.

5.2.9.3 Consumables

A minimum number of different lubricants or consumables shall be required for the car. Different styles or sizes of fittings shall be used to prevent the inadvertent introduction of the wrong substance at any point. Where possible, consumables for equipment furnished under this Contract shall be the same as those used for equipment on the existing cars.

5.2.9.4 Connectors/Fittings

The design shall incorporate such fittings and connectors with adequate keying to ensure that inadvertent misconnection of adjacent items is prevented.

5.2.9.5 Mean Time To Repair

The Contractor shall identify the mean time to repair (MTTR) for each major component, subsystem and system as defined by the Authority.

The MTTR is the mean time to detect, isolate, repair or replace and retest following a failure. The MTTR excludes logistic delays due to unavailability of spares or travel time for maintenance personnel. The MTTR provides an indication of the ease of maintenance inherent in the design of the systems.

The MTTR values, once approved by the Authority, shall be monitored during the early project phases and reliability test phase. The FRACAS process implemented by the Contractor shall include sufficient maintainability information to allow the Authority to judge the Contractors compliance with the agreed MTTR objectives.

Where the Contractor fails to achieve the MTTR objectives the Authority may demand such corrective action as necessary to achieve compliance. The Authority will consider the ease of maintenance of the overall vehicle and the time required for each planned maintenance period to determine the extent of any corrective action required. In cases where the MTTR puts at risk the ability of the Authority to operate under its existing maintenance policies corrective action by the Contractor will be required.

5.2.9.6 Maintainability Monitoring and Reporting

The Maintainability Monitoring shall be performed within the Reliability Monitoring System implemented by the Contractor. The results of the maintainability monitoring shall be reported within the monthly Reliability Test Report (CDRL 509).

5.3 SOFTWARE REQUIREMENTS

The Authority demands the highest levels of assurance for software implemented within the Vehicles and support equipment supplied under this contract. To that end the Authority requires that the Contractor implements a structured process to ensure that all software associated with the contract is suitable and sufficient for the intended purpose.

The Contractor should follow the practices recommended by the Software Capability Maturity Model and IEEE for the complete lifecycle of the project software. The Contractor shall submit a detailed report on its procedures and practices for software development and testing, and describe the extent to which those practices comply with CMM and IEEE standards.

5.4 SAFETY REQUIREMENTS

5.4.1 General

The Contractor shall comply with the Department of Labor's Occupational Safety and Health (OSHA) standards.

5.4.2 System Safety Program Plan

The Contractor shall develop a System Safety Program Plan (SSPP) that defines activities, management controls and monitoring processes to be used by the Contractor to ensure that safety considerations, compatible with other system requirements, are incorporated into the design of the vehicle. ***(CDRL 511)***

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-882, 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. A list of 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 system safety tasks.

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

E. A 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. A description of the hazard identification and elimination/control process described herein.

5.4.3 System Safety/Hazard Resolution Process

System safety contributes to mishap prevention by minimizing system risks due to hazards within the constraints of cost, schedule, design requirements, and system effectiveness. A hazard is defined as "any real or potential condition that can cause injury, illness, or death to personnel; damage to or loss of a system, equipment, or property; or damage to the environment". The fundamental objective of system safety is to identify, eliminate or control, and document system hazards throughout the system life cycle. Consideration must be given to systems and system interfaces and interrelationships with such factors as facilities, support equipment, operational procedures and environments, and maintenance programs.

System safety is based on the approach of studying the entire system under all possible operating conditions to identify potential hazards. The goal of system safety is to optimize safety by eliminating or controlling identified hazards, and managing the residual risks. Because safety is "the freedom from personnel injury, damage to equipment, or loss of resources (especially critical resources)," there are numerous system components that must be considered. The total system is a composite, of personnel, procedures, materials, tools, equipment, facilities, and software.

The objectives of the system safety program are to ensure:

A. Safety, consistent with system operating requirements is designed into the system in a timely, cost-effective manner.

B. Hazards are identified, evaluated, and eliminated, or the associated risk reduced to a level acceptable to WMATA throughout the entire life cycle of a system.

C. Historical safety data, including lessons learned from other systems, are considered and used.

D. Minimum risk is sought in accepting and using new designs, materials, and production and test techniques.

E. Actions taken to eliminate hazards or reduce risk to a level acceptable to the MA are documented.

F. Retrofit actions are minimized.

G. Changes in design, configuration, or mission requirements are accomplished in a manner that maintains a risk level acceptable to WMATA.

H. Consideration is given to safety and ease of disposal of any hazardous materials associated with the system.

J. Hazards identified after production are minimized consistent with program restraints.

The system safety process is a systematic approach to safety program management, consisting of:

A. Defining the physical and functional characteristics of the system

B. Identifying and Documenting Identified Hazards

C. Assessing identified hazards to determine severity and probability

D. Resolving hazards by implementing corrective action or accepting the risk

E. Following up to monitor for effectiveness of the hazard resolution effort and to monitor for unexpected results.

The above will be accomplished by applying the following hazard management and hazard analysis methodologies.

5.4.4 Preliminary Hazard List

The purpose of the Preliminary Hazard List (PHL) is to identify and list hazards or areas of concern related to people, procedures, equipment or facilities. The PHL is the initial document for the safety effort. The following hazard identification methods are typically used to identify the energy sources, hazardous operations, procedures, and potential accidents that may result in injury to personnel or damage to equipment or facilities.

A. Reviewing the specification and design information
B. Interviewing WMATA personnel;
C. Drawing on expertise in the specific areas (such as propulsion, brakes, ATC, etc.);
D. Reviewing lessons learned;
E. Analyzing similar vehicles or facilities;
F. Analyzing available technical data;
G. Reviewing energy sources;
H. Reviewing requirements documents; and
I. Reviewing the Project Management Plan.

Alone, any of these methods will identify some hazards, but a logical completion of all or a combination of these steps will result in the development of a more thorough PHL. Once the PHL is completed it is used to help determine what hazards exist in the system or facility. The PHL also provides input for the Preliminary Hazard Analysis (PHA). The PHL can be prepared in any logical format that allows the free flow of ideas.

5.4.5 Preliminary Hazards Analysis/Hazard Log

The Preliminary Hazard Analysis (PHA) is built upon the Preliminary Hazard List; however, this analysis is more detailed. This documentation provides useful safety input for the decision making process used in trade-off studies, design criteria, and operational goals. The PHA is a systematic method to identify, evaluate and document identified hazards and recommendations. The analysis includes an assessment of the systems and subsystems, operations, processes, equipment, personnel, environment, and materials. This document shall also serve as a Hazard Log to track identified hazards and recommendations to eliminate / control hazards. The term "Preliminary" relates to the stage when the PHA is produced within the project. However, this analysis remains a tracking tool throughout the life cycle of the system.

The PHA is prepared to identify, evaluate, and make recommendations for the elimination, control, or acceptance of hazards that could potentially cause:

A. Loss of life and/or serious injury to personnel;

B. Serious damage to facilities and/or equipment resulting in large dollar loss;

C. Failures with serious adverse impact on mission capability, mission operability, or public opinion; or

D. Detrimental harm to the environment and the surrounding community.

The Contractor shall prepare a PHA prior to reaching the 30% design level and shall submit the PHA to the Authority for approval. ***(CDRL 512)*** The Contractor shall perform a PHA on the entire vehicle, and shall ensure that hazards associated with the following subsystems are included in the PHA: ATC, Propulsion, Brakes, Auxiliary Electric, Communications, Doors, Trucks and Suspension, Coupler and Draft Gear.

The following hazards shall be included in the PHA:

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.

A006 K. ATP Faults

Note: The above hazards all have the potential to generate Catastrophic events, and must comply with
A006 the highest mitigation (Risk Index 1) as defined in Section 5.4.7.2 and Exhibit 5-5.

All identified hazards shall be documented in a Hazard Log. This Hazard Log shall initially be populated with the hazards identified during the Preliminary Hazard Analysis. The Hazard Log shall be used to track hazards throughout the acquisition process.

The potential hazards identified in the PHA are to be organized by functional area and shall be entered in a Hazard Log. They are to be subdivided into different areas of concern, types of hazards, and/or design disciplines. The following is an explanation of the various entries in Exhibit 5-2, Preliminary Hazard Analysis Data Sheet.

A. <u>Heading</u> - The heading on each PHA data sheet identifies the particular analysis. The "Project" for all data sheets should identify the name of the vehicle project. The "Date" indicates the most recent version of each data sheet. The "System/Subsystem" will indicate the aspect of the system covered by the PHA data sheet.

B. <u>Control Number</u> - The first column of the data sheet provides the "Control Number" for that particular hazard. The control number is related to the System/Subsystem provided in the heading, and to the corresponding number found in the PHA Data Sheet Organization on Exhibit 5-2.

C. <u>Hazard Description</u> - The second column, "Hazard Description," identifies the source that generates the hazard. This entry may also indicate the immediate cause for concern, such as a fire/explosion or toxic fumes buildup.

D. <u>Causes</u> - The third column, "Causes," describes those items that create or significantly contribute to the existence of the hazard. This entry will usually include the major causes of the hazard, including items or conditions that increase the severity of the hazard.

E. <u>Effects</u> - The fourth column, "Effects," describes the potential detrimental effects of the hazard, and analyzes the flow of energy between the source and the object that is to be protected. The data provided in this entry are used in assigning a severity to the hazard.

F. <u>Initial S-P</u> - The fifth column contains the initial Severity and Probability, "S-P 1," assigned to the hazard, based on Exhibits 5-4 and 5-5. The Severity and Probability recorded here relate to the hazard prior to any mitigation measures being implemented.

G. <u>Initial HRI</u> - The sixth column translates the "S-P 1" into an HRI of 1, 2, 3, or 4, as explained in Section 5.4.7.2 and Exhibit 5-5. This first Hazard Risk Index (HRI-1) is assigned based on A006 the severity and probability from S-P 1 with the assumption that no action has been taken to protect against the hazard. The HRI is used to assist management in deciding the best course of action for resolving the hazard.

H. <u>Recommendations</u> - The seventh column, "Recommendations," provides recommendations, including design revisions or safety measures, to eliminate or control the hazard. If applicable, cite the required codes, standards, guidelines, and good industry practices upon which the recommendation was made (e.g., NFPA, OSHA 1910, UBC, UFC, etc.).

J. <u>Final S-P and HRI</u> - The eighth and ninth columns reflect the revised or residual Severity and Probability, "S-P 2," and Hazard Risk Index, "HRI-2," after the recommendation has been addressed and the identified action has been taken to eliminate or control the hazard. It should be noted that for the S-P 2 the potential severity of the hazard is unlikely to be able to be decreased by design modifications or addition of safety measures; however, the probability of hazard occurrence can be greatly reduced, and thus, the Hazard Risk Index can be decreased.

K. <u>Responsible -</u> The tenth column, "Responsible", indicates the organizational element responsible for the identified hazard. This is used to track the implementation of the hazard and its corrective action to eliminate or control the hazard to an acceptable level.

L. <u>Status</u> - The eleventh column, "Status," lists whether the hazard is "OPEN,""CLOSED," or “ACCEPTED RISK” and to which phase of the vehicle life cycle the hazard applies (Concept, Design, Installation, Integration and Test, Operations and Maintenance, or Disposal). The eleventh column includes an explanation of how and/or why the hazard is open or closed. The column also lists appropriate references and correspondence if applicable. In order for a hazard to be closed, appropriate written documentation with verification is required.

Exhibit 5-2
Hazard Analysis Data Sheet

<table>
<tr><th colspan="12">Preliminary Hazard Analysis</th></tr>
<tr><td colspan="2">Project:
Hazard Category:
Prepared by:</td><td colspan="8"></td><td colspan="2">Date:
Page:</td></tr>
<tr><th rowspan="2">Control Number</th><th rowspan="2">Hazard Description</th><th rowspan="2">Causes</th><th rowspan="2">Effects</th><th colspan="2">Initial</th><th rowspan="2">Recommendations</th><th colspan="2">Final</th><th rowspan="2">Responsible WMATA Organization</th><th rowspan="2">Status</th></tr>
<tr><th>S-P</th><th>HRI</th><th>S-P</th><th>HRI</th></tr>
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5.4.6 Follow-Up Analyses

The process of hazard management is based on reducing the overall risk associated with the vehicle and its operations. To achieve this the Contractor shall develop further analyses of the hazards to ensure that high severity and/or high risk items are adequately understood and can therefore be appropriately mitigated.

The Contractor shall perform Failure Modes and Effects Analysis (FMEA) on all Catastrophic and Critical hazards, plus all items which result in Hazard Risk Index 1 or 2. Where FMEA is not considered the appropriate analysis method, the Contractor shall provide the Authority with justification for use of an alternative approach. The Contractor shall obtain Authority approval for the alternative approach prior to commencing alternative analyses.

The Contractor shall also perform an Operating and Support Hazard Analysis (O&SHA) for the complete vehicle and operating procedures.

Where appropriate the Contractor may make use of alternative analysis methodologies to support the minimum specification requirements. Alternative approaches include Fault Tree Analysis (FTA), Interface Hazard Analysis Event Tree Analysis (Consequence Analysis). For guidance, the analysis methodologies for FEMA, O&SHA and FTA are described in the following sections.

5.4.6.1 Failure Modes and Effects Analyses

A Failure Modes and Effects Analysis (FMEA) is an analysis tool that identifies the ways a particular component can fail and what its effects are on the system. The Contractor shall review all subsystem hazards found by the PHA to have a Hazard Risk Index of 1 or 2, and shall conduct a FMEA of those hazards. The results of the FMEA shall be submitted to the Authority for approval. ***(CDRL 513)*** Information provided in the FMEA shall include:

A. A system overview including schematics.

B. A complete list of system and subsystem components that will be analyzed.

C. Identification of the "modes" or ways the components can fail.

D. Assessment of the effects of the failure on the system.

E. Determination of the severity and probability of the failure.

F. Determination whether the failure is a single-point failure

G. Determination of methods to eliminate or control the identified failure

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

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 initially consider high-level functions, and will be iteratively expanded and revised as the design progresses. As it is being developed, the FMEA systematically challenges the design by

A006 probing the ways the system can fail and assessing the effects of these failures. The FMEA will normally be required to be expanded down to the lowest level component of the system or subsystem under consideration. However this will be dependent on the hazards associated with the items being analyzed. 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. In addition to consideration of the effect of single failures on the safety of the system the FMEA can be used to consider Reliability effects. It is recommended that the FMEA produced be reviewed for reliability implications so the Contractor can obtain maximum benefit from a single analysis.

5.4.6.2 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 "functions" 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.

The Contractor shall include in the O&SHA all operating and maintenance procedures for vehicle subsystems found by the PHA to have a Hazard Risk Index of 1 or 2 shall be reviewed and addressed by the O&SHA. ***(CDRL 514)*** Analyses should be performed as early in the design process as possible so that results can have a meaningful impact on final designs.

5.4.6.3 Fault Tree Analyses

A Fault Tree Analysis (FTA) is a graphical method commonly used in both reliability engineering and system safety engineering. It is a deductive qualitative or quantitative analysis tool. Once a "top level" event is identified, then the system is systematically analyzed listing the various sequential and parallel events or combination of faults that must occur for the top event to occur.

After review of the PHA, WMATA will identify hazards requiring further analysis. The Contractor shall analyze these hazards using a Fault Tree unless, as determined by WMATA, another hazard resolution or control methodology is more appropriate. The results of the analysis shall be submitted to the Authority for approval. ***(CDRL 515)*** FTA provides analysis of the results of multiple failures, thus it is appropriate for use on systems with redundancy or where multiple failures are required (such as brake systems and door systems). The FTAs must consider all interfacing items, which in conjunction with the analyzed system, can lead to the occurrence of the identified hazard.

5.4.7 Hazard Assessment

Identified hazards must be assessed to determine severity and probability, and to recommend means for their elimination or control.

5.4.7.1 Hazard Severity and Probability

5.4.7.1.1 Hazard Severity

Hazards do not necessarily result in mishaps. But if a hazard does occur, it creates mishaps of certain severity. Mishap severity categories to be applied to all identified hazards are shown in Exhibit 5-3. Example Mishap Severity Categories are defined to provide a

Exhibit 5-3
Mishap Severity Categories

Description	Category	Mishap definition
CATASTROPHIC	I	Equipment failures, human errors, and/or external circumstances that result in any 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.
CRITICAL	II	Equipment failures, human errors, and/or external circumstances that would result in serious injury to passengers, public or staff, 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.
MARGINAL	III	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, minor injury, danger or discomfort to the traveling public, a reduction in safety margins or functional capabilities, non-disabling damage to the Authority' equipment, a significant increase in operator workload or in conditions impairing operator efficiency.
NEGLIGIBLE	IV	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.

qualitative measure of the worst credible mishap resulting from personnel error, environmental conditions; design inadequacies; procedural deficiencies; or system, subsystem, or component failure or malfunction.

5.4.7.1.2 Hazard Probability

The probability that a hazard will be created during the planned life expectancy of the system can be described in potential occurrences per unit of time, events, population, items, or activity. Probability levels are generally qualitative but can be quantitative. The probability for all identified hazards shall be in accordance with the guidelines presented in Exhibit 5-4.

Exhibit 5-4
Hazard Probability Levels

Description	**Level**	**Specific Individual Item**	**Fleet or Inventory**
FREQUENT	A	Likely to occur frequently	Continuously experienced
PERIODIC	B	Will occur several times in life of an item	Will occur frequently
OCCASIONAL	C	Likely to occur sometime in life of an item	Will occur several times
REMOTE	D	Unlikely, but possible to occur in life of an item ($5.0 \times 10^{-7} \geq X < 1.0 \times 10^{-9}$)	Unlikely, but can be reasonably be expected to occur
IMPROBABLE	E	So unlikely it can be assumed occurrences may not be experienced ($1.0 \times 10^{-9} \geq X$)	Unlikely to occur, but possible

A003

5.4.7.2 Hazard Risk Index

The Hazard Risk Index Matrix is a number derived by considering both the severity and the probability of a hazard. The HRI shall be used to prioritize resources to resolve risks due to hazards and to standardize hazard notification or response actions. The Hazard Risk Index (HRI) values are shown in Exhibit 5-5. The HRI presents hazard analysis data in a format that helps provide clear concise information to enable decisions regarding whether hazards should be eliminated, controlled, or accepted. This process provides the basis for logical management decision-making, considering both the severity and probability of a hazard.

5.4.8 Hazard Resolution Process

The overall goal of a system safety program is to design systems that do not contain hazards. However, the nature of most complex systems makes it impossible or impractical to design them completely hazard-free. As hazard analyses are performed, hazards will be identified that will require resolution. Risk management is a decision-making process consisting of evaluation and control of the severity and probability of a potentially hazardous event.

By assigning a HRI, a determination can be made as to whether hazards should be eliminated, controlled, or accepted. System safety precedence is a methodology that can be used by the Program Manager to define the order to be followed for satisfying system safety requirements and reducing risks. The

Exhibit 5-5
Hazard Risk Index Matrix

Frequency of Occurrence	Hazard Categories			
	I Catastrophic	II Critical	III Marginal	IV Negligible
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C
D - Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

Hazard Risk Index	HRI	Suggested Criteria
1A, 1B, 1C, 2A, 2B, 3A	1	Unacceptable – Develop new hazard controls to lower the HRI to a category 2, 3, or 4. A003
1D, 2C, 2D, 3B, 3C	2	Undesirable – Shall only be accepted if proven to the Authority that no reasonable alternatives can be implemented. Shall require additional safety or warning devices and procedural controls to be implemented. Shall be shown to be less than 5.0 x 10^{-7} per car hour of operation.
1E, 2E, 3D, 3E, 4A, 4B	3	Shall be resolved using standard fail-safe engineering practices. May be acceptable with review by WMATA.
4C, 4D, 4E	4	Should be eliminated or controlled. May be acceptable without review.

alternatives for eliminating the specific hazard or controlling its associated risk will have to be evaluated so that an acceptable method for risk reduction can be pursued.

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:

Hazards with an initial Hazard Risk Index of 1 or 2 should be mitigated such that the Hazard Risk Index is reduced to HRI 3 or 4. Where it is not possible to reduce the risk to Level 3 or 4, specific detailed analysis shall be provided by the Contractor to obtain approval of the Authority. It should be noted that the Authority would normally expect the Contractor to introduce design changes to reduce the risk to an acceptable level. Items with an HRI of 1 shall not be accepted. Items with an HRI of 2 will only be accepted when it is proven to the satisfaction of the Authority that the Contractor has exhausted all reasonable alternative approaches

5.4.8.1 Hazard Reduction Precedence

The order of precedence for satisfying system safety requirements and resolving identified hazards is:

A. Design for Minimum Risk. Design to eliminate hazards. If an identified hazard cannot be eliminated, reduce the associated risk to an acceptable level, as defined by WMATA, through design selection. Defining minimum risk is not a simple matter. It is not a cookbook process that can be numerically developed without considerable thought. Minimum risk will vary from program to program.

B. Incorporate Safety Devices. If identified hazards cannot be eliminated or their associated risk adequately reduced through design selection, that risk shall be reduced to a level acceptable to WMATA through the use of fixed, automatic, or other protective safety design features or devices. Provisions shall be made for periodic functional checks of safety devices when applicable.

C. Provide Warning Devices. When neither design nor safety devices can effectively eliminate identified hazards or adequately reduce associated risk, device shall be used to detect the condition and to produce an adequate warning signal to alert personnel of the hazard. Warning signals and their application shall be designed to minimize the probability of incorrect personnel reaction to the signals and shall be standardized within like types of systems.

D. Develop Procedures and Training. Where it is impractical to eliminate hazards through design selection or adequately reduce the associated risk with safety and warning devices, procedures and training shall be used. However, without a specific waiver, no warning, caution, or other form of written advisory shall be used as the only risk reduction method for a hazard with a Hazard Risk Index of 1 or 2. Procedures may include the use of personal protective equipment.

It is an obvious interaction of both engineering and management considerations to bring about an optimal resolution of risk. Final resolution rests in the decision made by the managing activity.

Realistically, some risks must be accepted. How much is accepted, or not accepted, is the prerogative of management. That decision is affected by many inputs including additional analyses that may be required for hazards with a Hazard Risk Index of 1 or 2. As tradeoffs are being considered and the design progresses, it may become evident that some of the safety parameters are forcing higher program risk.

5.4.8.2 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. No single point failure shall result in a hazard with a Hazard Risk Index of 1 or 2. Multiple, latent, undetected failure modes shall be considered as a single point failure.

B. Vehicle design shall include component interlocks wherever an out-of-sequence operation can result in a hazard with a Hazard Risk Index of 1 or 2.

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

5.4.9 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.

All designs, material and equipment associated directly with speed control and the control of train movement shall be fail-to-safe (vital) standards whereby any single fault, breakage or disconnection shall result in a more restrictive condition being applied. The fault, breakage or disconnection shall be capable of being detected and rectified with such speed that there is a very low probability of a second fault occurring which, in combination with the first, may lead to a dangerous situation.

Whenever possible, all systems are to be designed to prevent single point failures from negating the ability of such systems to perform safely as intended.

Access control and alarm systems shall be designed to minimize the potential for unauthorized or inadvertent changes to equipment.

The use of microprocessors in vital circuits shall be as approved by the Authority on a case-by-case basis. A006

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.

All equipment, circuits, material and designs shall be so designed that faults or malfunctions are self-revealing, if not in the course of normal operation then by special means. For processor based equipment used for vital purposes, the probability of an unsafe failure of that equipment shall, as a minimum, be less than that of non-processor based vital equipment that it replaces.

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 or 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 that 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 18.2.

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.

5.4.10 Design Safety for Human Engineering

In considering system hazards during the design process, the Contractor shall take actions to satisfy the system requirements while taking account of human limitations as a design constraint The following order of precedence shall be followed:

A. Incorporation of fail-safe or vital features which will cause the system to transfer from high loss or risk mode to a lower loss or risk mode upon the occurrence of a critical failure.

B. Reduction of the probability of occurrence of a failure by increased component reliability, or by provision of redundant components.

C. Use of safety devices to reduce the magnitude of the loss or risk once a hazardous mode has been entered while ensuring that the safety device does not introduce an additional hazard or system malfunction.

D. Use of warning devices and systems which are an audio/visual portion of a vital system in which the human is the responder.

E. Implement special operating procedures to reduce the probability of a hazardous event, including the provision of any training requirements. (The level of training shall be based on the complexity of the task and the anticipated trainee qualifications.)

5.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 501	Quality Assurance Program Plan	
CDRL 502	Inspection and Test Plan	
CDRL 503	Quality Assurance Manuals	
CDRL 504	Sample Quality Assurance Reports	
CDRL 505	Statistical Quality Control Inspection List	
CDRL 506	FAI Packages	
CDRL 507	Audit Checklists and Reports	
CDRL 508	Reliability Assessment Response Report	
CDRL 509	Reliability Test Report	
CDRL 510	Maintainability Analysis	
CDRL 511	System Safety Program Plan	
CDRL 512	Preliminary Hazard Analysis	
CDRL 513	Failure Mode and Effects Analysis	
CDRL 514	Operating and Support Hazard Analysis	
CDRL 515	Failure Tree Analysis	
CDRL 516	Weight Control Report	
CDRL 517	Design and Development Review Report	
CDRL 518	Design Verification and Validation Report	A009
CDRL 519	Preliminary Systems Reliability Assessment	

5.6 REFERENCED STANDARDS

The following standards are referenced in this section:

AAR	Manual of Standards and Recommended Practices, Part 55
ASQC Z1.4	Sampling Procedures and Tables for Inspection by Attributes
ANSI/ASQC Z1.9	Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming

MIL-STD 105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD 882	System Safety Program Plan Requirements
MIL-STD 2155	Failure Reporting Analysis and Corrective Action
WMATA	Heavy Repair Manual, Chapter 15

SECTION 6
SYSTEMS SUPPORT

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SECTION 6
SYSTEMS SUPPORT

6.1 SPARE PARTS

See Contract Special Provisions.

6.2 DIES AND PATTERNS

The Contractor shall not destroy or otherwise dispose of dies, patterns, or molds used in the construction of the cars without first offering the Authority the opportunity to acquire them.

6.3 WARRANTY

6.3.1 General

Warranty provisions shall be in accordance with the Special Provisions. A warranty plan shall be submitted for review and approval. The plan shall identify the proposed approach to providing warranty support, addressing such issues as personnel, locations, response time, warranty spares, etc. ***(CDRL 601)***

6.3.2 Subcontracts

The Contractor shall obtain from each subcontractor providing any item of major equipment the same agreement with regard to warranty that the Contractor is required to extend to the Authority. ("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.) In addition, the Contractor shall obtain from each of those subcontractors, written certification that the method used for installation and connection of that subcontractor's equipment by the Contractor is satisfactory to the subcontractor.

6.4 REFERENCED CDRLs

CDRL 601 Warranty Plan

6.5 REFERENCED STANDARDS

No standards are referenced in this section.

SECTION 7
GENERAL PERFORMANCE REQUIREMENTS

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SECTION 7
GENERAL PERFORMANCE REQUIREMENTS

7.1 DIMENSIONS, WEIGHTS, AND MISCELLANEOUS DESIGN PARAMETERS

7.1.1 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)*
Rail gap	58-60 feet
Maximum height of top of roof	10 feet, 10 inches
Minimum vertical clearance inside car at center	6 feet, 9 inches
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	28 inches A003
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 8.3.17 and 17.2.11.

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.

7.1.2 Design Considerations

The carbody, trucks, and attached equipment shall be designed so that the maximum possible dynamic outline shown in Contract Drawing 97936-017, will not be exceeded under the most extreme combinations of broken and deflated springs, lateral and vertical motion, and roll permitted by the suspension system. 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 17, 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.

7.2 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 air conditioning system, specified in Section 12, shall be met at 700 VDC. Propulsion system performance standards in acceleration and deceleration, as defined in Section 15, 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.

7.3 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 the "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 3.4.1.

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 2% of the ready-to-run weight, measured at the trucks.

7.4 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	A005
B.	Maximum Design Temperature Above Running Rail	115° F	
C.	Relative Humidity:	20% to 100%, including conditions of condensation	
D.	Maximum Rainfall:	12 inches in 24 hours	
E.	Snow Accumulation Above Running Rail:	15 inches	
F.	Maximum Snowfall:	23 inches in 24 hours	
G.	Maximum Wind Speed:	80 mph (operational), 120 mph (storage)	
H.	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.

7.5 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 21.3), 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; however, devices to enable local adjustment 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.

7.6 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY

7.6.1 General

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

7.6.2 Control and Test Plans

A002 The Contractor shall submit electromagnetic compatibility (EMC) and electromagnetic interference (EMI) control and test plans to the Authority. The EMI/EMC control and test plan shall include a description of all criteria that must be met, including those specified for Conducted Interference (Section 7.6.5) and Inductive Interference (Section 7.6.6). Criteria shall be submitted to the Authority for review and approval ***(CDRL 701)***. Control of EMC and EMI shall be part of the earliest stage of apparatus design. 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 EMC qualification tests described in Section 7.6.4.

7.6.3 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 plans:

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.

7.6.4 Emission Limits

To preclude undesirable effects caused by onboard vehicle subsystems upon the external environment along the right of way, in no case shall the electromagnetic emission limits specified herein be exceeded. In addition, the Contractor shall review each vehicle's ("A" and "B" car) impedance to determine that the following desirable characteristics are met:

A. At 60 Hz, the input impedance shall not be capacitive in nature

B. The input impedance resonant frequency shall be below 50 Hz.

Meeting the requirements specified in the following subparagraphs 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-specified limits, if necessary, to prevent interference.

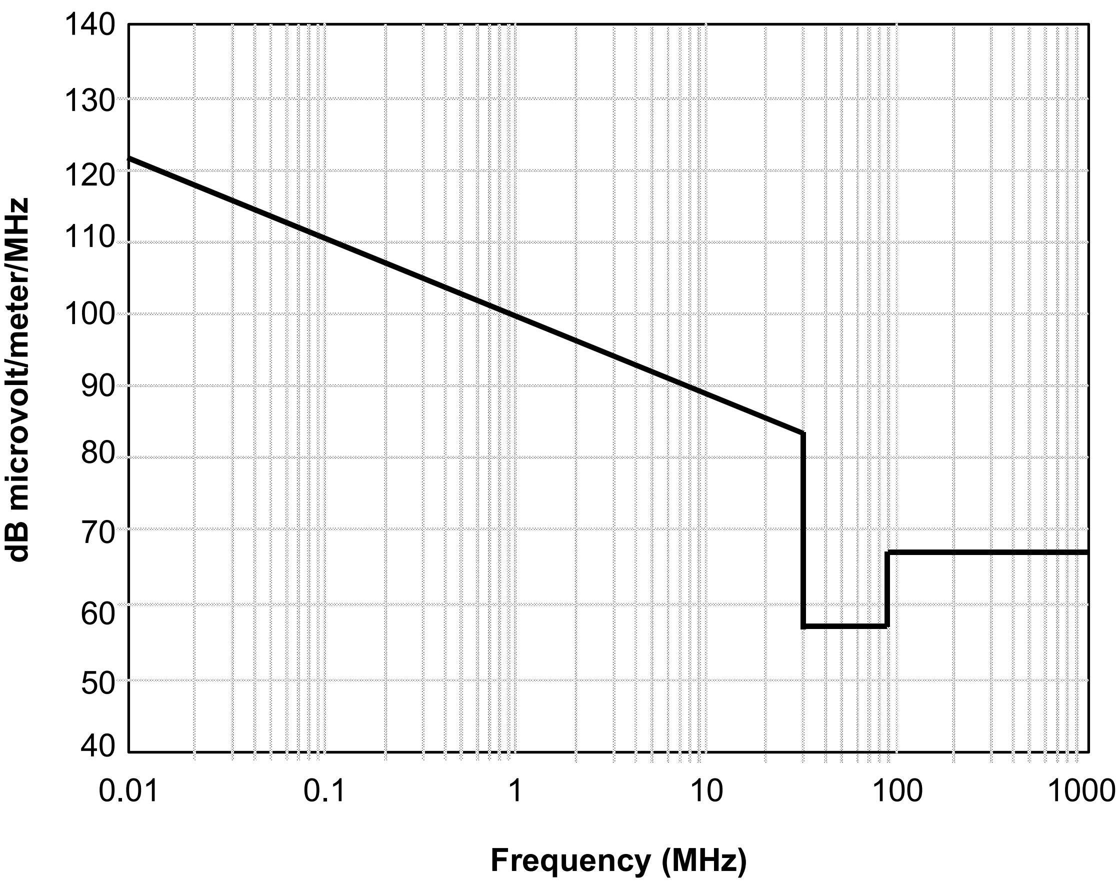
7.6.4.1 Radiated Emissions

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 7-1.

7.6.4.2 Conductive Emissions

The conductive emissions in the third rail shall have a maximum current limit (amperes RMS) of 1.1A between the frequencies of 55 Hz and 65 Hz. For all frequencies between 2000 Hz and 4000 Hz, the conductive emissions in the third rail shall have a maximum current limit (amperes RMS) defined by a straight line from 0.100 ampere at 2000 Hz to 0.050 ampere at 4000 Hz. For all frequencies between 4000 Hz and 6000 Hz, the conductive emissions in the third rail shall have a maximum current limit (amperes RMS) of 0.045 ampere. For all frequencies between 6000 Hz and 20,000 Hz, the conductive emissions in the third rail shall have a maximum current limit (amperes RMS) of 0.020 ampere. These third rail current limits shall not be exceeded by a train of any length up to 8 vehicles assuming 78% of the emission level produced when all equipment of like type on the train is producing in-phase emissions of the same frequency. This condition shall be met by each individual power component as well by as the simultaneous operation of all car apparatus on the train. To verify compliance with the third rail conductive emission limits, single inverter measurements shall be made on one car of a married pair, as measured by the procedures of "Conductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures," UMTA-MA-06-0153-85-6. The results of the single inverter measurements will used to calculate the emissions for a train of any length up to 8 vehicles.

Exhibit 7-1
Radiated Emission Limits



7.6.4.3 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 during the simultaneous operation of all car apparatus.

7.6.5 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.

7.6.6 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.

7.6.7 Cab Signal Interference

The Contractor shall minimize the amount of EMI that couples into the cab signal receiver coils and cables 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 the level that 45 mA (RMS) in the third rail produces for a train of any length up to 8 vehicles.

7.7 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
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.

7.8 REFERENCED CDRLs

The following CDRL items are referenced in this section :

CDRL 701	EMC/EMI Control and Test Plans

7.9 REFERENCED STANDARDS

The following standards are referenced in this section:

MIL-STD-461A	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
UMTA-MA-06-0153-85-6	Conductive Interference in Rapid Transit Signaling Systems, Vol. II, Suggested Test Procedures
UMTA-MA-06-0153-85-8	Inductive Interference in Rapid Transit Signaling Systems, Vol. II, Suggested Test Procedures.

SECTION 8
CARBODY

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SECTION 8
CARBODY

8.1 GENERAL

8.1.1 Arrangement

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 semi-permanently 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.

Apparatus requiring inspection or attention more often than once a year shall be accessible and replaceable without requiring the 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 60 days shall be accessible from the side of the car. The frequency of required service shall determine the degree of equipment accessibility. A008

8.1.2 Physical Protection

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 shall be located or guarded to prevent accidental contact. Doors and cover plates guarding said apparatus shall be securely fastened in place, and the inside and outside of the doors shall be 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.

8.2 CARBODY STRUCTURE/MATERIALS

8.2.1 General

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

8.2.2 Materials

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

A007 If the carbody is constructed of aluminum alloy, structural members shall be made of alloy 6061-T6, 5083-H111, 6082, 6005A, 6008, 6106 T6, 5454 H24 and 5754 H26. In order to minimize welding and HAZ (heat affected zone), the use of end-to-end hollow extrusions is desired. The structural use of any 2000 series and 7000 series alloys, and of aluminum castings of any alloy, is expressly prohibited. APTA SS-C&S-015-99 Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction shall be observed.

A006 All surfaces of all aluminum portions of the carbody, except exterior surfaces, shall be properly cleaned and given one coat of chromate-free two-part epoxy primer, or an Authority-approved equivalent primer. An alternative primer may be used providing that the Contractor provides data on all of the characteristics of the material; the material is shown to be equivalent to or better than the specified zinc chromate prime; and the alternative is approved by the Authority. Use of stainless steel and aluminum shall comply with all requirements of Sections 22.3 and 22.6, respectively.

Regardless of the Contractor's selection of 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 8 will be considered, providing that 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.

8.2.3 Construction Methods

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 as the sole means of joining 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.

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

8.2.4 Exterior Finish

8.2.4.1 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 brushed finish similar to that on the Authority's existing cars. Trim pieces may, however, be brushed parallel to the long dimension of the piece. The grain size of the exterior finish shall be approved by the Authority. All brushed surfaces shall have the same finish, whether applied by machine or hand, or furnished by a subcontractor.

8.2.4.2 Painted

All exterior surfaces to be painted shall be prepared according to Section 22.23.

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 (see Section 1, CDRL 109).

8.3 CARBODY STRUCTURE/ARRANGEMENT AND DETAILS

8.3.1 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 40-year anticipated life of A006
the car when loaded to the specified "Full" loading condition (AW2). 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 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 existing 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.

The carbody including roof, sides and R-end shall be flat and free of nicks, dents, weld marks and other surface imperfections. Flatness shall be better than 1/8" over a 3-foot span.

8.3.2 Carbody

8.3.2.1 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 outboard 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 60,000 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 25,000 lbs. at the “F” end and 25,000 lbs. at the “R” end, with no stress exceeding the yield point.

H. The carbody natural frequency in the first vertical bending mode shall be no less than 8 times the natural frequency of the secondary suspension.

8.3.2.2 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 an 8-car train of 6000 Series vehicles moving at speed V (with brakes applied), on level tangent track, impacting a stationary 8-car train with brakes applied, with the stationary train consisting of either 6000 Series cars or the Authority's existing cars, in normal passenger service at 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. 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 plastic deformation of the car ends outboard of the body bolsters shall be in the range of 550,000 to 675,000 lbs. The force required to crush the ends A009
shall be steady 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. For design purposes the same wheel to rail friction coefficient of 0.2 shall be used for both trains.

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 5.0 g. The Head Injury Criteria shall be used to evaluate the mode and severity of predicted injuries. The Abbreviated Injury Scale per AIS code shall be less than 3.

The Contractor shall provide test data and validated mathematical model simulation to demonstrate that A002
the vehicle will satisfy these requirements ***(CDRL 803)***.

8.3.2.3 Structural Analysis

The Contractor shall perform a structural analysis of the car/vehicle body, underframe and equipment supports, and shall provide both a preliminary and a final stress analysis to the Authority for approval. ***(CDRL 801)*** The preliminary stress analysis must be approved by the Authority before the Contractor proceeds with the final structural carbody drawings and any procurement of material.

The final stress analysis shall include all secondary structure and/or attachments designed to withstand operational loading of 200 lbs or greater. For Service Loading condition the load factors shall be: 1.5 g vertical, 1.0 g longitudinal and 0.5 g lateral. The loads shall be applied concurrently (as a static load) and shall not develop a stress greater than of the yield stress of material. For Overloading the load factors shall be: 3.0 g vertical, 5.0 g longitudinal and 2.0 g lateral. The loads shall be applied individually (as a static load) and shall not develop a stress greater than the ultimate strength of the material. This shall be considered to be a one-time crash situation, where the structure shall not fail or tear free. With the exception of above defined load factors, the APTA SS-C&S-002-98 Standard for Static Strength Attachment of Major Equipment to the Car Body Structure of Railroad Passenger Equipment shall be observed.

The final analysis 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 safety margin shall be positive. The analysis shall consist of finite element analysis and a combination of manual and/or computerized calculations. At a minimum, finite element analysis shall be used for any complex structural element that, in a failed state, affects safety. The analysis shall include at least the following:

A. Structural arrangements and layouts of the car/vehicle. 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, load applications and boundary conditions, and their relation to the car/vehicle structures.

C. Documentation showing the properties of the materials used in the vehicle structure. At a minimum, this documentation shall include 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.

F. Natural frequency of the body in the first bending mode.

8.3.3 Underframe

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

If the carbody is constructed of aluminum, the underframe, shall be of aluminum. The end underframe shall be constructed of aluminum or low-alloy, high-tensile steel

8.3.4 End Underframe

An end underframe unit shall be used at each end of the car. This unit shall be designed to comply with the structural design requirements of Section 8.3.2. 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 or aluminum 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. When engaged with the anti-climber of one of the existing cars, this arrangement shall resist, using only three of the four "ribs," a vertical load of 75,000 lbs. 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. 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 applied through the full stroke of the crushable element. The anti-climbing arrangement shall have the appearance shown in Contract Drawings 97936-005 and 97936-006. The anti-climber shall be parallel with the end structure.

The top surface of the front end anti-climber shall contain holes suitable for anchoring the emergency ladder specified in Section 10.12. The holes provided must drain water outside in such a way as to prevent entry of water into floor panels or insulation and to prevent formation of ice.

8.3.5 Subfloor

A stainless steel subfloor of a minimum 0.030 inch thickness shall be provided over the full length of the car.

8.3.6 Side

A formation in the side sheathing shall run the full length of the car, below the windows, as shown in 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. Aluminum or stainless steel cosmetic trim shall be used around the doorway to obscure the welded areas. At the rear end of the car cosmetic trim may be used. All trim shall be bolted to the body structure, protected against dissimilar material corrosion when applicable, and sealed using approved sealant. Door trim shall not create any hazard for passenger clothes.

8.3.7 Skirt

A fixed non-rattling skirt shall be provided.

8.3.8 End Construction – Design Requirements

Car end structures shall be provided, at the sides of the end door openings, with vertical collision posts that comply with the structural requirements in Section 8.3.2.3.

Each collision post shall have a section modulus about the carbody transverse axis of at least 4.5 cu. in. 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. 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 8.3.2.1. Corner posts shall be connected to principal side frame longitudinal members.

8.3.9 Cab ("F") End

A002 The cab end shall be arranged and contoured as shown in Contract Drawing 97936-005. Details of the contours must be approved by the Authority prior to manufacture ***(CDRL 804)***. The end sheathing shall be of stainless steel, aluminum alloy, or fiberglass-reinforced polyester plastic. See Section 8.9 for information on windows and Section 13.2 for specifications on headlights, tail lights, and marker lights. No visible caulking shall be used in the connection of the end to the sides and roof. Fiberglass-reinforced plastic used in the end sheathing shall conform to the fire-resistance requirements of Section 22.24.

8.3.10 Non-Cab ("R") End

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

8.3.11 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.

8.3.12 Underfloor Boxes

Underfloor boxes shall be of painted or powder coated 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 22.24. 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 requirement does not apply to boxes and apparatus with a clearance of less than 16-7/8 inches above top of rail; these 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 used to secure doors on underfloor boxes and enclosures, including latches and hinges, shall be made of stainless steel. All mounting hardware for access plates shall have captive fasteners. All equipment enclosures shall provide 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's dynamic envelope if not engaged.

A spring-loaded safety catch shall be provided at the center of each equipment box cover. The safety catch shall be designed to retain the cover within the vehicle dynamic clearance envelope at all operating speeds without the cover latches engaged.

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

8.3.13 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. If the underframe is constructed of longitudinal hollow aluminum extrusions, longitudinal provisions in extrusions may be used for underframe apparatus attachment.

Unless otherwise approved, underfloor apparatus shall not be supported by bolts in tension. An exception to this rule is made in the case of extruded longitudinal equipment support provisions as described above and for resistance grids, which may be supported by bolts in tension if the connecting A009
leads are strong enough to hold the grids should the bolts fail. In this case, if bolts in tension are used, safety straps, hangers or other devices per APTA SS-C&S-002-98 shall be provided for each individual support. All installation guides and recommendations from the original equipment manufacturer shall be observed, and installation approved by the Authority before underfloor mock-up review.

Apparatus requiring removal and replacement for other than accident damage shall be supported so that both bolts and nuts are accessible. 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, as defined in Section 8.3.2.3.

All underfloor equipment shall be grounded to the carbody.

8.3.14. Gutters

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

8.3.15 Jacking Pads

Jacking pads shall be provided in eight locations on each car:

A. On each side of the car, 53 inches from the longitudinal centerline and 31-1/2 inches toward each end of the car from the transverse centerline of each body bolster (4 locations)

B. At each corner of the car, for re-railing purposes (4 locations). The corner jacking pads shall be compatible with the Authority's existing wheel truing machines and associated towing bracket.

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 interference or requiring the removal or hinging of any part of the skirt or F-end mask. Adequate clearance shall be provided around the jacking pads to permit use of the Authority’s standard shop jacks and towing adapters. 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 or corner jacking pad without causing permanent deformation of any structural member.

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, with the exception of end sill and corner jacks, without permanent deformation of the carbody or the jacking pads. All jacking pads and their supports shall have a strength in all directions in the horizontal plane of at least 20% of the vertical strength.

8.3.16 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 17.4.

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.

8.3.17 Floor Level

With the car leveled, the height of each of the four corners of the carbody shall not be in excess of 1/8-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 17.2.11, and primary spring deflection.

8.3.18 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.

8.4 OPERATOR'S CAB

8.4.1 General

The "F" end of each car shall be equipped with a full-width Operator's Cab, as shown in Contract Drawing 97936-001. When the cab is 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 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.

8.4.2 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 8.11.7
B. Fire Extinguisher – See Section 10.6
C. Windshield Wipers Control – See Section 10.7.1
D. Visor, moveable type – See Section 10.7.2
E. Cab Curtain – See Section 10.7.5
F. Emergency Ladder – See Section 10.12
G. Third Rail Shoe Paddles – See Section 10.13
H. Heater – See Section 12.2.5
I. Heated Windshield – See Section 12.2.6
J. Reading Light – See Section 13.1.5
K. Circuit Breaker Panel – See Section 14.6
L. Operator's Auxiliary Control and Indicator Panel – See Section 14.6.2
M. Operator's Control Console – See Section 14.6.2
N. Trainline Circuit Breaker Panel – See Section 15.6.6
O. Handbrake – See Section 16.4.11
P. Automatic Train Protection (ATP) Cut-Out Switch – See Section 18.2.4
Q. Radio Loudspeaker – See Section 19.5.1
R. Passenger Call Loudspeaker – See Section 19.5.1

8.5 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
Radio (“B” Car only)
Front Truck Brake Cylinder Cut-out
Front Brake Control Air Supply Cut-out

Left Rear Seatwell

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

Right Front Seatwell

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

Right Rear Seatwell

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

Seatwell-mounted equipment shall be protected from spillage of liquids by a polycarbonate or other approved shield (i.e., drip pan) incorporated into the bottom of the back-to-back seat. The appropriate drainage, approved by the Authority, shall be provided.

Insulation, with equivalent thermal and acoustic properties to that provided in the floor, shall be provided under and around the wells. See Section 8.12 for insulation requirements. 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 in the seat bases or wells. The foregoing is not intended to preclude the installation of heaters operating on 700-volt circuits under seats.

8.6 CEILING AND SIDE LINING – INTERIOR FINISH

8.6.1 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 22.24. Conformance with the flammability and smoke emission standards of Section 22.24 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 smooth
A007 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.

Ceiling panels shall be designed to be removable with the removal of no more than two (2) adjacent panels. A006

8.6.2 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.

8.6.3 Lighting Fixture Supports

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

8.6.4 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. Ceiling shall be adequately supported, flatness shall be better than 1/16 " over 3-foot span, and the panels shall not sag. If approved by the Authority, this area of the ceiling need not be curved as shown on the carbody cross-section, Contract Drawing 97936-002,.

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 fiberglass-reinforced polyester, or approved equal.

8.6.5 Low Ceiling

The low ceiling under the evaporator-blowers shall be formed of 3/8-inch thick, integrally colored melamine-faced aluminum with honeycomb core, or approved equal. It shall be composed of the A006
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 prevent injury to maintenance personnel.

8.6.6 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 outlets for warm air discharge as specified in Section 12.2.3. 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 the window glazing or mounting arrangement will not permit discharge outlet holes, the outlet holes shall be located in the wainscot panels.

8.6.7 Wainscot Panels

Side and end linings 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 cannot 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.

A002 Brushed aluminum trim shall be used to hold the panels in place. The trim pieces shall be fastened to the carbody with screws in a manner that allows the wainscot panels to be easily disassembled and replaced. The trim attachment design shall be the same as that of the 3000 series cars or an improved design subject to Authority approval.

8.6.8 Door Pockets

Door pockets shall be constructed, from the floor to the ceiling, of plymetal with a minimum thickness of 3/8-inch. The plymetal shall be melamine-faced on the side exposed to passengers and stainless or aluminum facing on the side not exposed to passengers. The melamine facing shall continue, without joints, to junctions with the window mask, the wainscot panel, and the windscreen. All door pockets shall be of sufficient strength/support to the main structure, to bear passenger load under the most extreme conditions.

Four of the twelve panels shall be designed to hold Authority system maps ("map" doors) and the remaining eight (seven on the "A" car) shall be designed to hold advertising cards ("ad doors"). "Ad"
A006 cards are not located at the #7 door pocket where the ATC rack is located on the "A" car.

The "ad" frames shall provide 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 frame by simple manipulation of the card.

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At Doors 2 and 11, the map frame shall hold a system map approximately 31-1/2 inches wide by 36-1/2 inches high. At Doors 3 and 10, the arrangement shall hold system map 31-1/2 inches wide and 33-1/2 inches high, and shall contain a notch to accommodate the passenger emergency door release handle specified in Section 11.3.3. 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.

The maps shall be protected by a sheet of clear polycarbonate and enclosed so that airborne dust and dirt are not blown between the polycarbonate sheet and the map. The enclosure shall provide for periodic removal and replacement of the maps

8.6.9 Windscreens

A windscreen shall be provided at entrance doorway numbers 1, 3, 4, 6, 7, 9, 10 and 12, as shown in Contract Drawings 97936-001 and 97936-004. The windscreen shall be glazed in its upper portion, and shall be of melamine-faced plymetal below, or approved equal. A vertical stanchion shall be provided at the aisle edge of the windscreen, as shown in Contract Drawing 97936-004. Glazing in windscreens shall be 1/4-inch laminated safety glass, and shall be easily replaceable. . The strength of the windscreens shall comply with APTA SS-C&S-006-98 Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment.

At the outboard edge of the windscreen, provision shall be made for the threshold lights described in Section 13.1.4. Threshold lights shall have polycarbonate lenses and stainless steel or aluminum bezels.

8.6.10 Partitions

Operating compartment partitions, except for glazed areas, shall be constructed of 1/2-inch thick plymetal, with integrally colored melamine facing on both surfaces. Other construction techniques will be considered for approval by the Authority. Cab partitions shall be as shown in Contract Drawing 97936-003. The strength of the partitions shall comply with APTA SS-C&S-006-98 Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment.

8.6.11 Equipment Cabinet

A cabinet to house the handbrake operator and the ATP cut-out 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 doors as necessary to provide 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 cut-out switch can be determined without opening any door. The doors shall have stainless steel piano hinges and locks operable by the door key.

8.6.12 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 802)***

8.6.13 Passageways

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

8.7 FLOOR

8.7.1 Construction A009

The floor panels shall be of phenolic composite sandwich design and construction. They shall be ¾ inch thick and comprised of upper and lower fiberglass fabric reinforced skins, impregnated with a phenolic thermosetting resin and affixed to a structurally reinforced, rigid, closed cell foam core material. The floor shall be able to carry a passenger service load of AW4, uniformly distributed, at a simply supported beam condition.

All exposed edges of the individual floor panels, including openings for ducts and conduits, etc. and joints between panels, shall have a dense composite edge, machined smooth and free of sharp edges and burrs. The floor materials shall be non-vermin supporting and shall not rot or corrode.

The floor panels shall be composed of pieces as large as possible and shall extend the full width of the vehicle. Transverse shiplap joints shall be located over structural members. There shall be no joints in the top or bottom face skins of the panels.

All panels shall be isolated from any metallic structure, including floor penetrations, and be mechanically fastened to tapping plates attached to elastomeric supports. It shall be possible to remove, replace, and/or repair individual panels without damage to surrounding floor panels or structure.

The chosen floor and mounting configuration shall not exhibit any undesirable mechanical resonance nor support other disagreeable noise generation.

All materials used in the construction of the floor panels shall be suitable for the intended service and comply with the smoke, flammability and toxicity requirements stated in this specification.

8.7.2 Floor Coverings

Wool carpeting, complying with the requirements of Section 22.9.2 shall be installed throughout the car except in the cab.

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Glue-down carpet shall not be allowed in any area of the car interior. A suitable attachment system, allowing easy replacement of carpeting without damage to the floor panels, shall be chosen and submitted for approval. The carpeting shall be installed in accordance with the best practices of the industry and the specifications of its manufacturer.

8.7.3 Walkway and Thresholds

The side door thresholds and the end door walkways shall be of cast aluminum with abrasive grit cast in, similar to those on the Authority's existing cars. The end door thresholds and anticlimber diamond plates shall not create a slip or trip hazard for the passengers, maintenance personal or Train Operators, and shall not interfere with the intended anticlimber function. 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 shall be designed to be self-cleaning, and shall drain to the outside. Neoprene rubber or equivalent material block shall be used in the middle of the side door to prevent rattling. Block design, surface finish and attachment to the thresholds shall not create a slip or trip hazard for passengers.

The thresholds shall be heated with self-regulating devices operating on AC voltage to maintain a surface temperature of no greater than 50°F whenever ambient temperatures drop below freezing. The self-regulating heaters shall activate automatically, without the need for intervention by operating or
A008 maintenance personnel. The thresholds shall be designed so that the removal and replacement of the heater element takes no more than 30 minutes. Thresholds shall be attached to the carbody structure using stainless steel hardware.

The configuration and depth of the door tracks in the threshold shall be sufficient to provide for carbody deflection, such 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 the door and threshold and no less than 1/8-inch clearance between the 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.

The car body gap created by the WMATA station platforms at the side door thresholds shall be reduced by removable extension strips affixed at each of the six side door thresholds. The extension profile shall A008
not exceed the dynamic profile of the car body by more than 1.25 inches and shall not extend above the door threshold surface.

The extension assembly shall be equal in length to the door threshold and in a continuous level manner. The extension cross-section and profile shall be designed to physically appear similar to the Authority's A008
existing cars. The extension shall be segmented and affixed to the full-length metal support. The metal support shall be compatible with the car body material to which it is attached and shall be designed to allow for installation and replacement using standard hardware and tools. The installation and removal of the extension assembly shall be accomplished without the removal of the side door or threshold.

The extension shall be of extruded **NEOPRENE** Rubber and shall have the following properties: A008

ASTM D412	Tensile Strength at Yield Elongation	1500 PSI 250%
ASTM D2240	Hardness Durometer	70 +/- 5
ASTM D624	Tear Resistance	200 Min.
ASTM D1149	Ozone Resistance (1PPM at 40 Degree C at 100 hrs 20% elongation)	No Cracks
ASTM D471	ASTM #3 Oil Swell Vol. Change	+80% Max.
n/a	Color	Black

8.7.4 Rubber Flooring

Continuous, smooth sheet rubber flooring, 1/8-inch thick, as described in Section 22.9.1, shall be installed in the cab.

8.8 DOORS

8.8.1 Side Doors

Each car shall be designed with three bi-parting sliding-type doors on each side. The doors shall be located as shown in Contract Drawing 97936-001. Each side entrance door panel shall contain a stationary window as shown in Contract Drawing 97936-001. Doors shall be completely weatherstripped, including at the top and bottom, so as to effectively exclude water under operating conditions and when the car is passing through a mechanical car washer. Vertical gaps between door leaf and carbody shall be covered to prevent dirt and debris from entering the door pocket, or passengers from intruding fingers, without affecting proper door operation. A solution similar to that implemented on the Authority's 5000 Series cars may be used. The exterior of the side doors shall have an approved brushed finish, grain horizontal, matching that of the car sides. Interior door finish shall have an approved, brush finished, horizontal grain.

The side doors shall be opened and closed by door operators, which are described in Section 11.2.

Side doors shall be supported at the top and guided at the bottom. The door 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 the hanger shall be provided to facilitate adjustments. The sliding bottom surface shall be of A006 sufficient strength to bear passenger load under the most extreme conditions. It shall be possible to replace the sliding surface without removing the door leaf. The matting edges shall be cut at 45° to create a watertight seal.

A006 Door leafs hall maintain front-edge parallelism to 1/8-inch from top to bottom.

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 of 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 11.6.

A006 A stainless steel or aluminum drain pan, which drains underneath the car, shall be provided in the bottom of each door pocket to prevent the accumulation of water. The pans shall drain to the bottom exterior of the car through the dedicated drain tubes.

8.8.2 Body End Doors

A006 A hinged door shall be provided at each end of the carbody, between the collision posts. The body end door opening shall be 30 inches, and shall have a minimum clear opening width of 28 inches when the door is in its fully-opened position. The door shall have a fixed rectangular window as shown in Contract Drawings 97936-005 and 97936-006, and shall have a latch and lock. The latch shall have a lever-type operating handle on each side of the door. It shall be possible to lock the door by means of a door key, which is described in Section 10.9.2, 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 at any door, even those 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. The door closer shall have adjustable spring power adequate to fully close the door when released from the half-open position. The location of the door closer shall not interfere with the Authority regular maintenance practices. A means shall be provided to prevent doors, when fully open, from hitting a passenger seat or arm rest. The end door threshold shall have two 1/2-inch inside diameter drain holes, one at each end, and shall not create any trip or slip hazard for passengers or Train Operators.

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 the handles shall be arranged so that vibration shall not cause the latch to move to the opposite position, either while engaged or disengaged. The latched and unlatched positions of the handles shall be the same as on the Authority's existing cars. Opening and closing force for door and latches shall not exceed 25 lbs.

8.8.3 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 in Contract Drawing 97936-003. The top edge of the door 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 tamper-proof self-locking latch shall A006 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 replaceable louvered grille for ventilation purposes. The louvers in the grille shall be positioned to limit air drafts in the area of the seated Operator.

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 yet permit passengers to use the aisle and the two-passenger seat on the left side of the cab area. 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. The cab door shall not rattle in any position.

Door stops, or other swing-limiting devices, shall be provided as specified in Section 8.8.5

8.8.4 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 in 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 8.12.

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.

8.8.5 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 preclude injury to fingers.

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. These devices shall not present a tripping hazard.

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

8.8.6 Valance Door Arrangement

A006 For valance-mounted side door operators, as described in Section 11.2, hinged valance panels (18 per car) above and adjacent to each passenger side door opening shall be provided. The valance panels above passenger doors shall be of sufficient strength to support mounted equipment, and shall not sag. The locking assembly shall be of sufficient strength to prevent deflection under passenger load/passenger leaning on valance panel.

Valance panels providing access to the door cut-out mechanism shall be secured using a half-hinge design and captive, ½-turn, hand-operated fasteners. Adjacent hinged valance panels shall be secured using captive, Allen key ¼-turn fasteners.

A007 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 causing 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.

8.9 WINDOW CONSTRUCTION

All windows shall be capable of withstanding external and internal pressure differentials caused by head-on pressures, tunnel clearance, and passing trains while the cars are at maximum operating speed. The windows shall not leak water, either into the interior of the car or into the car or door structure. Glazing
A006 shall be retained in an endless GRS rubber or neoprene section, and shall be arranged with zip-strip type retention for easy reglazing without the need for sealing compounds.

8.9.1 Passenger Side Windows

A006 Passenger side windows shall be fixed, FRA Type II windows. Contract Drawings 97936-002 and
A008 97936-003 are intended to depict only the appearance of the window, not the design details.

A008 Construction of the sash shall permit easy replacement of glazing from inside the car.

8.9.2 Operator's Side Windows

A006 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, FRA Type II sash similar to those on the Authority's 1000 Series vehicles 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
A006 window from outside the car, with the latch in the locked position, and it shall automatically latch when closed. The front half of the sash shall be movable and shall be located on the inside track.

8.9.3 End Windows

End windows at the "F" end shall be fixed and of single laminated FRA Type I safety glass. The glass shall be set in a stainless steel or anodized aluminum frame with an inside clear opening smaller than the glass to prevent the glass from being forced into the car. The glass 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. The design shall facilitate replacement of any end window, including the heated operator's windshield, in less than 45 minutes. The design shall be submitted to the Authority for approval and compliance with the ease of replacement requirement shall be demonstrated on the first car ***(CDRL T856)***. A006 A008

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 in Contract Drawings 97936-005 and 97936-006, which are intended to depict only the appearance of the window, not the design details.

8.9.4 Door Windows

Side entrance doors and R-end doors shall be equipped with windows of FRA Type II single laminated safety glass. "F"-end doors shall be equipped with windows of FRA Type I single laminated safety glass. All door windows shall be set in neoprene glazing strips, and having no separate sash. A006

Side door construction shall permit easy replacement of glazing from inside the car without the use of grease or of any compound that stains, while making a weathertight seal.

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.

8.9.5 Sign Openings

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

8.9.6 Windscreens

Glazing in the upper part of windscreens shall be Safety Glass Type II, and shall be arranged as shown in Contract Drawing 97936-004. A006

8.9.7 Cab Partitions and Door

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

8.10 GLAZING

8.10.1 General

All passenger windows shall be single-glazed safety glass. The window glass shall be retained in the window opening with a continuous neoprene section, easily removable from inside the car. A008

Glazing in windows and doors shall have the characteristics specified in Exhibit 8-1.

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 22.8. All edges of glazing shall be ground smooth and rounded.

Exhibit 8-1
Glazing Characteristics

	Location	Thickness (inch)	Visible Light Transmission	Type/Color
A008	Side Windows, Passenger Area including sliding window opposite cab	3/8 inch	40% to 50%	Bronze Tint Laminated Sheet
	Side Window, Cab	3/8 inch	Clear	Laminated Sheet
A008 A008	End Window, “R” End	3/8 inch	40 to 50%	Bronze Tint Laminated Sheet
	End Window, “F” End, Passenger Side	See Section 22.8	Clear	Laminated Sheet
	End Window, “F” End, Cab Side	See Section 22.8	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 22.8	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 10.7.6.

8.10.2 Glazing Seal Sections

A008 Glazing seal sections shall be designed to permit easy replacement of broken glass without the use of
grease or of any compound that stains, while making a weathertight seal. Glazing details shown in
Contract Drawings are intended only to depict appearance. Glazing sections shall be continuous and
A006 shall provide proper edge engagement for glazing 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 22.24 and shall have the mechanical strength and other characteristics required consistent with the lowest possible smoke generation.

8.11 SEATS

8.11.1 General

Passenger seats shall be arranged as shown in Contract Drawing 97936-001. The required appearance of the seat is shown in 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, material, thickness and mounting arrangements are defined by the bottom and back cushions of the existing cars, of which two each will be furnished to the Contractor by the Authority. 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 in Contract Drawing 97936-001.

8.11.2 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 fiberglass-reinforced polyester may serve as the seat shell. Exposed back pans shall have an approved hair cell texture finish.

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

Armrests shall be provided at the aisle side of each transverse seat and at the side away from the windscreen of each longitudinal seat. The armrests shall be of the same size and shape as those in the Authority's existing cars. The armrests shall be composed of 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.

8.11.3 Seat Supports

Transverse seats, except for 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 either be installed on supports, which shall be covered with a full enclosure, or be supported by full base enclosures of steel or aluminum. The exposed surfaces of these enclosures shall be entirely covered 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 Contractor shall submit the grille design for approval by the Authority ***(CDRL 805)***. A002

The design of all seat enclosures shall allow a minimum of 2 inches of 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.

8.11.4 Cushions

A008 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 or painted carbon steel. A molded or fabricated neoprene foam cushion shall be glued to that plate and the entire combination shall then be covered with fabric-backed vinyl upholstery on all exposed surfaces. This covering shall be mechanically secured to the cushion support plate in an Authority-approved manner.

A005 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 of firm density with an ILD value of 40 ± 8 lbf when tested to ASTM D3574-95 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.

A008 The seat upholstery material shall be made of industrial grade fabric-backed vinyl which is suitable for use in the transit environment, with a wright of minimum 36 ounces per linear yard, but not to exceed 38 ounces per linear yard.

A008 The material shall be capable of passing all of the following physical tests for textile products, latest revision. Values shown are minimum allowable for testing.

Test Method	Description	Criteria
ASTM D-751	Weight	24 Oz/Sq. Yd. (min)
ASTM D-751	Tensile Strength (Grab)	110 MD* x 1000 CMD**(Pounds)
ASTM D-751	Seam Strength	95 MD x 85 CMD (Pounds)
ASTM D-751	Tear Strength (Tongue)	10 MD x 12 CMD (Pounds)
ASTM D-5733	Tear Strength (Trapezoid)	30 MD x 30 CMD (Pounds)
AATCC-16A	Colorfastness - 200 hours	Class 5 (No change)
ASTM D-751	Adhesion of Coating (lb/2in)	8 MD x 8 CMD (Pounds)
ASTM D-2097	Flexing (30,000 Cycles)	No cracking or flaking
ASTM D-751	Blocking	Scale rating No. 2 max. (175 Deg. F – 30 minutes)
FS191-5874	Cold Crack	-20 degrees Fahrenheit min.
ASTM D-4157	Abrasion (1500 double rubs)	No wear thru (#8 Cotton Duck abradant)
ASTM D-1308	Stain Resistance	Scale rating No. 3 min.
ASTM E-662	Smoke Generation	D_s (4.0) ≤ 200 (Coated) D_s (4.0) ≤ 125 (Uncoated)
FAR 25.853b	Fire Test	SE ≤ 10 sec. No Flaming Dripping

*MD – Designates Machine Direction

**CMD – Designates Cross Machine Direction

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 securely hold the cushion assembly in place, ensuring 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.

8.11.5 Handgrips

A full-width stainless steel tubing handgrip shall be provided on the back of all transverse seats, except for transverse seats at the ends of the car. Back-to-back seats shall have one handgrip per assembly.

8.11.6 Access to Apparatus

Convenient access shall be provided for Authority personnel 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 of those seats 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, or longitundinal or transverse seats at A006
the end of the car, the entire seat assembly shall be hinged above the level of the bottom of the seat cushions. 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 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 ensure 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 seat assembly travel to 20 degrees past the vertical position, thus preventing over-extension of the spring. When fully open, the seat and handgrips shall not interfere with the seat at the opposite side of the aisle.

8.11.7 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 be able to be rotated from the normal forward facing position by 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 of a quality equal to that used on the passenger seats. The seat design shall be demonstrated in the cab mockup for approval by 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. The location of the seat, both vertically and horizontally, shall be established using the cab mock-up and shall be similar to seat location on the Authority's 5000 Series cars. The seat shall be interchangeable with those on the existing 5000 Series vehicles.

8.11.8 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 minimum force or weight. The bottom and back cushions shall have padding that is at least 1-inch thick. Seat bottom and back angles shall approximate those of the other passenger seats if space permits.

8.11.9 Strength Criteria

Seats and their attachments to the carbody shall be designed and tested to comply with the following
A008 sections of APTA SS-C&S-016-99 Standard for Seating in Commuter Rail Cars.

1. Section 3.0 – Seat Testing
2. Section 3.1 – Static Strength Testing
3. Section 3.2 – Dynamic Sled Testing (except 5g crash pulse shall be used instead of 8g)
4. Section 3.3 – Lateral and Vertical Strength Test

In addition, the maximum seat deflection under vertical load shall not exceed the maximum seat deflection of the existing 3000 Series cars.

The testing shall be conducted and test results approved by the Authority prior to any seat frame installation in the car ***(CDRL T857)***.

8.11.10 Interchangeability

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

8.12 INSULATION

8.12.1 General

A002 The floor, roof, sides, and ends, of the cars shall be thermally and acoustically insulated. The materials used for thermal and acoustic insulation, as well as all materials used for vibration damping, shall meet the flammability and smoke emission requirements specified in Section 22.24.3.

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. The individual sheets shall be as large as possible. Vertical and horizontal posts shall be properly thermally insulated.

8.12.2 Heat Transfer

Heat transfer through the carbody (with 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 12.8.2.2,
A002 using car's own floor heaters. Prior to insulating the first production or pilot car, the Contractor shall provide an analysis to demonstrate adequacy ***(CDRL 806)***.

8.13 ATC APPARATUS LOCKER

8.13.1 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, to the degree possible, be minimized, in order to provide the Operator with the greatest amount of visibility of the passenger compartment.

8.13.2 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.

The ATC equipment rack shall be either moveable or removeable to allow access to wire terminals and connections. A006

8.14 BETWEEN-CAR BARRIERS

The ends of all cars shall be equipped with an ADA-compliant barrier on both sides to deter passengers from inadvertently walking off station platforms and falling between cars. Additional barriers shall be provided on either side of the end doors at both ends of the car to prevent passengers and employees moving from car to car from falling to the road bed. Two sets of barriers shall be provided – one set shall be attached to the corner posts and another set to the collision posts. The design of the barriers shall minimize wind resistance, shall be rattle-free when the car is operating as the lead car of a consist, and shall permit the cars to operate compatibly when coupled to existing vehicles in the Authority's fleet that do not have such barriers installed. The style and placement of the barrier shall be similar to the barriers on existing cars and shall require approval by the Authority. A008

8.15 TESTS

8.15.1 Watertightness Test

All areas of the car sides, ends, and roof, including doors and windows, shall be given a complete test for watertightness. ***(CDRL T851)*** The tests shall be made before installation of sound-deadening material, thermal insulation, and interior finish. For the tests, doors shall be completely weatherstripped and windows and necessary window masks shall be installed. The fresh air intake ducts in the car roof shall be tested, with ventilating fans running at full speed, to determine the effectiveness of the water-excluding features of the ductwork.

Water shall be sprayed from nozzles which are spaced no more than 3 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 review by the Authority and acceptance before test results are approved.

All spray applications shall run for 10 minutes before the inspection for leaks begins, and shall run continuously during the inspection. No leaks will be permitted.

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, in a manner simulating the conditions that would be expected with the boxes mounted on the car. The underframe boxes shall be tested 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.

As a part of on-site acceptance tests, all cars shall be re-tested and inspected for leaks using the Authority's car washer or approved equal. The fresh air intake ducts on all cars shall be water tested. During testing, the water spray shall be directed at the exposed sides and ends of the boxes. The Authority reserves the right to require partial removal of interior liners before the test is begun. No leaks shall be permitted.

For inspection of local repairs, such as windows, doors, etc., an approved portable washer machine will be permitted.
The traction motor lead connections specified in Section 15.3.14 shall also be subjected to a water test. The water flow rate and velocity shall be as specified for the carbody water test.

8.15.2 Body Compression and Vertical Load Tests

A. The first carbody structure shall be tested to prove compliance of the structure with the Specification requirements. ***(CDRLs T852 and T853)*** The carbody shall be structurally complete, and shall exclude such items as exterior and interior trim, windows, doors, seats, lights, insulation, and interior linings. Underfloor apparatus, however, may be installed.

A002 B. The carbody shall be subjected to a compression test ***(CDRL T852)***. 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 ensure accuracy to within ± 1%.

A test load of 200,000 lbs. shall be applied to the anti-climber, at its center, by means of a ram no more than 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 no 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 ensure uniform bearing on the anti-climber.

The coupler anchor shall also be subjected to a compression test ***(CDRL T854)***. 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. A002

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. The Authority may grant this request, provided that up to four additional strain gauges will be required in the same general area to determine the effects on surrounding materials 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. maximum, provided that no reading 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 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 ***(CDRL T853)***. 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 A002 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 8.3.1.

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, changes in transverse width of the car at the belt rail and top of the door caused by door post bending, and changes in the dimensions of the door opening caused by carbody shear loads, shall be measured and recorded.

The car will be considered to have met the Specification requirements 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 selected by the Contractor and approved by the Authority prior to the start of 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.

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

A002 D. The carbody shall be subjected to a diagonal jacking test ***(CDRL T855)***. With the same strain gauges in place, the carbody, loaded to equal its ready-to-run weight, shall be lifted at diagonally-opposite corners, using outboard jacking pads until clear of all other support except at one other corner, to determine compliance with the torsional strength requirements of Section 8.3.1. Twist shall be measured, and the absence of permanent deformation shall be determined.

E. With the same strain gauges in place, the carbody, loaded to equal its ready-to-run weight, shall be lifted at one corner jack pad with truck attached, for re-railing purposes, with the other end resting on its truck, without causing permanent deformation of any structural member.

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

1. Compression Test: 200 to 300 gauges
2. Coupler Anchor Test: 200 to 300 gauges
3. Vertical Load Test: 200 to 300 gauges A002
4. Diagonal Jacking Test: 200 to 300 gauges

G. In addition to Section 3.2.3 requirements, the test report content shall be agreed between the Authority and the Contractor before any test is begun. As a minimum, all load cases and all test steps shall be clearly presented, individual loads on each actuator shall be defined if applicable, and correction factors shall be included. Comparison with calculated data shall be also provided for major structural members.

8.16 REFERENCED CDRLS

The following CDRL items are referenced in this section:

CDRL 801	Preliminary and Final Stress Analysis of Carbody, Underframe, and Equipment Supports	
CDRL 802	Repair Procedure for Lining Materials	
CDRL 803	Crashworthiness Design Data	
CDRL 804	Cab End Contour Details	A002
CDRL 805	Grill Design for Seat Enclosures	
CDRL 806	Heat Transfer Analysis	
CDRL T851	Watertightness Test Report	
CDRL T852	Carbody Compression Test Report	
CDRL T853	Vertical Load Test Report	
CDRL T854	Coupler Anchor Compression Test Report	A002
CDRL T855	Diagonal Jacking Test Report	
CDRL T856	End Window Ease of Replacement Demonstration	
CDRL T857	Seat Strength Tests	A008

8.17 REFERENCED STANDARDS

The following standards are referenced in this section:

MIL-STD-889	Dissimilar Metals
49 CFR Part 38	Americans with Disabilities Act (ADA), Accessibility Specifications
ASTM D1055	Standard Specifications for Flexible Cellular Materials – Latex
FED-STD-191	Textile Test Methods
A-A-59517	Cloth, Coated or Laminated, Polyvinylchloride (Artificial Leather)

APTA SS-C&S-002-98 Standard for Static Strength Attachment of Major Equipment to the Car Body Structure of Railroad Passenger Equipment

APTA SS-C&S-006-98 Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment

APTA SS-C&S-015-99 Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction

APTA SS-C&S-016-99 Standard for Seating in Commuter Rail Cars

SECTION 9
COUPLER, DRAWBAR AND DRAFT GEAR

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SECTION 9
COUPLER, DRAWBAR, AND DRAFT GEAR

9.1 GENERAL

9.1.1 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 a clevis, anchor ball, or spherolastic-type pivot bearing anchor bracket or other approved type of anchorage. A006

9.1.2 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. Tests shall be conducted of structural strength in buff ***(CDRL T951)*** and structural strength in draft ***(CDRL T952)***. A002

All parts of the coupler on which it is possible for a person to stand in attempting to climb to the end door shall withstand, without permanent deformation, a vertical load of 360 lbs. Tests shall be conducted to conducted to confirm the ability of the coupler to withstand this vertical load ***(CDRL T953)***. A002

As a minimum the Contractor shall provide a finite element structural analysis of the coupler hook (***CDRL 901***), drawbar ***(CDRL 902)***, and anchor assembly ***(CDRL 903)***. A006

9.1.3 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 7.1, 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."

Tests shall be conducted to confirm the ability of the coupler, drawbar and draft gear to remain properly centered under the conditions described above ***(CDRL T954)***. A002

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. Tests shall be conducted to confirm the gathering range ***(CDRL T955)***. A002

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

9.1.4 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, without further action.

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 9.9.

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 the 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 requiring the use of any special tools other than the manual uncoupling lever 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 lever handle shall be coated with OSHA Orange, as specified in Section 10.14, and shall be stored on the vehicle in accordance with Section 8.5. 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 before the latch can be used to retain the mechanism in the uncouple position.

9.1.5 Drawbar

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 9.7, 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 the 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 cut-out cocks between the carbody piping and coupler hoses shall be provided. Closing of the cut-out cock shall vent the hoses to permit their removal without requiring the bleeding of car air. The cut-out cocks shall be lockwired in the open position and shall be operable from between the cars.

9.1.6 Material

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.

9.1.7 Drainage

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

9.2 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.

9.3 DRAFT GEAR AND AUTOMATIC RELEASE FEATURE

9.3.1 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 9.3.2 permits the coupler head to move back or the drawbar to collapse.

9.3.2 Automatic Release Feature

The coupler design shall include primary and secondary automatic release features. A primary release feature shall be incorporated in the coupler and drawbar which, upon a buff load of approximately 120,000 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. The primary release feature of the draft gear shall consist of a shear ring, four ground shear pins, and four caps. The ground shear pins shall include a shear groove for control of shear load. The caps shall be threaded. It shall be possible to replace sheared pins without disassembly of the draft gear. Tests shall be made to confirm that the pins shear at the specified buff load ***(CDRL T956)***. A002

The secondary release feature, the coupler anchor shall include a shear plate design that utilizes calibrated shear bolts to be activated at approximately 155,000 lbs or otherwise approved by the

Authority. 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. The design shall hold coupler captive to the underframe while the car energy management system is activated.

9.4 COUPLER SUPPORT AND CENTERING DEVICE

9.4.1 Coupler Support

The coupler draft gear shall be self-supporting and shall mount to the car underframe at the coupler anchorage. Alternatively, coupler carriers may be provided, which meet the geometric requirements of Section 9.1.3 and support the coupler at its nominal height.

9.4.2 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 centerline 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. The centering device, when uncoupled, shall not under any circumstance come into contact with the third rail.

9.4.3 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 subject to specific Authority approval, and shall be designed so as to require lubrication no more often than annually.

9.5 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.

9.6 ELECTRIC COUPLER HEAD

9.6.1 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 of the Authority's existing cars. Tests shall be made of a 6000 Series car coupled to a car of each of the other series to confirm that the electric
A002 coupler heads are fully compatible ***(CDRL T957)***. 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 during coupling.

9.6.2 Operation

Electrical isolation shall be accomplished automatically during normal operation by the use of a rotary switch, as specified in Section 9.9. An additional manually operated rotary switch shall be provided for electrical isolation only, as required by Section 9.1.4. The handle of the manually operated rotary switch shall be coated with OSHA Orange, as specified in Section 10.14.

9.6.3 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.

9.6.4 Contacts

Each electric contact pin shall be of sufficient ampacity to handle 150% of the maximum current to which it will be subjected (i.e., shunt type), and shall be of the spring-loaded button-type with rounded contact face, the same as used on the Authority's 5000 series cars. Spring pressure and preload 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.

9.6.5 Protection

Electric coupler contacts shall be protected by steel covers, which shall 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 of the Authority's existing cars. The covers shall be coated with OSHA Orange, as specified in Section 10.14, with the phrase "DO NOT STEP" stenciled over the orange vertical faces in 1-inch-high black letters.

A combination of seals and drains shall be used to prevent the retention of moisture and water within the A006
electric coupler assembly. 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 A002
couplers of the Authority's existing cars. Tests shall be made to ensure that a watertight seal is maintained under each of these conditions ***(CDRL T958)***

9.6.6 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-5015, 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.

9.6.7 Spare Trainlines

Ten spare wires shall be run from end to end of the car. They shall be No. 12 AWG, and two of them shall be shielded. They shall be clearly 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.

9.6.8 Trainline Data Acquisition Module

A data acquisition module (DAM), to monitor trainlines as required by Section 20.6, 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 to the portable test device via the car
A008 communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. 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 20.5. The DAM shall convert the trainline signals, analog or digital, to serial packages and store for transmission to the VCU viathe car
A008 communications network, in accordance with Lon Works serial data communication or other Authority-approved protocol.

The DAM shall be assigned a message identification (MID) character within the network so that communications between all units can be managed and controlled.

9.7 "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 9.6.6. The jumper cables shall provide sufficient wires to make all active connections plus a total of at least 20 spare wires. Spare wires shall be No. 12 AWG, and four of the spare wires 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.

9.8 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.

9.9 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. The switch 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 preclude damage by arcing.

Provision shall also be made for manual operation of the switch. The switch shall be designed so as to prevent creeping from the "On" or "Off" position. The manual handle shall be coated with OSHA Orange as specified in Section 10.14. The rotary switch enclosure shall also serve as the trainline junction box specified in Section 9.7.

9.10 COUPLER ADAPTORS

The Contractor shall furnish a total of four adaptors, two for the "F" end and two for "R" end, 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.

9.11 STEP

A nonslip step of sufficient size shall be provided on top of the mechanical coupler for use when entering the train through the end door.

9.12 TESTS

All tests shall be documented and shall meet the requirements of Section 3. Trainline tests specified in Section 3 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 8.15.2, and shall be in accordance with the manufacturer's recommended procedures. ***(see CDRL T854 in Section 8)*** A002

A watertightness test shall be conducted per Section 8.15.1.

9.13 REFERENCED CDRLs

The following CDRL item is referenced in this section:

CDRL 901	Finite Element Structural Analysis of Coupler Hook
CDRL 902	Finite Element Structural Analysis of the Drawbar
A006 CDRL 903	Finite Element Structuctual Analysis of the Anchor Assembly
CDRL T951	Coupler Anchor Compression Test
CDRL T952	Structural Strength in Draft Test
CDRL T953	Step Strength Test
A002 CDRL T954	Centering Ability Test
CDRL T955	Gathering Range Test
CDRL T956	Shear Pin Device Release Test
CDRL T957	Compatibility Test
CDRL T958	Electrical Equipment Watertightness Test

9.14 REFERENCED STANDARDS

The following standard is referenced in this section:

MIL-C-5015	General Specification for Connectors, Electric, Circular Threaded, AN Type

SECTION 10
MISCELLANEOUS CARBODY ITEMS

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SECTION 10
MISCELLANEOUS CARBODY ITEMS

10.1 INTERIOR SIGNS

10.1.1 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.

10.1.2 Interior Sign Style

Unless otherwise specified, all lettering on signs visible to the public shall be Helvetica Medium, upper and lower case.

10.1.3 Car Number

Car numbers shall start at 6000. 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 19.2.4.

10.1.4 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.

10.1.5 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 described in Section 8.6.8.

10.1.6 Passenger Notices

Passenger notices, listed in Exhibit 10-1, shall be applied at the locations shown.

Exhibit 10-1
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

10.1.7 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. Notices shall be easily inserted into and removed from frames within 1 minute.

The frames shall be constructed of plastic of the same color as the liner to which they are applied, so as to be as unobtrusive as possible when no notice is inserted. The frame assemblies shall have a clear polycarbonate protective sheet to protect the replaceable notice insert. In addition, the edges of the frame shall protect the insert from intrusion of dirt, dust and moisture.

10.2 EXTERIOR SIGNS

10.2.1 Logotype

The Authority's Logotype shall be applied to the outside of the car, as shown in Contract Drawing 97936-001.

10.2.2 Car Number

The car number shall be applied to a plate on both sides of the car at both ends, as shown in Contract Drawing 97936-001.

10.2.3 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. The outside of each apparatus box shall be marked with a designation of each major item of apparatus contained therein. Each air brake reservoir and 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.

10.2.4 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. Upper edges of vinyl film shall be protected by being extended under the glazing rubber at windows. Edges of the film shall be sealed.

10.2.5 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, 6, 7 and 12. A006

10.3 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.

10.4 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 in Contract Drawing 97936-001. One sign shall be on the front end of the car, as shown in 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.

A006 Each side sign shall have a capacity for at least 97 different destinations and two special indications, “NO PASSENGERS” and “SPECIAL.” A list of destinations will be provided to the Contractor within 60 days of contract award. 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 the Authority’s existing cars. It shall also be possible for the control signals on the cars furnished under this Contract to operate destination signs on the Authority’s existing 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 in Contract Drawing 97936-011.

Access to the sign and color-coded indicators, shall be from inside the car, and shall provide for easy replacement and maintenance of all components.

A006 All signs shall be discernable in bright daylight.

10.5 CAR IDENTIFICATION SYSTEM

Intentionally left blank. A008

10.6 FIRE EXTINGUISHER

Two UL and/or CE certified rechargeable fire extinguishers, each containing 10 lbs. of ABC dry chemical and equipped with a pressure gauge, shall be provided in each car. One extinguisher shall be mounted in the Operator's cab, and the other shall be 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.

Placards indicating the location of each fire extinguisher shall be mounted on the door frame by the seat where the fire extinguisher is located. The placards shall be 6 inches wide and have a red background with white printed letters that glow in the dark and read "Fire Extinguisher" and a white arrow that glows A006
in the dark and points to the extinguisher's location. The fire extinguishers shall bear the Authority's name.

Fire extinguishers shall be hydrostatically tested prior to initial filling and have tags indicating the inspection date and the inspector's signature.

10.7 CAB ACCESSORIES

10.7.1 Windshield Wipers

A heavy-duty, air- or electrically-driven windshield wiper shall be provided for the cab side "F" end window. The wiper shall be able to clear the glass satisfactorily at train 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 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.

All exterior metal components shall be stainless steel. A006

10.7.2 Visor

An opaque visor shall be provided for the Operator's end window, and shall measure approximately 8 inches by 24 inches. The visor shall be mounted on an extendable, double-ball-jointed arm, shall be easily operated, and shall remain in the selected position. When not in use, it shall be able to be stored unobtrusively near the cab ceiling.

10.7.3 Signal Buzzer

The cab shall be equipped with a buzzer for receipt of signals. It shall be energized, through a trainline, by the signal pushbutton in any cab in a train. The tone of the buzzer shall be the same as the tone of the signal buzzer in the Authority's existing cars.

The buzzer shall have a volume sufficient to be readily audible with the cab window open under the highest ambient noise level conditions.

10.7.4 Overspeed Warning

An audible overspeed warning signal device shall be provided in the cab. The signal device shall
A006 function under command of the Automatic Train Control apparatus as specified in Section 18.2.2.3.

10.7.5 Cab Curtain

An accordion-pleated curtain of opaque vinyl-coated fiberglass fabric shall be provided for the transverse
A006 cab partition window behind the Operator. The curtain shall be able to cover all or part of the window and shall be capable of being secured at different positions.

10.7.6 Cab Door Window

The cab door window (ref. Section 8) shall be shielded or shaded in such a way as to eliminate disruptive reflections on the windshield originating from the passenger area when the cab door is in the operating position; yet still permit passengers to effectively view the cab and to see forward through the windshield and bulkhead door window. The necessary provisions may be external to the window, if mounted on the
A006 cab-side, or internal.

10.8 HORN

10.8.1 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 on 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 Authority's existing cars.

10.8.2 Yard Horn

A006 The road horn described above may 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" pushbutton on the Operator's Auxiliary Control Panel from the keyed-up cab console. Alternatively, an electric horn similarly located and operated may be provided. Horn action shall be instantaneous.

10.9 STANDARD KEYS

10.9.1 Control Key

Two control keys shall be provided for each car. The total quantity of control keys required for all 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.

10.9.2 Door Key

Two door keys shall be provided for each car. The total quantity of door keys required for all 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.
J. ATP Cut-Out Switch Access Door A006

10.9.3 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 types of keys (control and door) for the Contractor's use in selecting locks.

10.10 EXTERIOR HANDHOLDS AND STEPS

10.10.1 General

Exterior handholds and steps shall be provided at the locations specified in Sections 10.10.2 and 10.10.3. 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 (ref. Section 7).

10.10.2 Handholds

Handholds are required at the following locations on each car:

A. Three handholds on "F" end collision posts, for use when entering or exiting the car by the coupler step. One handhold shall be 6 inches long, and two shall be 15 inches long, as shown in Contract Drawing 97936-005.

B. One outside handhold adjacent to center side door leaf number 9.

C. One handhold on the "R" end collision post, 15 inches long, as shown in Contract Drawing 97936-006.

10.10.3 Loop Steps

A loop step is required under the center side door handhold referred to in Section 10.10.2. The left side of the loop step shall be approximately even with the centerline of the handhold; and the 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 9.11.

10.10.4 Material

Exterior handholds shall be of one-piece construction, and shall be made of 5/8-inch diameter stainless steel rod.

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.

10.11 INTERIOR HANDHOLDS

Interior vertical (stanchions) and horizontal handholds shall be provided as shown in 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.

Interior handholds shall be made of stainless steel tubing. The finish on the handholds shall be600 grit. Flanges, tees, and other fittings shall be made of stainless steel or anodized aluminum, and shall be tapered similar to the flanges on the existing 4000 series cars. All fasteners shall be flush or recessed. The design shall be free of sharp edges. Welding as a joining method is prohibited.

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 500 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. Handholds and their attachments to the carbody structure shall also comply with the APTA SS-C&S-006-98 Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment. In the case of conflict the most stringent requirement shall prevail.

The height of the horizontal handholds shall be 76-1/2 inches from top of finished floor to centerline of handhold.

Short horizontal handholds, as shown in Contract Drawing 97936-007, shall be provided in the area adjacent to the door pockets housing door panels 2, 5, 8 and 11. These handholds 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.

A006 Stanchions and handholds shall not obstruct visibility of next station sign, whether standing or seated.

10.12 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 Authority's 4000 series cars, and shall hook into holes provided in the top surface of the front anti-climber to prevent slipping.

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 22.24 for interior materials, shall have nonskid feet, and shall have flat steps at least 3 inches deep. The ladder shall be constructed of fiberglass-reinforced polyester with sufficient strength to support a 300-lb. maximum static load, and to comply with OSHA requirements 1926.1053 section (a)(1)(ii)

10.13 SHOE INSULATING PADDLES

Two Authority-standard, third-rail contact shoe insulating paddles shall be provided in each car and shall be 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.

10.14 RAPID IDENTIFICATION COATING

To aid in the rapid identification of various control points, the following apparatus on each car shall have a permanent coating that matches OSHA Orange paint (DuPont No. 93-082-DH or approved equal), or shall be painted with the 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.

10.15 WHEELCHAIR RESTRAINING DEVICE

A device capable of engaging a wheelchair wheel and restraining uncontrolled movement of the engaged wheelchair shall be installed in each car. This device shall be located in the space provided to accommodate wheelchairs immediately adjacent to the windscreen at door number 7 (left side, front end) on the "A" car and adjacent to the windscreens at doors number 1 (right side, front end) and door number 7 (left side, front end) on the "B" car. The device shall be mounted on the door pocket paneling at an appropriate height and shall be similar in installation to that on the Authority's 4000 series cars.

10.16 REFERENCED CDRLs

No CDRL items are referenced in this section.

10.17 REFERENCED STANDARDS

The following standards are referenced in this section:

ADA	Americans with Disabilities Act
OSHA 1926.1053	OSHA Regulations (Standards 29 CFR): Part 1926, Safety and Health Regulations for Construction; Subpart 1053, Ladders

APTA SS-C&S-006-98 Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment

SECTION 11
DOOR OPERATION AND CONTROL

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SECTION 11
DOOR OPERATION AND CONTROL

11.1 SIDE DOOR OPERATION

11.1.1 General

Door operators and controls shall be a service proven design, and shall have been used with a door panel
of comparable weight. The side doors shall be arranged for remotely controlled electric operation. The
control shall be trainlined so that all doors on each side of a train may either be operated automatically by
the ATC apparatus, or from manually operated pushbuttons. The doors on the left-hand side shall be
operable manually by the use of pushbuttons located on the cab door-control panel beside the side A003
window on the left side of the car, across from the Operator's console. The doors on the right-hand side
shall be operable manually by the use of pushbuttons on the cab door-control panel beside the side
window on the right side of the car in the Operator's cab. Refer to 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 in the data acquisition module (DAM) for use by A008
the vehicle monitoring system (see Section 11.8).

Maximum use shall be made of solid-state controls for the door system; 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.

11.1.2 Door-Control Selector Switch

A sealed, three-position selector switch shall be provided as part of the Operator's circuit breaker panel A008
(see Section 14.6.2). The switch shall be effective only in the leading cab of a train, and shall permit the
Operator to select one of the following methods of door operation:

A. Auto: When the selector switch is placed in the "Auto" position, doors shall be opened and
closed by commands from the ATC system. Manual override shall be possible, except that A003
doors on the "wrong" side of the train shall be prevented from opening, as per Section 11.1.13. A008

B. Auto\Man: The "Auto/Man" switch position shall enable doors to be opened by commands
from the ATC system (with manual override) and closed manually by means of any activated
cab door-control panel. . Manual override shall be possible, except that doors on the A003
"wrong" side of the train shall be prevented from opening, as per Section 11.1.13. A008

C. Man: This switch position shall enable doors to be opened and closed manually by means of
any activated cab door-control panel. Doors on the "wrong" side of the train shall be prevented A008
from opening, as per Section 11.1.13.

A003 **11.1.3 Door/Train Speed Interlock**

The manual door controls shall be interlocked with the ATC system's zero-speed relay so that the door trainline or crew switch commands cannot be issued and doors shall not respond to trainline or crew A003 switch commands unless train speed is less than 2 mph and friction brake is applied. The interlocking shall be accomplished on each car individually by the removal of power from the door-opening push-buttons and crew switches. Further, door controls and the door operators shall be interlocked against opening at speeds over 2 mph. Power removal at speeds over 2 mph shall be a vital function accomplished in a fail-safe manner.

11.1.4 Door/Traction Interlock

Traction controls shall be interlocked with door signal lights (see Section 11.4) so that a train cannot be moved unless two sensing switches for each door panel indicate that all doors are closed and locked. One sensing switch shall check that the door is closed, and the second shall then check that the door is locked. All closed and all locked limit switches shall be wired in two separate loop circuits for each side A003 of the individual car before energizing the relevant Left or Right side summary relay. The car loops shall be arranged in such a manner as to prevent single point failures to both loops concurrently. The trainline circuit performing door/traction interlock shall be a fail-safe, double-break circuit with two trainline wires to provide maximum protection against erroneous door-locked signals (i.e. contacts of each Left and Right summary relay shall be wired in series with both wires of the train traction interlock trainlines).

The local car door closed 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, by de-energizing the relevant summary relay and interrupting the trainline circuit. After the zero-speed circuitry indicates the train is no longer A003 at zero speed, movement of a door's pushback feature will have no effect on train movement. The trainline circuit shall change polarity with each change in leading end in order to be able to detect ground faults or false positive energy. Brakes shall be applied at Braking Level 4 whenever the door/traction interlock trainline circuit is open.

11.1.5 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.

11.1.6 Compatibility

Door-control signals shall be fully compatible in all respects with door-control signals on the Authority's existing cars, so that new and existing cars can be mixed in any order in a consist and all doors will A003 function as specified. Door control software and hardware performance shall be capable of following the A008 operation of manual door open an close pushbuttons consistent with existing WMATA train operating A009 practices. All door-closed trainlines (left and right) shall be pulsed momentarily by the ATP system after motion is detected.

11.1.7 Door/Master Controller Interlock

Controls shall be arranged so that if, in manual operation, the master controller is advanced to a power A003 position while any door on a train is open, obstructed, or unlocked, no traction power shall be applied until (1) all doors have become closed, unobstructed, and locked; and (2) the master controller has been returned to a coast or brake position before it is again advanced to a power position.

11.1.8 Door Operator Cut-Out Switch and Lock

A combined 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. The cut-out switch shall be accessible through the door operator access panel. Traction controls shall be interlocked with the door signal lights as described above in Section 11.1.4.

The cut-out switch shall bypass the "door closed, obstructed, and locked" signal circuit at that door operator but shall not reduce the effectiveness of the obstruction detection system on the remaining A003 doors. The cut-out switch shall also disable the visual indicator (see Section 11.5) on the affected doorway when either of its door operators are cut out.

11.1.9 Door/Traction Interlock Bypass

A door/traction interlock bypass switch shall be provided in the Operator's circuit breaker panel (see Section 14.6.2) to permit a train to be moved 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.

11.1.10 Door-Control Trainline Cut-Out Switch

A cut-out switch shall be provided in the Operator's circuit breaker panel to allow disabling of the automatic and manual trainline 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 A003 rear of the train. Door status indication for the train 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 the operating cab shall not affect door status indication for the train, nor disable side door operation in the lead pair.

11.1.11 Trainline Commands

Doors shall be opened and closed by signals on two 37.5 VDC trainline wires on each side of the train. A003 Energization of these wires (for 50 +/- 10 milliseconds) with voltage of one polarity shall open the doors A009 on that side, and energization with voltage of the opposite polarity shall close them. Hardware and / or software filtering shall be applied to these signals to prevent transient voltages appearing on these lines from appearing as valid requests.

11.1.12 Power Source

Door controls shall operate on nominal 37.5 VDC with a range of 23 to 42 VDC. A003

A008 ### 11.1.13 Platform Detection System

A008 #### *11.1.13.1 General Requirements*

The door control system on each car shall incorporate equipment and logic to inhibit manual door openings on the off-platform side of the consist. The Platform Detection System shall operate in all door control modes described in Section 11.1.2. This platform detection system shall interface with the left and right Door Open push buttons located in the operator's cab, independently disabling the left and right Door Open push button functions until one of the following conditions are met:

- Platform is detected, or
- Doors are opened by automatic train control (ATC), or
- System is manually bypassed, or
- System is off (cut-out).

Platform detection equipment shall be included on each car, but shall be active only in the controlling car of the consist. Platform detection outputs shall be active only when the car is at rest, i.e. at or below the zero speed threshold. The system shall reset when motion is detected. The platform detection system shall not interfere with the Door Close functions.

As part of the Door Control subsystem, the platform detection system design and equipment shall be subject to the performance requirements in Sections 11.7 and 11.8, and the FMECA requirements of Section 11.10

A008 #### *11.1.13.2 System Description*

The Platform Detection system shall include the following features:

- Automatic detection of platform
- Left and right manual bypass (override) capabilities
- Automatic enabling (override on platform detection function) of door open pushbutton (on appropriate side of car) after detection of ATC and/or crew switch door openings on the controlling car.
- Automatic override (bypass) of platform detection functions when in yards
- System cut-out switch (sealed) and circuit breaker
- In cab visual indication of system status – different color for "bypassed" condition

Platform detection shall be active only when the vehicle is at the zero speed state. Platform detection shall be automatic, requiring no operator interaction or control. The Contractor shall be responsible for assuring that the system will detect all current station platforms. Performance verification testing shall be incorporated in the Contractor's test plan, Section 11.10.

Manual bypass switches for left and right platform detection shall be momentary, or spring, type. Manual bypassing of platform detection shall be possible only when the vehicle is at the zero speed condition (e.g. stopped at a station platform). Full, automatic, system functionality shall be restored when the vehicle exceeds zero speed.

All switches. circuit breakers, and indicator lights shall meet the requirements of Sections 14.6.2 and 14.6.3. Bypass switches, system cut-out switch, and circuit breaker components shall be incorporated into the operator's circuit breaker panel – See Section 14. Any exterior mounted sensors used for platform detection shall be mounted in the F-end fiberglass nose of the vehicle in such a way as to facilitate direct replacement without the use of special tools or fixtures. Sensor replacement shall not require the removal of any other components from the car. The platform detection system shall not require adjustment or calibration.

The platform detection system shall be automatically overridden (right or left side) when doors are opened via ATC or a crew switch on the controlling car. The platform detection system shall be automatically overridden (right and left side) when the vehicle is in a yard.

Visual indication of system status shall be provided to the operator by dual color LEDs (green/yellow) incorporated in to the right and left door control pushbutton panels detailed in Section 11.3.1. The right and left LED circuits shall be separate and distinct. A green LED shall illuminate when the platform detection system has detected a platform or when the system has received an automatic override command. A yellow LED shall illuminate whenever the system has received a manual bypass command via the operator controlled switch.

11.1.13.3 VMS Interface A008

As part of the door control system, the platform detection system shall interface with the Vehicle Monitoring System (VMS) as detailed in Section 11.8 and Section 20. VMS and DAM interfaces shall incorporate, at a minimum, system status (On, Off, manual bypass, platform detected, auto-enable) and system and/or component fault data.

11.2 SIDE DOOR OPERATORS

Each side door leaf shall be activated by a separate electric operator and corresponding microprocessor controller. The operator controls shall be in a self-contained local control panel mounted in the valance panels above and adjacent to each side door. Each door leaf shall operate by means of a drive-screw spindle. All adjustments to a door operator shall be readily accomplished from the exposed side of the operator. A003 A009

The operator and controls 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, even if the obstruction detection mechanism has been disabled. In case of failure of the obstruction detection mechanism and when selected to be active, the door shall close at reduced speed and remain closed until the problem has been corrected. This failure shall be reported via the VMS with a high priority status. The operator and controls shall provide sufficient damping to keep the door from bouncing off the stops and nose rubbers at the end of the opening and closing cycles. A003 A008

The elapsed time for door opening shall be a maximum of 1.5 seconds from the moment of energization of the door operator to the moment of completion of the operation, including cushioning. Door-closing time shall be adjustable from 2.0 to 2.5 seconds in 50 msec intervals, and shall be easily changed by the Authority. The Contractor shall provide the correct closing profile (acceleration, constant speed and cushioning) for the variable closing time parameter to ensure changing the closing time does not compromise other requirements. All variable parameter changes for all twelve (12) door locations on a car shall be up-loaded from a central location. Both leaves of a door shall open and close simultaneously and there should be no discernible differences when observing the whole side of a car. Changes in supply voltage over the range specified shall not affect the door timing. Compensation for friction variation on a A003 A008 A009 door-to-door basis shall be provided in the motor controls and the obstruction detection sensitivity shall not be affected by the compensation for friction.

A003 All limit switches used in the door operator shall be of the replaceable-unit type. The limit switches shall be activated by gross movements of the operator mechanism, cut-out switch or emergency handle. The design and installation of these switches shall be such that adjustments to replacement units will neither be necessary or even possible for proper functioning. Limit switches for controlling the cushioning and interruption of motor current are not permitted with the exception that the locked limit switch may be used as a reference point to 'zero' the distance count from a shaft encoder or other method of distance counting. When power is lost while the doors are open, the next closing sequence shall be performed at a slower speed until the door locked reference is attained again.

A002 The door mechanism shall incorporate a spring-loaded pushback feature allowing 1-1/2 inches of pushback per panel at a force of 24 to 31-1/2 lbs., even if the door is locked.

A003 Current limiting to control door force and to protect the motor during prolonged periods of stalled condition shall be provided by electronic controls.

A003 A mechanical device shall ensure the locking of each door panel in the "Door Closed" position. Locking shall be automatic. The door-locked indication shall be given only after the door has been mechanically locked. Closed and locked limit switches shall undergo 'cycle checking' to ensure they change state when the door panel is known to be open, based upon motor current or distance counting techniques.

11.3 DOOR CONTROL SWITCHES

11.3.1 Cab Controls

A008 Heavy-duty, industrial type door control pushbuttons 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. The second pair of pushbuttons shall be provided on the door-control panel on the forward side of the left side window, opposite the Operator's console, and shall control the doors on the left side of the train (see Section 14.6.2 and Contract Drawings 97936-008 and 97936-011). All pushbuttons shall be barrier type. Dual color (green/yellow) LEDs shall be incorporated in each door control panel as per Section 11.1.13.

The door-control panel on the left side of the cab 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. In addition to the "open" and "close" pushbuttons, this panel shall be fitted with an "all doors closed" indicator light and an Emergency Stop button (mushroom).

Enabling of the door-control pushbuttons on either panel shall be accomplished by activation of the control lock on the control console, or by activation of the door-control key switch on the auxiliary panel. It shall be possible to remove the key and have doors remain open, and to close and lock the doors from a different master door-control panel than that from which they were opened.

In the leading cab, the Operator shall be able to forestall the opening function by holding the "Close" pushbutton, and to forestall the closing function by holding the "Open" pushbutton, when the commands for these functions are being initiated by the ATC system.

The door-control pushbuttons shall be of the spring-return type. Circuitry shall be arranged so that, once the button is held down for at least the period specified in Section 11.1.11, the operating cycle will be A003 completed even if the button is subsequently released.

11.3.2 Crew Switches

Key-switch stations for crew 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, gasketed covers to A003 ensure they are weathertight. Covers shall have a brush finish identical to the exterior of the car. Interior crew switches shall be flush mounted in a convenient but inconspicuous location in the windscreen or side wall near the door leaf the switch 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. The "Open" and "Close" key positions shall be engraved on the faceplate of the A006 switch, and shall be filled in with black ink.

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 panel, and the door shall thereafter function normally.

Crew switch circuits shall be zero speed protected and there shall be no single point failures that can A003 cause a crew door to open whether in motion or at zero speed.

11.3.3 Emergency Door Operation

All side doors shall be arranged so that they may be manually opened for emergency exit. The release lever or handle shall be located inside the car, behind the door operator access panel. The handle shall be coated OSHA Orange as specified in Section 10.14.

In addition, door leaves number 3 and 10 shall be arranged for emergency opening by passengers through use of a lever located at a convenient and ADA compliant 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 shall require breaking of the seal and opening of the cover door. When the emergency lever is pulled, it shall cause the mechanical lock to unlock that is sensed by the locked limit switch and de-energizes the summary relay causing train brakes to be applied. With the door unlocked it A003 is then possible to manually slide the door panel open. The emergency lever operating mechanism shall A008 be interlocked with the car's zero-speed circuitry so that when the emergency lever is attempted to be pulled, the handle movement is restricted and the door will not open until the train is stopped. However, loss of ATC power at zero speed shall not inhibit emergency door operation.

11.3.4 Emergency Door Opening Device Access Panel

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 Phillipshead screws. Panels shall be finished with aluminum moldings along their edges. The arrangement shall be submitted to the Authority for approval.

A008 11.3.5 Emergency Door Recovery

The emergency door system shall provide for a powered recovery of the door leaf to the closed and locked state. In the event of an emergency door opening, the train operator shall be able to restore the door leaf to the closed and locked state by restoring the emergency handle, or by other approved means. Upon activation, the emergency door leaf shall be powered closed and locked. This function shall not affect the state of any other door on the car or consist. It shall also be possible to manually restore the emergency door leaf to the closed and locked state with no more than routine physical effort. These functions shall be active when the vehicle is at rest and the operator keys are removed from the operating console.

11.4 DOOR SIGNAL LIGHTS

11.4.1 Exterior 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 housing shall conform to clearance requirements and shall be of a design that will not be damaged by car-washing machines.

The circuitry shall be arranged so that the light will be illuminated when any door leaf on either side of
A003 the local car is open, obstructed, or unlocked. The light shall be visible from both ends of the train. The light shall have sufficient brightness so that a person with normal visual acuity will be able to discern whether the light is illuminated or not in bright sunlight at a distance of eight car lengths on tangent track.

11.4.2 Threshold Lights

Door threshold lights, described in Section 13.1.4, shall be illuminated at all times irrespective of speed
A003 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 irrespective of speed when either door leaf is open, obstructed, or unlocked.

11.4.3 “Doors Closed” Indicator

Indicator lights shall be provided on 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 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.

A003 When a door-control panel is not activated, the light shall be extinguished.

11.4.4 Lamps

A003 Door signal lights and threshold lights shall use cluster-type LEDs., per Section 13.1.4.
A008

11.4.5 Service Indicator Lights A009

A red LED indicator shall be located in the valance panel above each door leaf panel (12) and shall be illuminated whenever its associated leaf is open, obstructed or unlocked, irrespective of car speed. This local indicator shall also illuminate whenever its associated door leaf is preventing the train from moving due to other causes, such as: Emergency door release; detection of unsafe conditions by the diagnostics; etc. The objective being to locate the problem door in the quickest time possible, such that it may be cutout and bypassed. Indication of Door Cutout annunciation, whether real or due to failure, shall be an available option for the Authority. Annunciation of these same causes shall also be transmitted and displayed by the VMS, to the greatest extent possible, so that there are redundant Detection Methods during normal operation. The method of Detecting and Annunciating failures to minimize recovery time shall be addressed by the Door System FMECA.

11.5 DOOR WARNING AUDIO AND VISUAL INDICATORS

A door operation audio and visual warning system shall be provided for the car. This system shall comply with the relevant requirements of the ADA. When doors are ordered closed, either manually or automatically, audible and visible warning signs shall be provided to alert passengers of closing doors.

The electronic door chime system shall not interfere with the public address (PA) system. There shall be
six separate speakers, one located above each side doorway. There shall also be six door operating A003
indicator lights, one located at each side door opening, which shall be clearly visible from inside and
outside the vehicle.

Door-opening and -closing voice announcements shall be provided in conjunction with door chimes.
Voice recording shall be as provided by the Authority. Upon door opening, the trigger signal shall be
simultaneous for the voice command and door opening. Upon door closing, the voice command shall be A003
triggered by the door chime signal before the doors begin to close.

A verbal announcement (*"Please stand clear of the doors. Thank you."*) shall be initiated whenever 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). This verbal announcement will be provided by the Authority.

11.5.1 Closing

The door-closing voice announcement, in conjunction with door chime tones, shall sound upon receipt of
a command to close the doors. To provide a waiting period after the second tone, the door shall begin to
close at the end of a period adjustable from 0 to 4 seconds, beginning at the command to close. Initially, A003
this shall be adjusted to a 2-second delay. In parallel with the door warning chime, the door operation
indicator lights shall commence pulsing on and off upon receipt of the door close command, and shall
continue pulsing until the doors are closed and locked. The initial pulsing frequency shall be 2Hz, but
this shall be adjustable if necessary. The door-closing indicating lights shall remain extinguished during A006
the opening cycle, and the light in the appropriate doorway shall remain extinguished if a door is cut-out
in that doorway.

11.5.2 Opening

The circuitry shall be so arranged that pressing the door-opening button in any active master door control A008
panel will instantaneously stop the door operation at any time in the closing cycle and cause the doors to

A003 reopen without any delay. 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.

11.6 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
A006 the presence of a 3/8-inch-thick by 3-inch-high bar, when one is inserted between the leaves, at any location along the nose rubber except for the top and bottom six (6) inches. This sensitivity shall be
A003 maintained even if the adjacent door panel is cut-out and mechanically locked.

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
A002 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 between 24 to 31-1/2 lbs., even if the door is locked. The obstruction detection system shall not be overridden by a passenger intentionally holding back the door panels against the pushback feature in the nearly closed position.

An obstruction shall be detected through the measurement of the door operator motor current and by
A003 comparison to the distance vs. time relationship stored in the electronic door control
A008 The following three methods of operation shall be available to the Authority:

A. When the doors have started to close, the detection of an obstruction at either leaf of a door set shall cause both leaves of that door set to reopen fully one time. After a waiting period, which shall be adjustable from 0 seconds to 2 seconds in not more than half-second increments, the door shall again attempt to close.

B. When the doors have started to close, the detection of an obstruction at either leaf of a door set shall cause both leaves of that door set to reopen for approximately 0.25 second, one time, and immediately attempt to close again.

C. No obstruction detection active.

In any of the above methods, the detection of an obstruction during the second closing attempt shall not reopen the door or remove power from the operators, but shall continue to lock out traction control as described in Section 11.1.4. The warning chime shall not sound during the second attempt to close.
At the time of car delivery, the door controls shall be connected to provide method B. However, it shall be possible for the Authority to convert to other methods, or to render the obstruction detection system inactive, by adding or removing a jumper wire or relocating a connection on a terminal strip on either the operators or the door control panels, or by another simple, and approved method.

11.7 DOOR DIAGNOSTICS

At a minimum, microprocessor-based door controllers shall have an Authority-approved self-diagnostic routine that is initiated automatically each time the unit is powered-up. It shall also be possible to initiate the self-test routine via a control local to the unit.

The controller shall have a comprehensive diagnostic system capable of diagnosing failed components. The Contractor shall submit documentation defining the capabilities of this system for Authority approval ***(CDRL 1101)*** A008

Door controllers shall interface with a laptop computer-based portable test device that automatically measures door currents and timing sequence of opening and closing, and allows automatic repetitive cycle tests. The portable test device shall also 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 (see Section 21), which shall include automatic repetitive cycle tests. A008

11.8 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 stored, along 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 incident 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 to the portable test device via the car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. 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. A008

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 20.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via the car communications network. Serial data communication between the DAM and VCU shall be in accordance with LonWorks or other Authority-approved protocol. A008

The DAM shall be assigned a message identification (MID) character within the network so that communications between all units can be managed and controlled.

11.9 CIRCUIT BOARDS AND SOFTWARE

Selection and development of circuit boards and software shall be in accordance with the requirements of Section 22, as well as any other applicable sections of this Specification. Circuit board traces shall be sized to carry the highest current to which they may be exposed, or shall be isolated as approved by the Authority. Fuses shall not be used to protect circuit board traces.

11.10 TESTS

The doors and their operating equipment, including voice announcements, shall be checked and adjusted in accordance with the manufacturer's recommended procedures to ensure smooth and proper functioning and alignment; attainment of the specified speed, closing and pushback forces; and proper functioning of control signals and interlocks. ***(CDRL T1151)*** The Contractor shall submit, for Authority

A003 approval, a test plan detailing the test steps necessary to verify the functional requirements of the door
A008 operating system as defined by this Specification (see Section 3, CDRL 301). The door system shall be subject to performance, qualification, factory acceptance, vehicle level, and reliability testing per procedures generated by the Contractor and approved by the Authority (see Section 3, CDRL 302). The vehicle level tests shall include as a minimum: Obstruction Sensing / Traction Interlock at zero speed and above, Pushback Force, Manual Opening Force, Passenger Emergency Release and Interlocks and Opening / Closing Time on every door panel. The platform detection system, all indicators, lights, chimes and recorded messages shall also be included in the test. Further, a cycle test box shall be connected to the coupler electric heads to exercise the doors on each married-pair a minimum of 500 cycles without failure before the cars are offered for acceptance. Following any failure and corrective action, the cycling test shall recommence until completed without failure. All failures shall be recorded in the appropriate test reports.

A thorough Failure Modes, Effects and Criticality Analysis (FMECA) shall be conducted on the door controls/system in order to ensure the safety of the overall system (see Section 5, CDRL513). This shall include the elimination of all single point failures or multiple failures from a common source leading to either Category I or II hazards. Dormant failures shall not be included as multiple failure modes when addressing single point failures. The system shall be designed to annunciate the first failure by assuming
A003 a safe state (such as door open-traction interlock inhibited) and requiring WMATA intervention to close and cut-out the door. The 'criticality' shall be included to indicate the Mean Time or Mean Distance Between Failure (MTBF or MDBF) as a means of measuring and controlling the probability of undesirable events. The FMECA shall be performed in accordance with Mil-Std-882 latest revision. In addition to the 'bottom-up' FMEA analysis the Contractor shall submit a Fault Tree Analysis (FTA) to indicate the results of multiple failure modes ***(CDRL 515)***. The FMEA / FTA results shall require Authority approval. The Authority shall, at its discretion, require that failures be induced to confirm the validity of the analysis. The induced failures shall be evaluated at the bench level, or at the vehicle level with the controller driving the vehicle doors, as required by the Authority.

The production door operator(s) shall undergo a 1.5-million life-cycle test, per an approved test procedure, where a cycle is defined as one complete open and close movement. ***(CDRL T1152)*** A pair of Operators shall be assembled onto a test frame that is representative of the installation on the car and is transportable, including: the actual door panels (no simulated weights) with nose rubbers, weather seals, interior brush seals, threshold, door guides, crew switches, emergency releases, etc. The cycling shall be arranged to simulate the trainline commands emanating from the cab and shall include all
A003 controls utilized on the individual car. Relays and other controls shall be loaded to simulate the maximum switching load, if this is not provided by one pair of doors. The test rig shall be automatically stopped from further cycling if either door panel fails to reach the fully open position after an open request or if either door panel fails to reach the closed and locked position after a close request. Prior to the start of the test, the Contractor shall demonstrate that the test set up complies with these requirements by introducing obstacles or otherwise jamming the doors. With each failure simulated, the contents of the DAM shall be read to ensure the diagnostics are reporting the correct symptom before the test commences. An electro-mechanical counter shall be included to indicate the total number of cycles accumulated and shall be used as a reference point for all failure reports during the test. The effects of temperature extremes including hot/cold soaking shall be included to evaluate the thermal expansion rates of dissimilar materials, grease selection and elastomer effects on obstacle sizes. Cycle times shall be arranged to provide a duty-cycle that can be sustained by the equipment and may include supplemental air movement if required. A portion of the test shall include human interaction and simulate passenger abuses such as obstructions, leading edge impacts, and stalling of the door operator. The requirements for the test to include human interaction and passenger abuse may be satisfied by placing the test rig in a

location where Authority employees will need to pass through the door opening on a routine basis, or by simulating them at time intervals as specified in the approved test procedure. All operational components shall be exercised as part of the test including, but not limited to, emergency release devices, crew switches, and cut-outs.

Wear and performance parameters shall be initially recorded and then recorded, at a minimum, every 100,000 cycles throughout the test. All adjustments, maintenance and failures shall be logged and made
available for Authority review throughout the test period. Cleaning and re-greasing of the spindle shall A003
not be required more often than twice during the conduct of the test.

All tests shall be performed and documented to meet the requirements specified in Section 3.

11.11 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 513	Failure Modes, Effects and Criticality Analysis	A003
CDRL 515	Fault Tree Analysis	
CDRL 1101	Documentation on Door Diagnostic System	
CDRL T1151	Door Function Test Report	
CDRL T1152	1.5-Million Cycle Test Report	A003

11.12 REFERENCED STANDARDS

Mil-Std-822		A003
49 CFR Part 38	Americans with Disabilities Act (ADA), Accessibility Specifications	A008

SECTION 12
HEATING, VENTILATION, AND COOLING

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SECTION 12
HEATING, VENTILATING, AND COOLING

12.1 GENERAL

The HVAC system shall provide automatic control of interior temperatures as required herein at any ambient temperature from– -5°F to 105°F at the specified wet bulb conditions, with or without solar gain A005 or variable internal heat loads such as passengers, miscellaneous electrical apparatus and lights. Unless otherwise specified herein, the HVAC shall be powered by the auxiliary power system (APS) and shall start and operate within the voltage and frequency ranges specified in Section 7.2 or Section 14. A005

The HVAC system for each vehicle shall include the following:

A. Two overhead heating/ventilating/cooling units, which shall be located in the low ceiling area at each end of the car. The overhead units shall be completely independent of each other.* A003

B. Two compressor-condenser units, mounted beneath the car floor at each end of the car. Each compressor-condenser shall be completely independent of the other.* A003

C. Floor strip heaters.

D. Cab heater.

E. Windshield defroster/defogger.

* The Front- and Rear-HVAC systems, including controls, shall be separated to the greatest extent possible to preclude failures on one half of the system from affecting the normal A003 operation of the other. The Contractor shall supply for Authority approval, a list of failure mechanisms that could affect the operation of both systems concurrently ***(CDRL 1204)***.

F. A service-proven HVAC Control Box shall be mounted underneath the car, within the A005 clearance envelope and shall be serviceable from the side of the car.

G. Outside-air, Return-air, Discharge-air sensors, thermostats, etc. as necessary to control the HVAC system within the limits of this specification. A005

Each overhead heating/ventilating/cooling unit shall consist of a motor and centrifugal blower, an evaporator, and a heater section. Failure of one heating element shall not affect the operation of the other A005 elements. Each of the elements shall be individually removable from the plenum for repair or replacement.

The overhead fans shall continuously introduce a minimum of 1,400 cfm total fresh air into the car whenever the HVAC system is energized and the nominal 230 VAC, 3-phase auxiliary power is available. The overhead electric heat shall heat the fresh air and provide an optimum amount of reheat during the modulated cooling cycle for extended humidity control. Direct expansion cooling and dehumidification coils shall be located upstream from the overhead heating elements. A005

Floor heating shall be convection-type baseboard heating, under the HVAC system's control. The floor heaters shall draw cool air from the floor to promote air circulation and an even temperature distribution within the car under normal operation, and shall provide layover heating when required by the control system.

Both fresh and return air shall be filtered. Fresh and return air shall be drawn locally, and conditioned air shall discharge into the main air distribution ducting and enter the passenger compartment via continuous slot air diffusers adjacent to the fluorescent light fixtures.

Temperature control for each car shall be from a single panel mounted under the car with controls split between front and rear to obtain redundancy and limit single point failures as specified in 12.1.A.
A005 Primary temperature sensing shall be from the rear end of the car to control both systems. In the event the rear unit fails, a temperature sensor in the front end of the car shall control the temperature. Other alternative arrangements of achieving the redundancy may be proposed for Authority approval.

An outward-facing refrigerant service box shall be provided for each compressor-condenser and shall be accessible from the side of the car. Each box shall contain pressure switches or sensors as required by Section 12.4.3 (K) and (L) and valved pressure gauge connections. All for-service connection
A005 ports/service valves shall be equipped with Schraeder valves with captive dust caps. Each service box
A008 shall contain a three-position switch for testing and servicing. Besides the AUTO position that places the compressor-condenser unit under the control of the HVAC controls, there shall be an OFF position and a MANUAL position that places the HVAC control system in the full cool mode for an adjustable time period of from ten to thirty minutes.

The cooling system shall utilize a conventional vapor cycle using a refrigerant compatible with the standards of the U.S. Environmental Protection Agency (EPA). 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.

"All forced-air heating elements shall operate on either the 230 Vac or 700 Vdc supply. The Contractor
A005 shall coordinate the APS capacity, regulation and phase imbalance requirements of Section 14 to achieve this goal. DC heaters where used shall be designed to meet the requirements at 700Vdc and the capacity shall be permitted to vary as the square of the voltage.

All AC motors used in the HVAC system shall undergo a 'type-test' at the manufacturer's facility or testlaboratory, the timing of the test roughly corresponding to First Article Inspection (FAI). Continuous
A005 load on the motors during temperature rise tests shall be that used in the design calculations. The
A008 manufacturer shall demonstrate that the resulting temperature rise will result in an insulation life of no less than 15 years. Actual loads and temperatures measured during climate chamber testing shall be compared to the results of the 'type-test' and any necessary adjustments made to the insulation life prediction.

Temperatures in this section are given in degrees Fahrenheit (°F). The Contractor shall measure and report temperatures in degrees Fahrenheit, and shall determine compliance with stated requirements by comparison of measured temperatures with the appropriate Contract-specified Fahrenheit value.

12.2 HEATING SYSTEM

12.2.1 Overhead Heat

Overhead heat shall be provided in the passenger area by electrical heater elements, which shall be an A005 integral and serviceable part of each of the overhead HVAC units. The overhead heater elements shall be downstream from the evaporator coils and shall be split into two stages and 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 above ambient. Performance shall be met at the nominal supply voltage and nominal heater element design resistance values. The heaters may be powered from high voltage DC or the 230 VAC supply. If A005 powered by the APS, they shall be arranged so that failure of an individual element does not unbalance A008 the APS beyond its capability or the limits given in this specification by monitoring the three phase A009 heater currents and protecting against phase imbalance beyond the design limit.

The heater elements 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. The elements shall be 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 effect of that inertia on the establishment of thermostatic-control operational differentials so as to ensure compliance with the requirements of Section 12.5.4. The Contractor shall also consider thermal inertia when establishing the location and set point of the thermostat specified in Section 12.2.2, paragraph B, as well as the fusible links. A005

Direct electrical connections to the heater elements shall be via approved high-temperature crimp A005 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.

12.2.2 Overhead Heat Protection

Three safety features shall be incorporated into each overhead heater to prevent damage in the event that air circulation stops. They are listed below, in order of precedence of operation:

A. An air-flow sensing device shall open the overhead heat supply whenever air circulation is stopped or excessively reduced. This switch shall be located wherever it will react to failure of A005 the blower, clogging of the filters, restriction or blockage of the cooling or heating coils.

B. A thermostat located in the heater plenum, upon detection of temperatures higher than normal, shall break the overhead heat supply and shall also open the overhead heat circuit breaker by A005 means of a shunt trip. It shall be located within the plenum in such a fashion that it will not be activated by residual radiation or heat stratification when the evaporator fans and overhead A008 heaters shut down simultaneously during a full-heat cycle.

A005 C. In the event that the above two features fail to protect against a hazardous temperature rise, non-resetting fusible link(s) in the high-voltage supply shall positively interrupt the high-voltage heater circuit.

12.2.3 Floor Heat

Panel-type floor heat shall be provided using electric strip heaters consisting of a nickel-chromium resistance wire embedded in a baked, compressed, refractory material, sealed with a rust-resistant, high-heat transfer sheath. The strip heaters shall be mounted behind stainless steel heater guards at floor level
A005 along the side walls and beneath the transverse seats. The front panels of the heater guards shall be constructed so that small sections may be removed for replacement of heating strips without requiring the seats to be dismantled, 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. The heater enclosure shall be designed to resist damage and permanent deformation from passengers kicking or standing on them. There shall be no gap between the top of the heater enclosure and the sidewall
A005 which would allow objects to fall behind the heater enclosure and present a potential fire hazard.

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 (see Sections 8.6.6 and 8.6.7). 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 7.2.

The heaters shall be mounted with ceramic insulators with suitable provision for thermal expansion and contraction of the heater strip. The heater assemblies shall be thermally isolated to prevent direct transfer of heat to the outside of the car.

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 an average interior temperature not less than 47°F above the outside ambient temperature when the overhead heating and ventilation system is inoperative and the line voltage is 700 VDC or higher. In this mode of operation, the average interior temperature shall not be more than 70°F when measured at a minimum of four places equally spaced along a line on the vertical and horizontal centerline of the passenger compartment. Heater performance shall be permitted to vary as the ratio of the square of the voltages.

An approved over-temperature sensor shall be located close to the element at the +700 VDC end of each series string of heater elements (4 minimum). These sensors shall connect 37 Vdc to a shunt trip coil in the applicable circuit breaker, and shall disconnect power to the string(s) if an over-temperature condition is present. The time constant of this protection shall be sufficient to preclude nuisance trips
A005 due to intermittent high voltage caused by regeneration. Each stage of floor heating shall consist of at least two series-strings of heating elements to provide some redundancy in case of failure to a single element. Further the two stages shall use interleaving-elements within the two separate circuits. All wire sizes shall be compatible with the circuit breaker rating and the temperature of the surrounding air.

12.2.4 Layover Heat

Layover heat shall be automatically provided to meet the winter average interior temperature
requirements of Section 12.5.4, whenever the environmental control circuit breaker (ECCB) is closed and
the environmental control trainline is de-energized. Layover heat shall be provided by floor heat only. A005
Control of the layover heat shall not require the HVAC Control Box to be functioning and shall be A008
controlled by a simple thermostat. The same philosophy shall also be used for protective heaters unless
otherwise approved.

12.2.5 Cab Heat

The Operator's cab shall be provided with a forced-air floor heater powered by the auxiliary power
supply system. It shall have adequate capacity to maintain a temperature of not less than 70°F in the cab
compartment at an ambient exterior temperature of -5°F with the overhead heat shut off and the door and
side window closed. For this requirement, no assistance shall be provided by the floor heater, situated A005
under the left side cab window.

The cab floor heater shall be mounted under the console. 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. Fusible-links shall A005
also be provided. The cab floor heater shall be designed to prevent surfaces with which the Operator
may come into contact from exceeding 125°Funder all conditions.

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.

A three-position switch shall be provided on the Operator's console for control of the cab heater (see
Section 14.6.2). The switch shall provide "Off," "Medium," and "High" positions. 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, or when the cab is 'keyed-up' and A005
the cab heater control switch is in "Medium" or "High" position.

Conditioned air shall also be supplied to the cab (see Section 12.3.2) under the control of the heating and A005
cooling control system.

12.2.6 Heated Windshield A008

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 A008
window of ice, frost, and fog under the most adverse weather conditions specified. A lighted indicator
"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.

12.3 VENTILATION

12.3.1 General

Ventilation of the car shall be accomplished by AC motors / blowers that are supplied as a part of the overhead air-conditioning evaporator units and shall be powered by 230 Vac, 60 Hz, 3-phase, from the auxiliary power system (APS). Unless otherwise approved by the Authority, the blowers shall be supported independently at both ends and shall be coupled to the motor shaft by a self-aligning coupling. All motors and all blower wheels shall be fully inter-changeable from one location to any other car in this supply without requiring rebalancing. The Contractor shall consider the noise and vibration requirements
A005 of Section 23 when selecting the arrangement to be used. The fans shall be of heavy-duty construction that does not exhibit imbalance/vibration due to normal handling, dirt build-up between scheduled maintenance and cleaning, including dismantling and re-installation. Maintenance requirements in this area shall be minimal / restricted to inspection during filter replacement and occasional cleaning of the wheels. Shock mounts utilized to minimize vibration shall be bypassed by a flexible ground strap to the carbody.

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 12.3.5, from which it will be discharged into the car.

Baffle plates, if necessary, shall 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 the plate 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 nominal 60 Hz
A005 supply is available. The total evaporator air mass flow rate shall be determined by the following factors:

A. Interior thermal loads

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.

A005 The ventilation system shall pressurize the carbody interior to a minimum of 0.15 inch of water when all doors are closed, the car is not moving, and 230 VAC, 3-phase nominal frequency is supplied for the blower motors.

A008 The evaporator blowers shall operate whenever the car's environmental control trainline is energized, as specified in Section 12.5.1.

12.3.2 Air Diffusers

Air shall be discharged into the passenger compartment through continuous, flush, adjustable (for A005 balancing), slot-type air diffusers located in the ceiling. The air diffuser design shall preclude the impingement of undesirable air 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 70 feet per minute (fpm) when measured in any direction in the normal seating or standing areas and at least 6 inches away from the diffuser. The diffusers may be omitted in A005 the low ceiling areas if the specified uniformity of interior temperatures can be met without them. The slot-type diffusers shall be fixed during vehicle assembly and shall maintain the requirements of Section A008 12.5.5.

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.

12.3.3 Air Grilles

Recirculated air shall be drawn in through grilles in the low ceiling areas. These grilles shall have 'sight-tight' cores and satin finished frames of unpainted stainless steel, and shall be provided with safety A008 catches and limit chains. The grilles shall be designed to pass the required quantity of air without exceeding the specified noise limits.

Fresh air intake grilles located on the exterior of the car shall be removable and shall be made of perforated aluminum or stainless steel plates. Information on the size and style of the perforations shall be submitted to the Authority for approval ***(CDRL 1203)***. The grilles and their fasteners shall be flush A002 with the skin of the car.

12.3.4 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 such is not feasible due to the plenum design, the filter size shall be selected to enable cutting of the filter 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

0.5-inch water gauge pressure drop as tested in accordance with ASHRAE 41.3. The filters shall be adequately supported to prevent blowout of the elements under clogged filter conditions.

12.3.5 Air Ducts

Fresh-air intake ducts shall be constructed of stainless steel, aluminum, or fire-resistant plastic per the requirements of Section 22.24, 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 or 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 22.24 and shall be able to withstand without damage the maximum temperature developed by the overhead heat unit before over-temperature cutoff.

A008 Average air velocities in the ducts shall not exceed 1,200 fpm. Acoustic insulation shall be used on the outside of ducts as required to control objectionable noise.

Metallic ducting shall not be connected directly to the metallic roof structure. Thermal isolation shall be used between the ducting and the structure to minimize heat transfer from or to the ducts.

12.4 COOLING SYSTEM

12.4.1 General

The car shall be cooled and dehumidified by electromechanical equipment having adequate capacity to cool the cars to the temperature specified in Section 12.5.5 under the following exterior ambient temperature, humidity conditions, and heat loads:

A. Ambient temperatures:

1. 95°F dry bulb (105°F dry bulb air into condenser), 78°F wet bulb
2. 105°F dry bulb (115°F dry bulb air into condenser), 80.5°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 utilizing 407 C refrigerant and 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. A008

12.4.2 Air Conditioning Evaporator Units

Evaporator units that are an integral part of each overhead HVAC unit shall cool and dehumidify the fresh and recirculated air. The evaporator-coil fin assembly shall be housed in a rigid stainless steel frame. The coils shall consist of copper tubes and copper fins with a minimum thickness of 0.008 inch and a minimum fin spacing of 0.10 inch. The coil area shall be maximized so that the average face velocity of air flow does not exceed 500 fpm; however, where the coil area is limited by the low ceiling dimensions, air flow velocity exceeding 500 fpm may be approved by the Authority if necessary to achieve specified cooling requirements.

An easily removable condensate drain pan shall be provided beneath the evaporator coil and shall extend to beneath the thermal expansion valves and coil return elbows 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 conditions, including acceleration or deceleration on the maximum grade and jerking. Condensate carry-over into the main duct shall be precluded. A007

Condensate drain lines shall be readily accessible for cleaning and shall be maximum-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. A005

All cold surfaces, including condensate drain lines, coil housings, bottom sides 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 22.24 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 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 capacity 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 12.4.3 are met. A008

C. Serviceable thermal expansion valves for the evaporator coil circuits, having external equalizers and internal superheat adjustment only. Minimum superheat shall be 9°F. A005

D. Brass-bodied liquid line strainer and sight glass with service valves. A005

E. Capped Shraeder valve test fittings in each suction header adjacent to the expansion valve equalizer connections for test 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 for routine inspection and maintenance from inside the car. Motor insulation shall be Class H rated. The motors shall have permanently lubricated ball bearings. A flexible safety
A005 ground strap shall be provided from the motor frame to the grounded carbody structure around the vibration isolation mounts. The motors shall not require thermal protection unless otherwise approved, and shall be designed for continuous duty with the temperature rise due to solar radiation found above the ceiling.

12.4.3 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:

A005 A. Permanently lubricated, totally enclosed, transportation class 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. 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 unit shall automatically adjust its capacity under varying load conditions. A scroll-type compressor may be used in place of a reciprocating compressor, if such is approved by the Authority and meets all relevant requirements of this Specification.

C. An approved flexible coupling between the motor shaft and compressor shaft to facilitate rapid compressor replacement, if an open-type compressor is utilized.

D. A condenser fan. The direction of air flow shall be approved by the Authority for the specific
A005 application of the car, including noise control.

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 a minimum plate fin thickness of 0.008 inch. Minimum fin spacing shall be 0.10 inch. The tube shall be expanded to positively retain the plate fins in position. The coil shall be designed with adequate capacity to keep the system in full cooling at the extreme operating points (as specified in Section 12.4.1, paragraph A2) and full internal loading. 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
A008 the filter core element without loss of refrigerant.

G. A liquid receiver of sufficient capacity to, in combination with the condenser, hold the entire refrigerant charge (in combination with the condenser). The receiver shall be equipped with a sight glass to visually indicate refrigerant level and a fusible plug to protect against excessive system pressures. A008

H. A combination sight glass and moisture indicator located for convenient observation during servicing of equipment.

I. A purge valve located at the high point of the high side system to provide purging of non-condensable gas.

J. Service valves for charging and for test gauge attachment.

K. High-pressure and low-pressure cut-out switches. The low-pressure switch shall stop the compressor motor upon a loss of refrigerant or for a normal pump-down cycle. The high-pressure switch shall stop the compressor upon excessive condenser pressure and before damage to the system would otherwise result. Automatic reset shall be provided for both switches when the pressures become normal. The software shall detect an abnormal frequency of short run times and preclude the affected system from restarting until serviced.

L. An automatically resetting pressure switch shall force the system into reduced cooling (by closing of the modulation valve) when the discharge pressure approaches the set point of the modulation-pressure cut-out switch. For condensing units with more than one compressor, the modulation-pressure cut-out switch may perform a similar function by shutting off one compressor, provided that the compressor is of a type that will not be damaged in this mode. A005 A008

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 23 of this specification.

12.4.4 Insulation

The top and sides of the main air duct shall be insulated with a minimum of 1-inch thick, long-fiber, unfaced fiberglass insulation, or an Authority-approved alternative material, 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., or an Authority-approved alternative material. A003 A003

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.

12.4.5 Piping Design and Installation

Refer to Section 22.14 for piping materials.

The Contractor shall follow the procedures of ANSI B31.5 and the recommendations of the HVAC system's manufacturer regarding 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 22.24 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 the 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 that 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 will be permitted in the suction line.

When its installation is complete, the entire system shall be thoroughly tested to ensure that it is absolutely pressure-tight. No leaks will be permitted.

The system shall be evacuated and charged according to procedures approved by the HVAC system's supplier and by the Authority.

12.5 HEATING AND COOLING CONTROL SYSTEM

12.5.1 HVAC System Activation

A008 The automatic operation of the heating and cooling control system shall be activated through the car's environmental control circuit breaker (ECCB) and environmental control trainline. The control system shall utilize a microprocessor with fault indications as approved by the Authority. ***(CDRL 1201)*** Layover heat shall be controlled by the layover thermostat whenever the ECCB is closed and the environmental control trainline is de-energized. It shall be necessary for the environmental control trainline to be activated as described below, for normal control of heating and cooling.

A008 After the ECCB has been closed, it shall be possible to energize the environmental control trainline, 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.

12.5.2 HVAC System Deactivation

A time delay arrangement shall be provided which shall delay the de-energization of the heating and cooling control system 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 system has been energized on the cars in a train by the methods described in Section 12.5.1, paragraphs B or C, the time delay arrangement shall de-energize them automatically at the end of the preset time interval. A A008
'dry-contact' output of the same time delay function shall also be provided to de-engergize the main, non-emergency car light. The time delay arrangement shall be compatible with that used on the Authority's existing cars.

It shall be possible to deactivate 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 active on every functioning HVAC system in a train. A008
It shall be possible to activate the automatic HVAC control in every car in a train from any point in the

train; and to deactivate it 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 Authority's existing cars.

12.5.3 HVAC Automatic Controls

The heating and cooling control system shall use microprocessor-based solid-state controls for direct A005 control of solid-state devices used for power switching. The accuracy and operating differential of all sensors shall be sufficient to meet the specified car interior temperature requirements.

The battery circuit logic and power devices 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, including AC wiring, shall be separate and suitably permanently identified. High-voltage A005 apparatus adjacent to or part of reset or test devices shall be properly isolated to prevent accidental contact by maintenance personnel. Wire and wire insulation shall be of an approved type as specified in Section 22, and shall be selected to meet the required ampacities for the ambient temperature conditions A008 within the control box. Drain holes with cotter pins that serve to keep the drain holes clear shall be provided in the bottom of the box to prevent accumulation of moisture. All 700 VDC wiring into the box shall be to Authority-approved barrier-style terminal strips in accordance with Section 22.18.2. For all other wiring, mult-pin connectors in accordance with the requirements of Section 22 shall be used to the maximum extent possible. Where connectors are not utilized, strain-relief fittings shall be placed upon removable, gasketed, metal plates such that box replacement does not involve pulling all wires and terminals out of the strain-relief. All wiring shall be permanently tagged or otherwise identified by wire number.

Appropriate high-voltage warning labels shall be attached to the equipment interior and exterior.

A005 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 interlocking of the overhead heating and the air conditioning compressor motor controls shall A005 be provided to prevent heater or compressor activation unless the applicable front or rear blower fan is first energized and delivering the minimum required air-flow.

A005 All high-voltage DC switching devices shall be rated for 1,500 VDC operation. All electrical devices, terminals and plated metal objects shall be compatible with the internal environment of this enclosure for the design life of the equipment. Ventilation shall be provided as required and shall be baffled to prevent car-wash detergents from entering the enclosure.

A005 All relay coils shall have suppression networks across each coil to inhibit transients on the battery circuits.

Printed circuit boards shall be mounted in accordance with Section 22.28.1.

A005 Blocking diodes used in the low-voltage control circuitry shall have a minimum 1,000 Peak Inverse Voltage (PIV) rating.

A mode-indicating panel shall be provided to indicate that the controls are calling for one of the following operating modes: (1) floor heat first stage, (2) floor heat second stage, (3) overhead heat first stage, (4) overhead heat second stage, (5) modulated cooling front end, (6) modulated cooling rear end and (7) full cooling. The indicating devices shall be located so that they can be observed from the face of A008
the heating and cooling control system box and shall be easily visible from the side of the car, with the cover closed. The color of these indicators shall match the existing cars unless otherwise approved. Other LED displays shall be provided for trouble-shooting faults associated with the microprocessor and may A005
be on that enclosure. Critical input and output logic levels, self-test failure, etc. shall be included. A conspicuous red warning LED shall annunicate when protective heaters are required to be ON but heater current is not flowing.

The microprocessor shall also monitor HVAC 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 12.7. Diagnostic testing with the aid of discharge-air sensors at each end of the car A005
shall be implemented during start up. Voltage and current sensors, etc. shall be placed at strategic locations to be able to diagnose and report failures in the system at the earliest time.

Connection of the PTU to the Control Box shall be made via a standard RS 232 connector. Connection of the PTU to the Control Box will automatically display the revision level of the software of both units and the vehicle ID number. This number to be used by the VMS shall utilize a wired connector that stays with the car when Control Boxes are replaced. All data down loaded via the PTU will include the vehicle ID number. Besides the monitoring function and communications with the VMS, the Control Box shall A005
be capable of exercising all controls, overriding the environmental train-line and simulating various interior and exterior temperatures under the control of the PTU. To the greatest extent possible the Control Box shall be able to measure the response to these simulations and give fault indications to the LLRU. Where that is not practicable, the PTU shall provide a prompt for the technician to verify a function or a physical inspection. Additional requirements for PTUs can be found in 21.2.

Covers shall be fully inter-changeable, requiring jigs and proper tooling for manufacture. They shall be A008
sturdy to withstand handling and shall be shaped to prevent ‘drumming’ in the tunnels due to pressure gradients from passing trains, etc. The car number shall be painted/stenciled inside the cover. Hinges and latches shall be manufactured from stainless steel. Latches shall also be the ‘over-center’ locking type that can be adjusted to keep the gasket compressed/box water-tight for the life of the equipment.

12.5.4 Winter/Summer Mode Selection

A winter/summer mode selection device shall be provided so that, when the device is activated, the average interior temperature range will be from 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 within which a more specific temperature will be maintained dependent on load and whether heating, or modulated cooling with or without reheat, is required to balance the load within the range. When either mode is selected, the interior temperature shall not float between the corresponding ranges specified in Section 12.5.5, but will be driven by heat or by full cooling depending on the mode selected. This feature shall be automatically changed by the sensing of A005
exterior temperature, but shall have a suitable time constant to prevent rapid cycling during entry or exiting of the tunnels.

12.5.5 Required Interior Car Temperatures

A008 The following average temperatures (in °F) shall be maintained within the car interior depending on whether winter or summer mode is in effect and the ECCB is “On.

A008

Environmental Trainline	Mode	Ambient Temperature (Dry Bulb)	Average Interior Temperature
OFF	Winter	-5° to 45°F	45° ± 10°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 12.8.1 and 12.8.2, 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 exterior ambient dry bulb temperature exceeds 95°F , the cooling system shall have adequate capacity to maintain either the specified car interior temperatures or a temperature not higher than 15°F below ambient. Similarly, if the exterior ambient temperature falls below 5°F, the heating system shall have adequate capacity to maintain either the specified car interior temperature or a temperature in the car not less than 60°F above the outside ambient temperature.

The wet bulb temperature of the car shall not exceed 64°F (55% RH at 75°F, or 69% RH at 71°F) in the summer mode or 58°F (60% RH at 67°F, or 74% RH at 63°F) in the winter mode when cooling is called for.

The temperature in the Operator’s cab, with the side window closed, the cab floor 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 and the drop ceiling areas, where 5°F variation is acceptable): 3°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: 3°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: 6°F. (This requirement shall not apply to simultaneous opening of the doors on both sides of the train.)

12.5.6 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.

12.6 DESIGN REVIEW REQUIREMENTS

The detailed design of the system shall be presented to the Authority during the system final design review (See Section 2, CDRL 209). Information to be submitted shall include, but not be limited to, 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 frequency. A005

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 at the specified flow rate; dividing of the coil for modulated cooling (if used), and number of rows and fins per inch.

C. Compressor: Volumetric efficiency vs. absolute pressure ratio curves, along with the sweep volume of the cylinders: design RPM for 230 VAC, 3-phase nominal frequency; make and model number of the compressor A005

D. Condenser Coil Design: Air-to-refrigerant temperature differential; degrees of subcooling; pressure drop at design conditions and air flow A005

E. Motors: Current draw, horsepower, insulation class, NEMA description and RPM versus percent load for 230 VAC, 3-phase nominal, 10% overvoltage and 10% undervoltage for the blowers (evaporator and compressor) and compressor motors; make and model number A005

F. Pressures/Temperatures: Design saturated suction and discharge temperatures at full load and 230 VAC, 3-phase nominal voltage; saturated suction pressure setting for the unloaders; 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. Diagrams/Schematics: Electrical schematics, wiring and piping diagrams showing resistance values of each resistor, contactor and solenoid valve coils, wire sizes, and piping sizes. The condition of the circuits as drawn shall be stated A005

I. Vibration Mount Design

J. Balancing Criteria for Motors and Fans.

12.7 VEHICLE MONITORING SYSTEM (VMS) INTERFACE

The input and output signals from each performance-dependent item of equipment within the HVAC system, together with the equipment's power supply voltage, shall be monitored; and these data shall be 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
A008 module shall be capable of being readily downloaded to the portable test device via the car communications network and the local RS232 port and transmitted by the car communicatins network to the central vehicle monitoring system equipment specified in Section 20.6. A functional block diagram of the diagnostics system and its equipment together with all signals that will be stored in the DAM shall be submitted to the Authority for approval as part of the design review process. ***(CDRL 1202)***

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 20.5. The DAM shall convert the signals from its associated
A008 system, analog or digital, to serial packages and store for transmission to the VCU viathe car communications network. 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 (MID) character within the network so that communications between all units can be managed and controlled.

12.8 TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 3.

12.8.1 Air Conditioning Tests

The following air conditioning tests shall be performed.

12.8.1.1 Qualification Test

A002
A009 The air conditioning system in one of the cars of the pilot cars shall be tested in an approved climate laboratory capable of being heated to and maintaining a temperature of 105°F and of maintaining any level of humidity between 25% and 90%. ***(CDRL T1251)*** Temperature in the climate laboratory shall be uniform throughout; a maximum of 5°F variation will be permitted from the rail to a point 2 feet above the roof and from one end of the car to another. 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 105°F for at least 16 hours. After the air conditioning equipment is energized, the length of time required for the car temperature to pull down and enter modulated cooling 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 HVAC operating from the APS supply with 700 VDC at the input, as required by Section 7.2. 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) for any piece of equipment not supplied by a constant frequency AC source. The current drawn by the equipment, its speed, and the line voltage shall be recorded at a minimum of 1-minute intervals 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: A005

A. 50°F dry bulb; 48°F wet bulb
B. 65°F dry bulb; 60°F wet bulb
C. 80°F dry bulb; 75°F wet bulb
D. 95°F dry bulb; 78°F wet bulb
E. 105°F dry bulb; 80.5°F wet bulb

For the temperature conditions specified in paragraphs A through D, tests shall be run twice, once with full passenger and full solar loads simulated, and once with neither of these loads. For the temperature condition specified in paragraph E, the tests shall be run only once, with full passenger and full solar loads simulated. In all cases, equipment load shall be simulated.

12.8.1.2 Functional Test and Adjustment

The thermostatic operation of the air conditioning equipment in all cars shall also be demonstrated by test. ***(CDRL T1252)*** Controls and dampers shall be checked and adjusted for even distribution and proper circulation of air in all cars.

12.8.1.3 Air Diffuser Test

Compliance of the diffusers with the requirements of Section 12.3.2 shall be tested in a laboratory prior to finalizing of the design of the diffuser and, subsequently, in the air conditioning test referred to above, to confirm compliance in the actual car. ***(CDRL T1253)***

12.8.2 Heating Tests

The following heating tests shall be performed:

12.8.2.1 Qualification Test

The heating system, including cab heating, in one of the pilot cars shall be tested in an approved climate laboratory capable of being cooled to and of maintaining a temperature of -18°F. ***(CDRL T1254)*** Temperature in the climate laboratory shall be uniform throughout; a maximum of 5°F variation will be permitted from the rail to a point 2 feet above the roof and from one end of the car to another. Fans may 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 -18°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 A002 A009 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 of -18°F, -5°F, 5°F, 20°F, 35°F and 50°F and/or just above and just below the operating temperatures of any fresh air thermostats that are set close to one of these temperatures. 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 12.8.1.1 shall be recorded every minute for 30 consecutive minutes in order to determine temperature variation as the heating apparatus cycles. Line voltage, current and power drawn by the heating elements shall be continuously recorded. The specified car interior temperature requirements (winter mode) shall be maintained with the car operating at 700 VDC as required by Section 7.2.

12.8.2.2 Heat Transfer Test

Using the car's floor heating elements only, heat transfer through the carbody shall be measured to verify conformance with Section 8.12.2. ***(CDRL T1255)*** This test shall be performed as part of the above-specified qualification test in the climate room held at -5°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. The fresh air intakes may be sealed with light plastic for this test.

12.8.2.3 Functional Test

The heating system in all cars shall be functionally tested. ***(CDRL T1256)*** 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.

12.8.2.4 Defroster Test

The ability of the cab windshield defroster/defogger to comply with the requirements of Section 12.2.6 shall be demonstrated during the heating test described above. ***(CDRL T1257)***

12.9 REFERENCED CDRLs

The following CDRL items are referenced in this section:

	CDRL 1201	HVAC system fault indications
	CDRL 1202	Functional block diagram of DAM
A002	CDRL 1203	Air Grille Details
A003	CDRL 1204	Potential Failures Affecting Both HVAC Systems Concurrently
	CDRL T1251	Air Conditioner Qualification Test Report
	CDRL T1252	Air Conditioner Functional Test Report
	CDRL T1253	Air Diffuser Test Report
	CDRL T1254	Heating System Qualification Test Report
	CDRL T1255	Heat Transfer Test Report

CDRL T1256	Heating System Functional Test Report
CDRL T1257	Defroster Test Report

12.10 REFERENCED STANDARDS

The following standards are referenced in this section:

AAR	Recommended Specification for Air Conditioning
ANSI B31.5	Refrigeration Piping
ASHRAE 41.3	Standard Method for Pressure Measurement
EPA	EPA Standards
SAE J381	Windshield/Side Windows Defrosting/Demisting System Test Procedure and Performance Requirements - Trucks, Buses and Multipurpose Vehicle

SECTION 13
LIGHTING

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SECTION 13
LIGHTING

13.1 INTERIOR LIGHTING

13.1.1 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, white LED fixtures shall be provided to illuminate each side door threshold when the adjacent door is open (see Section 11.4.2).

The arrangement of the fluorescent fixtures in the passenger-area ceiling shall generally be as shown in Contract Drawing 97936-007 and shall be subject to approval by the Authority.

An incandescent or LED reading light shall be supplied for the cab, as shall lights illuminating console controls (see Section 13.1.5).

All incandescent and LED fixture 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 14.2.5 during interruptions of primary power.

13.1.2 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	10 footcandles	A008

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, the reading plane is at a 45-degree angle, 51 inches above the floor.

13.1.3 Fluorescent Fixtures

The exposed portions of fluorescent fixtures shall be similar in appearance to those on existing Authority rail cars, and shall be subject to approval by the Authority. The fixtures shall be arranged with access for maintenance from below, with access provided by a hinged door which contains the diffuser lens. The door hinge shall be made of metal and shall be able to withstand dropping of 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 shall be a concealed type and shall be located on the side of the fixture nearest the side or end of the car. On the side opposite the hinge, the door shall be held closed 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 the requirements of Section 13.1.7. 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.

Lamps shall be limited to 20-watt (F17T8WW), 30-watt (F25T8WW), and 40-watt (F32T8WW) sizes. The lamps 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 the entry of dust, moisture, and insects. The diffuser lens shall be made of UV-stabilized polycarbonate meeting the flammability requirements of Section 22.24. 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 but must be 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.

13.1.4 Threshold Lights

Each windscreen shall have dual white LED lamp fixtures. The lamp beams shall be directed so as to illuminate the door threshold and the floor immediately inboard of the threshold. The fixtures shall be similar in appearance to those on the Authority's existing cars.

The threshold lights shall operate on battery voltage and shall be controlled as required in Section 11.4.2. If required, resistors shall be used to reduce the line voltage to the nominal lamp voltage. The LED bulb or bulb cluster shall be held securely in place and shall be easy to replace.

13.1.5 Cab Lighting

An incandescent or white LED reading light having an adjustable swivel-base type of mounting, similar to those currently in use on the Authority's existing rail cars, shall be located in the ceiling of the cab above the Operator's seat. This light shall provide at least 25 footcandles on the reading plane at 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. Incandescent bulbs used for the cab reading light shall use a 15 candlepower, S-8, double-contact, bayonet-base, long-life lamp, Chicago Miniature 895 or approved equal. LED lamps used for the cab reading light shall provide similar illumination and shall be approved by the Authority.

The console controls shall be illuminated by lights built into the console as specified in Section 14.6.2. The intensity of the console lights shall be controlled by a dimmer arrangement.

13.1.6 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, after a period adjustable from 20 minutes to 1 hour, when there is no control key in the console at either end of the train. This time-delay arrangement may be combined with the time delay arrangement used to de-activate the heating and cooling control systems, as described in Section 12.5.2.

13.1.7 Fluorescent Lighting Ballasts

13.1.7.1 General

Ballasts shall be rapid-start units that shall meet the requirements of UL 595, ANSI C82.1 through C82.3, and ANSI C82.11. 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 inherent in this type of service, including the most severe transients. The ballasts shall operate at a frequency (minimum 20 kHz) above the audible spectrum and shall have electrical noise suppression to meet the EMI requirements of Section 7.6. The ballasts shall operate lamps with minimum detectable flicker with total harmonic distortion of less than 10%. Ballasts shall be solid-state electronic type with a power factor greater than 98%. Lamp current crest factor shall be less than 1.7%. Ballasts shall meet Federal requirements for EMI/RFI (47 CFR 0-19, Ch I). Ballasts shall also meet all applicable ANSI and IEEE standards regarding harmonic distortion and transient protection, such as ANSI C62.41.

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 when one lamp is 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.

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 the reliability and cost-effectiveness of the ballasts.

A008

13.2 EXTERIOR LIGHTS

13.2.1 Headlights, Tail Lights, and Running Lights

Two headlights, two white running lights, two red tail lights, and two red running lights shall be furnished on the end of each cab. The headlights, tail lights, and running lights shall be located as shown in Contract Drawing 97936-005. The lights shall be set in waterproof enclosures.

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 LED cluster lamps as approved by the Authority, 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 white LED cluster lamps as approved by the Authority.

The red running lights shall utilize red LED clusters as approved by the Authority.

13.2.2 Indicators

Exterior indicating lights shall be located as shown in Exhibit 13-1.

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 13.2.3.

Exhibit 13-1 – 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

Indicator Description	Indicator Color	Exterior Location
		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

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 train.

13.2.3 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.

13.2.4 Design

The red and white running lamps shall be designed for replacement from the interior of the car. All other exterior lights called for in this section and elsewhere in this Specification shall be designed for replacement from the exterior of the car and shall feature easy maintenance access. Headlight and tail light aiming shall be accomplished from the car exterior. The hardware used to permit maintenance or alignment of lights 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 in 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 if necessary.

13.2.5 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 bypass switch in the Operator's circuit breaker panel shall permit the tail lights and red running lights to be extinguished and the headlights and white running lights to be illuminated 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 pushbutton on the Operator's console. An indicator light on the console shall be illuminated when headlights are bright.

13.3 EMERGENCY LIGHTS

13.3.1 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.

13.3.2 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.

13.3.3 Power

Emergency lighting shall be powered from 37.5 VDC battery voltage.

13.4 TESTS

The light intensity values specified in Section 13.1.2 shall be verified on the first car during qualification testing. ***(CDRL T1351)***

13.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL T1351	Light Intensity Test Report

13.6 REFERENCED STANDARDS

The following standards are referenced in this section:

47 CFR 0-19	Telecommunications
ANSI C62.41	Surge protection in Low-Voltage AC Power Circuits
ANSI C82.1	Electric Lamp Ballast – Line Frequency, Fluorescent Lamp Ballast
ANSI C82.2	Fluorescent Lamp Ballasts – Methods of Measurement

ANSI C82.3	Fluorescent Lamp Reference Ballasts
ANSI C82.11	High-Frequency Fluorescent Lamp Ballasts
Federal Law 100-357	Federal Efficiency Law
UL 595	Marine-Type Electric Lighting Fixtures
UL 935	Fluorescent Lamp Ballasts

SECTION 14
POWER SUPPLY AND MISCELLANEOUS ELECTRICAL APPARATUS

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SECTION 14
POWER SUPPLY AND MISCELLANEOUS ELECRICAL APPARATUS

14.1 POWER SUPPLY

14.1.1 General

Electrical equipment shall be energized from the following power sources: (1) primary power, (nominally 700 VDC) from the third rail or maintenance shop power; (2) low voltage DC supply (nominally 37.5 VDC) from an installed storage battery system, which shall include a low voltage power supply operating on third rail power that provides battery charging; (3) 3 phase 60 Hz 230 VAC supplied by auxiliary inverter(s) operating on third rail power; (4) 120 VAC, isolated single-phase, 60 Hz generated by the auxiliary power system (APS) inverter.

The Contractor shall submit for approval an overall block schematic diagram of the electrical auxiliary and propulsion circuits showing the proposed circuit topology.

14.1.2 Third Rail Source

Third rail voltage shall be used for propulsion, via inverters for AC drive, floor heating (cab heaters shall use 230 Vac), and as input to the low-voltage power supply (LVPS) and the APS inverter(s). Except under fault conditions, the maximum current draw per car from the third rail shall not exceed 1,620 amperes for more than 1 second. Staggered starting of auxiliary loads may be provided to minimize start up current on the APS or shop supply. If provided, sequencing shall not inhibit any load from starting A005
because the previous load failed to start. Although heavy loads may be started up ahead of smaller loads, the sequencing scheme shall always ensure that the priority is given to the essential loads, such as the air compressor.

All equipment powered from the third rail shall be designed to handle multiple / closely spaced input power interruptions including gaps in the third rail and shoe bounce. A005
Suitable filtering and protection shall be provided to ensure that equipment is protected if the primary power voltage exceed the specified range, and that no damage occurs to equipment as a result of sustained abnormal voltages. The voltage on capacitors shall be discharged to less than 50V within one minute after removal of the power supply, and less than 10V within two minutes after removal. Suitable warning labels and or warning devices of an approved design shall be provided for filter capacitors. Means shall be provided whereby maintenance personnel can easily, reliably and safely verify that each high voltage capacitor has been discharged.

14.1.3 Auxiliary Power System (APS)

14.1.3.1 General Configuration

A service-proven static inverter with microprocessor-based control shall be provided, complying with IEC 61287-1 shall be provided on each car. The inverter shall be capable of operating from primary A002
power and of providing 230 VAC, 60-Hz, three-phase power for AC loads. Galvanic isolation shall be provided for all 230 VAC equipment and for all 120 VAC outlets. The neutral shall be grounded at one location. A005

The inverters shall provide power to the equipment in an adjacent car of a married pair during an inverter
failure. Load shedding will be allowed during inverter failures to allow performance critical equipment
A002 to remain fully functional on both cars. Performance critical equipment shall include the air compressor,
equipment cooling fans if required, half of the HVAC systems in each car, cab heaters / windshield
A005 defrosters, and any other equipment necessary to maintain the operation of the married pair. Load
switching between inverters under such failures shall be automatic and shall prevent both inverters from
supplying power to the same equipment simultaneously should the failed inverter restart.

The inverter output waveform generation scheme, output transformer quality, component mounting, acoustical shielding, and other parameters shall be optimized to minimize audible noise, EMI and interference to the wayside signaling system.

14.1.3.2 Capacity

The auxiliary inverter shall have a 10% minimum excess capacity to start and simultaneously operate all
A002 auxiliary subsystems on one car while operating as a lead car, with battery receiving maximum charge
A003 A005 and HVAC in full cooling. Supplementary supply of an adjacent car during inverter failure as described
A009 in 14.1.3.1 shall also be possible with the above established capacity. The Air Compressor shall be
considered a constant load to account for the occasions when one unit is supplying all compressed air to a 4-car train. All loads must be carried through the specified voltage and elevated undercar tempeature range. If used, sequenced starts shall be completed within 5 seconds after the inverter starts. Load shedding as described in 14.1.3.1 shall only be permitted during inverter failures. The Contractor shall consider the worst-case combinations of loads and inrush currents, as well as elevated undercar temperatures at the specified high-ambient conditions, and that two or more loads may require start-up at the same time during normal operation. During the starting of a heavy load, the inverter frequency and voltage output shall not exceed the specified ranges.

The Contractor shall perform and submit an initial analysis of the auxiliary inverter loads to confirm the
A008 equipment rating ***(CDRL 1401)***. Should sequence starting of auxiliary loads be proposed, the Contractor
shall submit details of the proposed approach for approval. A final analysis of the auxiliary inverter loads shall be submitted prior to the final design review and shall be updated as required to reflect changes in the auxiliary power inverter loads (CDRL 1404). The analysis shall include worst case steady state operating conditions and starting currents and shall be updated with measured load values when available.

A009 The efficiency of the inverter shall be at least 85% over the output power range of 50% to full load.

14.1.3.3 Power Circuit Devices

The auxiliary inverter shall utilize service proven Insulated Gate Bipolar Transistor (IGBT) devices. The power semiconductor assemblies shall be service proven and shall be functionally grouped, keyed, and mounted in modular form to facilitate repair and replacement. The inverter design shall be such that the maximum junction temperature of power semiconductor devices shall be at least 10°C (18°F) below the device manufacturer's maximum allowable junction temperature under the worst-case duty cycle
conditions, including 110% loading and with filters, if used, in a condition representing the replacement
A005 condition.

Power electronic devices and firing circuit modules shall be readily accessible for inspection, maintenance, replacement and testing. All functionally identical modules shall be interchangeable. The device and its firing circuits and protection circuits shall be suitably coordinated to ensure reliable operation of the auxiliary power supply.

14.1.3.4 Fault Tolerance and Protection

The inverter control circuits shall be designed to prevent damage to both the auxiliary equipment and the inverter itself resulting from input power and load variations. The control logic shall allow the power supply to restart automatically for shutdowns caused by self-correcting failures. For major faults when the auxiliary power supply fails to restart, it shall latch the equipment off until manually reset from within the vehicle, or an alternately-approved location. A005

The Contractor shall establish the permissible range of voltage and frequency deviations for faults, which shall be set in the protection circuitry and shall be testable using a portable test unit (PTU). See Section 21.2 for PTU requirements.

14.1.3.5 Self-Test

The APS shall incorporate a self-test to verify that all system components are working normally within pre-defined limits, and to check and troubleshoot the integrity of the static inverter. The APS shall initiate a self-test upon start up. The self-test shall be capable of being initiated by the PTU. Failure A005
conditions from the electronics self-tests shall be communicated to the VMS, stored as faults in the DAM, and shall be downloaded as part of the fault log by the PTU. The Contractor shall submit information on all self-test functions to the Authority for approval. ***(CDRL 1402)***

14.1.3.6 Regulation and Control

Steady-state voltage regulation shall maintain inverter output voltage within ±5% over the entire range of connected loads and over an input voltage range between 430 and 860 VDC and the full range of output loads from zero to full load. The inverter shall start automatically when the steady-state input voltage is between 525 VDC and 860 VDC. The inverter may shut down when the steady-state input voltage is less than 430 VDC. Hysterisis shall be utilized between turn-on and turn-off at both extremes of the range to A005
prevent cycling. The Contractor shall coordinate the design of the APS with the propulsion system to ensure that the APS does not shut down due to transient over-voltages occurring during interruption of the propulsion regenerative braking cycle when traversing third rail gaps and during transition from motoring to coast or braking. The inverter shall be sized for continuous operation of all loads A005
simultaneously and short-time rated for the starting of the largest individual load with all other loads applied. Steady-state frequency regulation shall maintain inverter frequency at 60 Hz, ±2 Hz. The output voltage shall be regulated to maintain a constant voltage-to-frequency ratio during start-up. The system A005
shall be designed to maintain a phase-to-phase voltage unbalance of 1% or less on the 230 VAC subsystem.

The inverter output waveform shall not exceed 10% total harmonic distortion. The root mean squared (rms) value of the harmonic voltages shall be compatible with all permanently connected loads.

Transient response shall be adequate to prevent damage or degraded performance. The voltage or frequency shall return to steady-state value within two seconds after an input voltage step change of 100 volts or a 50% step change in the output current.

It shall be possible to start the auxiliary power supply using only primary power. Alternatively, the dead A005
battery start may be located in the LVPS as described in Section 14.3.

Starting and restarting of the AC loads shall be coordinated with the design of the inverter to prevent prolonged delays. The Contractor shall submit for approval details on the load management subsystem. ***(CDRL 1403)***

All control hardware shall be isolated to protect against possible flashovers that might occur between
A005 high-voltage and low-voltage components or wiring.

The inverter control equipment shall comply with the applicable requirements of Section 22 of this specification. The Contractor shall submit a software architecture plan to the Authority for approval in accordance with Section 22. The plan shall describe the all tasks and define required inputs and outputs.
A005 ***(CDRL 2211)***

14.1.3.7 Line Filter

A line filter shall be provided to ensure transient voltage protection, to filter power frequency components, and to suppress all high-frequency transients as required to comply with Section 7.6 of this Specification. The line filter shall be independent of any propulsion system filtering devices.

14.1.3.8 Cooling

Natural convection cooling of the APS and associated heatsinks is preferred. Over-temperature protection shall be included to protect the equipment from overheating. The detection of over
A005 temperature shall result in annunciation on the Operator's console. If air intakes are necessary, they shall be screened and oriented to prevent ingestion of water, snow and debris. Air intakes shall be arranged so as to prevent obstruction or blocking by snow. Suitable baffling and drains shall provide for removing and draining ingested moisture.

If forced air cooling is proposed, external, filtered, air may be used only for cooling heat sinks. Cooling air shall only be routed through channels free of high-voltage stress to avoid dirt build-up zones and arc over. The reliability of fans, their control equipment and power supply shall be such as to have a negligible effect upon system availability. The design and arrangement of the cooling equipment, control equipment and APS shall be such that failure of the cooling equipment shall not cause damage to the devices being cooled. If a forced air cooling system is proposed, full details shall be submitted for approval.

Air flow sensors or over-temperature protection shall be included to detect the absence of cooling and protect the equipment from overheating. The detection of a failure in the cooling equipment shall result in annunciation on the Operator's console.

All air filters shall be subject to approval. If replaceable filter elements are installed, they shall have a
A005 service life of at least 10,000 miles and shall conform to the requirements of Section 22.

The blower and motor shall have sealed bearings rated for a life equivalent to 6 years or more of operation.

14.1.3.9 Diagnostics

The control equipment shall continuously monitor the operation of critical APS performance-dependent equipment, together with its power supply voltage, and shall identify problems down to the line replaceable unit. All data shall be timed, dated, and recorded in Eastern Standard Time (EST), automatically adjusted for Daylight Savings Time (EDT) and stored in a data acquisition module (DAM). 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 20.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU. The Contractor shall submit for approval data on the design and functionality of the system. ***(CDRL 1405)***

At least 100 operational faults shall be stored in non-volatile memory. Storage of the fault information shall be circular such that the most recent fault will overwrite the oldest fault when the fault logger is full. The level of fault reporting shall be sufficiently detailed to allow operating and maintenance personnel to uniquely identify common faults. The Contractor shall submit for approval a list of faults, together with a functional description of the fault logic. ***(CDRL 1406)***

The fault logging system shall also record at least three fault traces, sampling data at a rate no slower than 100 milliseconds and recording relevant data for 3 seconds before and 2 seconds after the fault. Trace data shall be triggered by major APS faults. The Contractor shall submit for approval a list of triggering faults, together with a functional description of the trace recording system. ***(CDRL 1407)***

Recording of operational 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 a query from the VCU.

All fault, trace, and operation data shall be capable of being readily downloaded to the portable test device via the car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. The PTU shall be capable of downloading the entire contents of the fault logger and displaying the information in real units, e.g. volts, amperes, time of day, etc. A008

All fault, trace, and operational data shall also be available at a standard port for transfer via the car communications network to the central vehicle monitoring system equipment specified in Section 20. 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 (MID) character within the network so that communications between all units can be managed and controlled. A008

14.1.3.10 Testing

Prior to acceptance of each car, the auxiliary inverter and all associated components shall be checked for proper operation. ***(CDRL T1451)***

14.2 BATTERY AND LOW-VOLTAGE DC POWER SUPPLY

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, automatic train control, ATC power supply, and propulsion and braking controls. All systems 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 1408)*** 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. All circuits / sub-systems that can be damaged by reverse
A005 voltage shall be protected by reverse polarity protection within the particular equipment.

The battery system shall be designed to supply the heaviest possible combination of loads that can be
A005
A009 applied thereto in an eight-car train. There shall be no more than a 2.5-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 that can occur (excluding faults) when battery voltage is 26 volts and non-essential loads have been shed. This 2.5-volt maximum drop shall apply to all essential loads within the pair of cars supplied by the battery in question. The Contractor shall be required to conduct a test to demonstration that all essential loads on the married-pair are still performing normally and with a safety margin, while there is 26 volts at the battery terminals, including allowance for the worst-case temperature conditions ***(CDRL T1457)***. The objective is to show that the under-voltage trip will shut-down the married-pair, before any sub-system stops performing normally. 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 26 volts. The B(+) and B(-) battery system trainline 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 shall be accomplished as described in Sections 13.3.2 and 14.2.5.

14.2.1 Battery Capacity

Each "B" car shall be equipped with a nickel-cadmium-alkaline 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
A005 sufficient electrolyte reservoir capacity to be able to endure 6 months of normal service without requiring inspection of electrolyte level or the addition of water, including summer time operation with elevated under-car temperatures. The choice of ampere-hour capacity shall be the Contractor's responsibility, subject to the limitation that all other requirements are met or exceeded. At normal battery operating temperature (+10 to +40°C), the battery shall have sufficient capacity before the under-voltage device trips to:

A. Carry all loads of the married-pair until load shedding, then provide all 37.5-volt loads (including emergency lighting) on a two-car train in the absence of battery charging voltage for a period of 40 minutes, including 20 station stops with passengers boarding and alighting. A005

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. Access via crew doors shall be available but not used during this period A005

C. Carry emergency lighting, communications equipment, 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 2 hours.

Each of the above conditions shall be met beginning with a battery charged to 85% of capacity. A005

Battery capacity outlined in A, B, and C shall be validated with a battery load analysis utilizing either constant resistance or constant power, as each circuit dictates and the battery manufacturer's discharge curves. This analysis shall be included in CDRL 1408. Prior to acceptance of the first married-pair the Contractor shall demonstrate the validity of the analysis as proof that the chosen battery meets the requirements of this section. Data from the test such as individual loads shall be used to up date the analysis. A005

Battery capacity shall not degrade below 85% C_5 A-hr after 2000 cycles with depth of discharge of 40% at a constant ambient temperature of 40°C. Life expectancy of the battery in the WMATA environment shall be 12-years or longer and end of useful life will be defined as: when the battery has degraded to 75% C_5 A-Hr. Procedures for any commissioning charge and reasonable maintenance practices shall be included in the Maintenance Manuals. Reasonable in this instance means: WMATA wishes to reduce battery maintenance to a minimum and capitalize on technology and life cycle costs. A005

The low voltage distribution and train-line circuits shall be adequately sized/rated with a maximum voltage drop of 3V under all operating conditions on an eight car train. A005

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. The protection circuit shall open the battery circuit breaker via the shunt trip 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 are avoided. Its location and mechanical protection shall prevent damage to the sensor during operation and all battery maintenance procedures. Further, its terminals and other parts of the circuitry shall be enclosed or otherwise arranged so that they cannot be the source of an ignition 'spark'. A005 A005

All cells shall include flame-arresting vent and filler caps that stay open for watering and positively lock in place during service. Bus-bars shall be protected by insulating covers. Inter-cell jumper cables shall be a minimum of 3/0 AWG. All positive terminals shall be identified with bright red insulating discs and all negative terminals shall be black. A005

14.2.2 Battery Box

14.2.2.1 General

The battery shall be carried in a box located under the "B" car. The box shall be constructed of 300
A005 series stainless steel and shall provide protection against vermin entry. The box shall be mounted with brackets that comply with Section 8.3.13. A system of guides and rollers shall be provided to allow the battery box interior trays 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, retain it in both extreme positions, and allow it to be maintained by one person. When rolled out, the entire top of the battery shall be exposed.

An automatic topping up device for the battery electrolyte shall be provided. This device shall be portable and easy to operate, and shall allow the routine replacement of battery electrolyte to be
A005 performed automatically. As an option, the Authority would consider the concept of a centralized filing system. Details about these devices shall be submitted for approval.

14.2.2.2 Box Interior and Construction

The box interior shall be lined with 3/16-inch to 1/4-inch thick fiberglass insulating board or an approved
A009 alternate nonflammable, electrolyte-proof, insulating structural material. Each cell shall be suitably separated from the adjacent cell to provide electrical isolation and heat dissipation. Several cells shall be connected together via bus-bars in an insulated carrying cradle with handles. Each cradle shall be
A005 connected to the next by inter-cell jumper cables. The box shall be ventilated to preclude the possibility of hydrogen gas build up in excess of 2% during over-charge, while the car is stationary or irrespective of the direction of motion. Vents shall be baffled to prevent the entry of car washing fluids and precipitation. A removable drain plug shall be provided in the bottom of the box. The box shall be designed to accommodate batteries from alternative manufacturers while still meeting all other requirements of these specifications. During the design reviews, the Contractor shall submit drawings showing the lay-out of each battery type and arranged in such a manner that the main cables will reach the output terminals. Data sheets shall be provided to confirm the electrical characteristics of the alternative batteries relative to the capacity, life expectancy, watering frequency, etc.

14.2.2.3 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
A005 other than the tool required to unlock the trays. The Contractor shall ensure that the roll-out tray is designed to support 150% of the battery weight in the fully extended position without permanent deformation.

The 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. Bearings and slides shall be over-sized,
A005 heavy-duty type and shall be locked in the stowed position to prevent 'brinneling' of the bearings with the motion of the train.

The battery box and tray locks shall be electrically interlocked so as to prevent train movement at all A005
times unless both the box and trays are locked in the fully housed position. The interlocks shall be
provided by a heavy-duty, industrial-style, totally-enclosed, limit switch with adequate pre-travel / over- A005
travel and selected specifically for this vibration environment. The locks shall have sufficient strength to
prevent movement of the battery box and trays when subjected to the specified forces and loads during
normal operation of the car and shall minimize ‘brinnel’ damage to the roll-out bearings.

14.2.3 Battery Circuit Breaker

A battery circuit breaker of adequate capacity and approved design shall be mounted in a separate
enclosure under the “B” car adjacent to the battery box. The breaker shall isolate the battery from the 37
VDC circuits except for those on the battery bus that are protected by a separate fuse(s). The breaker
shall be as specified in Section 14.6.1.3. Main cables between the battery terminals and the battery
circuit breaker shall be: flexible, adequately sized, insulated, supported and protected to preclude A005
accidental puncturing during battery roll-out for maintenance and fretting due to vibration, etc. The main
cable passageway to the circuit breaker shall have no sharp edges, shall be lined with suitable material
and all steps must be taken to ensure there is no possibility of a short circuit up-stream of the protection.

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, a local annunciator light at the A005
breaker to be illuminated, and indication via the VMS to the active cab. Trip voltage shall be set at 26 A009
volts and shall incorporate some hysterisis. Reset shall be achieved by manual lifting of the handle at the
breaker. Tripping on this basis shall function to prevent battery damage that might otherwise occur due
to cell reversal and shortening of battery life due to deep discharging. 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.

14.2.4 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.

14.2.5 Load Shedding

In the event of LVPS failure or the loss of third rail power, the battery load shall be shed automatically A005
after a predetermined length of time approved by the Authority, leaving the battery sufficient capacity to
meet the requirements of Section 14.2.1. 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, including crew doors, operators, indicator lights, and voice announcements A005
C. ATC power conditioning equipment
D. Exterior lights
E. Emergency lighting, including threshold lights
F. Emergency brake controls
G. All protective heater circuits

H. Control lock interlock and master controller signals
I. Fault indicator lights
J. Friction brake
K. Radio
L. VMS and VCU in the lead car
M Public address and intercom.
N. Propulsion control
O. Windshield wiper and horn control
P. APS control

14.2.6 Battery System Testing

A003 Batteries shall be given a capacity test at the point of manufacture in accordance with IEC 623 ***(CDRL T1452)***.

Prior to acceptance of each car, all components of the battery system shall be checked for proper operation, including the operation of the load shedding system. ***(CDRL T1453)***

14.3 LOW-VOLTAGE POWER SUPPLY

An approved low-voltage power supply (LVPS) shall be furnished and installed on each "B" car. The LVPS shall be service proven in a rail vehicle environment. The LVPS 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 7.2.

A005 The LVPS shall provide the low voltage power for a pair of cars that includes battery charging, traction control, trainline control, all emergency loads, normal and emergency fluorescent lighting, and all other auxiliary car circuits connected to the battery supply. 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 7.2 and over the full range of output power up to 100% output loads.

The LVPS shall be a regulated DC power supply complying with IEC 61287-1. The LVPS shall provide for complete electrical isolation from input to output, and from both input and output to the enclosure and carbody. The LVPS shall be able to charge a dead battery without battery damage or LVPS overload.

Converter control circuitry shall be accessible from the side of the car for maintenance.

The Contractor shall review the converter interface design with the supplier of the propulsion equipment to ensure that the energy storage characteristics of the converter do not interfere with propulsion system operation and protective devices such as potential relays.

14.3.1 Capacity

A005 The LVPS is used to charge the battery and supply all low-voltage DC loads, including essential loads specified in Section 14.2.5. Power supply capacity shall be rated to supply 120% of worst-case combinations of peak loads of a married pair, or 375 amps, whichever is greater. The LVPS shall recharge a fully discharged battery to 50% of capacity within 2 hours and to 85% of capacity within 5 hours.

The Contractor shall submit for approval a load analysis and description of operating characteristics. ***(CDRL 1409)*** The LVPS output shall be current limited. In case of LVPS failure or loss of input power, LVPS loads shall be transferred automatically without delay to the battery.

14.3.2 Power Circuit Devices

The LVPS shall be provided with power circuit device features as specified in Section 14.1.3.3. A005

14.3.3 Fault Tolerance and Protection

The LVPS shall have overload protection. For load or fault conditions of very low load resistance (such as a dead short), the LVPS control shall "fold back" (limit both current and voltage), disconnect the output, or shut off. Normal operation shall resume automatically when the overload or short circuit is removed. Over-voltage and reverse polarity protection shall be provided.

14.3.4 Self Test

The LVPS shall provide self-test capability as specified in Section 14.1.3.5 and shall be reported in CDRL 1402 along with the APS. A005

14.3.5 Regulation and Control

The LVPS supply shall maintain a constant output voltage of 37.5 VDC ±0.5 volts, adjustable ±10%, for input voltages from 430 to 860 VDC and for any combination of output load, returning to regulation band within 0.1 second. LVPS regulation shall be as required by the loads, including the battery. Negative temperature coefficient (NTC) compensation of voltage shall be permitted if necessary to meet battery electrolyte servicing requirements. A005

The power supply shall have an output ripple of less than 5% peak-to-peak from zero to full load with battery connected. The over-charge current shall be such that the battery electrolyte servicing intervals are no more frequent than every 6-months. The LVPS shall include circuitry to detect and annunciate failures. 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. A005

The LVPS control system shall comply with the relevant requirements of Sections 14.1.3.6, 14.1.3.7, and 14.1.3.9.

14.3.6 Cooling

The LVPS shall be cooled as specified in Section14.1.3.8.

14.3.7 Diagnostics

The LVPS shall be provided with diagnostics as specified in Section 14.1.3.9 and shall be reported in CDRLs 1405 and 1406 with the APS data. A005

14.3.8 LVPS Testing

The LVPS shall be tested in accordance with IEC 61287-1, including optional sudden variation in load test (4.2.6) and effectiveness of filter test (2.4.6.5c) and IEC 61133. ***(CDRL T1454)*** The Contractor shall perform noise vehicle tests per IEC 61133 and vehicle acceptance tests in accordance with Section 3 of this Specification.

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 ensure that the power converter conforms to the vehicle ATC specifications identified in Section 18 and shall secure the approval of the ATC equipment manufacturer for the design and installation of the power converter. ***(CDRL 1410)***

14.4 CONVENIENCE OUTLETS

Two duplex convenience outlets shall be provided in each passenger compartment, located in the wall
A005 under the transverse seat or in the base of the adjacent back-to-back seats, as shown in Contract Drawing 97936-001. Convenience outlets are also specified for the cab area as shown in Exhibit 14-2.

At each location, one of the outlets shall be supplied with nominally 37.5-volt battery voltage; the other outlet shall be supplied with 110-volt, 60 Hz. The 37.5-volt outlet shall have a capacity of 50 amperes and shall be protected by a suitable circuit breaker. It shall have the same plug interface as Hubbell Model 9367 used on the Authority's existing cars. The 110-volt outlet shall have a capacity of 20
A005 amperes and shall be protected by a suitable circuit breaker. It shall be a 20-ampere, 125-volt, 2-pole, 3-wire, grounded receptacle. The outlets shall have hinged cover plates that close automatically when not in use and shall be secured with a ¼-turn, tamper-proof fastener as approved by the Authority. The rear of each individual outlet shall be enclosed by a grounded electrical box that prevents accidental contact with the terminals, and shall trip the appropriate circuit breaker should the 'hot' side touch the box. The boxes shall also prevent the battery and AC voltage terminals or wiring from contacting each other should they become loose.

14.5 BATTERY SYSTEM CIRCUIT GROUNDING

14.5.1 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.

14.5.2 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. 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 14.2.4 shall be returned to the battery system return bus plate on the "B" car via the B(-) trainline cable described in Section 14.2 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 14.6.1.3. In addition to sizing negative return wires based on current carrying capacity, the Contractor shall consider voltage drop and noise sensitivity of the involved circuit in the final selection of wire size.

14.5.3 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 copper posts or terminals, brazed or silver soldered to the bus plates and of adequate size to accommodate the wiring. No more than two wires may be connected to any one terminal. The battery return bus plates shall contain sufficient terminals to handle all return wires from the connected loads including the ATC and communications systems, 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 22.17.4.

14.6 CONTROL AND CIRCUIT BREAKER PANELS

14.6.1 General

14.6.1.1 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 Sections 14.6.2 through 14.6.4 are not necessarily complete; they are intended principally to identify the desired locations for the various items listed.

14.6.1.2 Switches

Switches shall be of the toggle-action, indicating type unless otherwise specified.

14.6.1.3 Circuit Breakers

Circuit breakers shall be an approved type of highly shock-resistant design suitable for railway service and bolted in place. They shall clearly indicate whether "On," "Tripped," or "Off." Circuit breakers 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 prevent 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 this 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. Currents that 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 Authority's existing 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 ensure 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.

One branch circuit breaker shall be provided for each AC load and shall be rated to provide short circuit and overload protection. Spare spaces shall be provided, equivalent to at least 10% of the total number of circuit breakers. Circuit breakers shall comply with the requirements of Section 22.

Circuit breakers feeding performance critical systems shall be monitored and circuit breaker trips shall be annunciated in the controlling cab and recorded in the VMS.

Circuit breaker terminals shall not be used as junction points.

14.6.1.4 Fuses

Circuit breakers shall be used for circuit protection wherever possible. However, fuses may 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.

14.6.1.5 Auxiliary Circuit Testing

Prior to acceptance of each car, all auxiliary circuits and equipment shall be checked for proper operation. ***(CDRL T1455)***

14.6.2 Operator's Control Console and Auxiliary Control and Indicator Panels

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 14-1. 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 1.2.5.1.
All pushbuttons and indicators shall be uniform in style, and shall be arranged, sized and labeled as shown in the Contract Drawings. Insofar as possible, all pushbuttons and indicator lamps shall be of the same manufacture.

All pushbuttons indicated in Exhibit 14-1 as being normally lighted shall have their legends engraved on the top surface or marked in such a way that the legend visible by reflected light as well as by internal illumination. All pushbuttons on the portion of the console angled 15º from the horizontal shall be of the barrier type, to prevent undesired activation.

All indicators, except combination pushbutton/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 pushbuttons and indicators shall be adjustable, under control of the four-position console light control 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 light 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 replaceable 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 pushbutton 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 control switch is set to "Low." The communications channel selector switch shall illuminate the number corresponding to the channel selected.

All pushbutton switches and combination pushbutton/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, pushbutton 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 pushbuttons 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 shall be capable of being tilted upwards at least 45º, to provide 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, pushbuttons, 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, who 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 18 and the Contract Drawings.

Exhibit 14-1
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-For" position of 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 A005
*** 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.							
3.	Master Controller	Controls propulsion and	P5, P4, P3, P2, P1,	(1)	White	--	Increasing power position numbers

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
		braking in manual operation.	Coast, B1, B2, B3, B4, B5, Emergency, and Auto/Store				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 14-1
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 Pushbutton	Immediately 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 Pushbuttons (2 locations)	Opens side doors on entire train. Forestalls automatic closing.	Open Doors	(5) (6)	White White	-- --	
11.	Door Close Pushbuttons (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	--	
15.	Regulated Speed Indicator	Indicates input to ATO speed regulator.	Regulated Speed	(1)	Yellow	--	Indicates either ATS or ATP speed command, whichever is lower.

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
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	--	
26.	Motor Overload or Ground Fault Indicator and Reset Pushbutton	Indicates motor overload or ground fault has been tripped on one or more cars in train. Reset pushbutton 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.

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
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 head-lights, bright or dim.	High Beam	(1)	--	Blue	
29.	Emergency Brake Pushbutton (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 Pushbutton	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	Immediately actuates Yard Horn, and sounds buzzer in all cabs.	Yard Horn and Buzzer	(5)	--	--	
39.	Signal Buzzer	Permits others onboard to signal to operator and vice versa.	Intercar Buzzer	(1)	--	--	

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
40.	Snow Brake Pushbutton/ 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 Pushbutton	Cancels programmed station stop.	Station Stop Cancel	(1)	--	--	
43.	Train Berthed Pushbutton	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 Pushbutton	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)	--	--	

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
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 Bypass 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						
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	Alerts Operator to incoming		(9)	--	--	Activated by a pushbutton adjacent to

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
	Chime	call on passenger call system					each passenger call microphone.
63.	Passenger Call Talk Back Pushbutton	Allows Operator to reply to a passenger call.	Talk Intercom	(1)	--	--	When pushbutton is released, Operator will hear conversation from passenger.
64.	Passenger Call Reset Pushbutton	Disconnects activated passenger call station.	Reset Intercom	(1)	--	White	Annunciator lamp indication button is lighted when any pushbutton adjacent to a passenger call microphone is depressed. Remains illuminated until Reset pushbutton 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 varia-tion 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 Pushbutton	Activates public address system.	Talk P.A.	(1)	--	--	Pushbutton must be held depressed while announcement is being made.
70.	Radio Public Address Pushbutton	Provides for train announce-ment over public address sys-tem from train radio input.	Radio P.A.	(1)	--	--	Pushbutton must be held depressed while announcement is being made.
71.	Central Call Pushbutton	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	Permits override of	Dest. Sign Input;	(5)	--	--	

Exhibit 14-1
Operator's Cab - Train Operation and Communication Controls - Functional Description

Item No.	Control	Function	Nomenclature	Location*	Normal Color Lighted	Color of Indication	Remarks
	Control	automatic control of destination sign.	Auto, Special, No Passengers				
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 Transmitting.	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 Cut-out	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.	Blank						
86.	Brake Fault Detected	Indicates a blue light condition exists within the train.	Brake Fault	(1)	--	Blue	
87.	Dead Car Indicator	Indicates a dead car within the train.	Dead Car	(5)	--	Red	
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.

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14.6.3 Operator's Circuit Breaker Panel

A panel containing the circuit breakers listed in Exhibit 14-2 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 14-2
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 HVAC system; 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 for easy identification of a tripped breaker during marginal lighting conditions without the aid of a flashlight.

In addition to the circuit breakers listed in the Exhibit 14-2, the Operator's Circuit Breaker Panel shall contain the following switches:

A. Door Control Selector Switch: Refer to item number 13 in Exhibit 14-1.

B. Door/Traction Interlock Bypass Switch (Door Interlock): Refer to item number 53 in Exhibit 14-1.

C. Door Control Trainline Cut-Out Switch: Refer to item number 55 in Exhibit 14-1.

D. Propulsion Cut-Out Switch: Refer to item number 56 in Exhibit 14-1.

E. Dynamic Brake Cut-Out Switch: Refer to item number 57 in Exhibit 14-1.

F. Power Knockout (Brake Release Interlock Bypass Switch): Refer to item number 58 in Exhibit 14-1.

G. Headlight Override Switch: Refer to item number 59 in Exhibit 14-1.

14.6.4 Auxiliary Power Breaker Panels

A005 Auxiliary power circuit breaker panels shall be located in separate equipment boxes under each car. The circuit breakers shall be accessible from the side of the car. These panels shall contain, as a minimum, the circuit breakers listed in Exhibit 14-3, and shall separate the 230 VAC and 700 VDC circuits.

Exhibit 14-3
Auxiliary Power Breaker Panels

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 shall be provided for the 37.5 VDC circuits listed in Exhibit 14-4. This panel shall be located either in a separate enclosure adjacent to the Auxiliary Power Circuit

Breaker Panel and 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 22.17.3.2.

Exhibit 14-4
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

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.

14.7 THIRD RAIL CONTACT SHOE ASSEMBLY

14.7.1 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 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.

14.7.2 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 of 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 the shoe holder or 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. Attaching 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.

14.7.3 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.

14.7.4 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.

14.7.5 Third Rail Shoe Testing

Prior to the acceptance of each car, each third rail shoe shall be set at the proper height and spring tension and functionally tested. ***(CDRL T1456)***

14.8 VEHICLE GROUNDS

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 14-5.

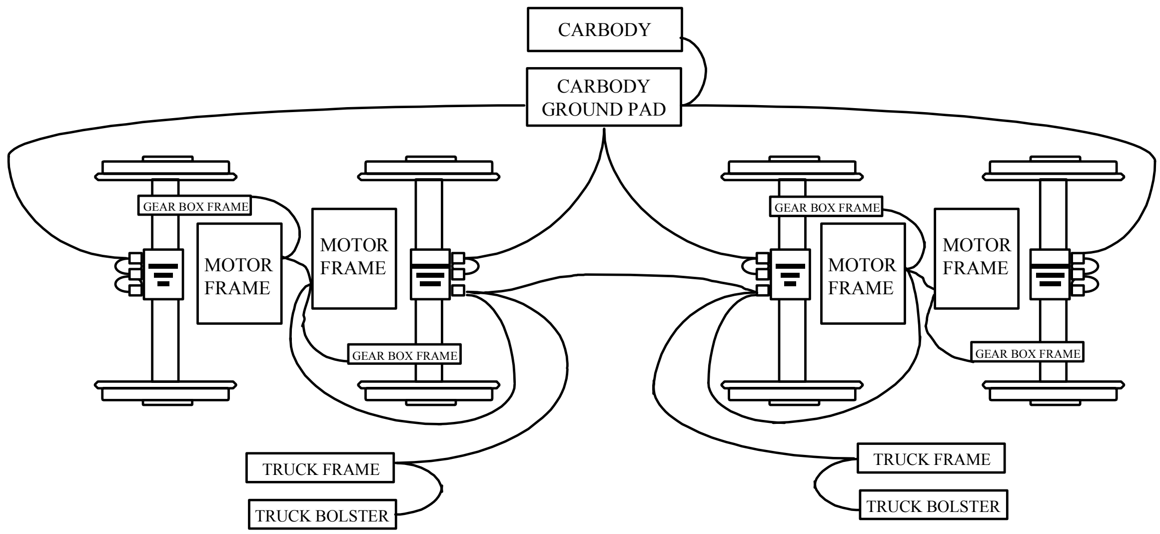
The traction return ground pad shall be electrically insulated from the carbody. The ground pad shall be electrically connected to the vehicle chassis through a shunt cable of adequate capacity.

Provisions shall be made on the vehicle chassis to connect the brushes of the truck apparatus safety groundbrush 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.

Exhibit 14-5
Vehicle Grounds



14.9 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 these 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 to the portable test device via the car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. 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. A008

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 20.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via the car communications network. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol. A008

The DAM shall be assigned a message identification (MID) character within the network so that communications between all units can be managed and controlled.

14.10 REFERENCED CDRLs

The following CDRL items are referenced in this section:

A008	CDRL 1401	Initial Analysis of Auxiliary Inverter Loads
	CDRL 1402	Self-Tests of APS
	CDRL 1403	Details of Load Management System
A008	CDRL 1404	Final Analysis of Auxiliary Inverter Loads
	CDRL 1405	Data on Design/Functionality of Diagnostic System
	CDRL 1406	List of Faults and Functional Description of Fault Logic
	CDRL 1407	List of Triggering Faults and Functional Description of Trace Recording System
	CDRL 1408	Plan for Battery System Electrical Compatibility
	CDRL 1409	Load Analysis of LVPS and Description of Operating Characteristics
	CDRL 1410	Design and Installation of the Power Converter
A005	CDRL 2211	Software Assurance Plan
	CDRL T1451	Auxiliary Inverter Test Report
	CDRL T1452	Battery Capacity Test Report
	CDRL T1453	Battery Function Test Report
	CDRL T1454	LVPS Type Test Report
	CDRL T1455	Auxiliary Circuit Function Test Report
	CDRL T1456	Third Rail Shoe Function Test Report
A005	CDRL T1457	Under-Voltage Trip Test

14.11 REFERENCED STANDARDS

The following standards are referenced in this section:

IEC 61133	Electric Traction - Rolling Stock - Test Methods for Electric and Thermal/Electric Rolling Stock on Completion of Construction and Before Entry into Service
IEC 61287-1	Power Converters Installed On Board Rolling Stock - Part 1: Characteristics and Test Methods

SECTION 15
PROPULSION SYSTEM

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SECTION 15
PROPULSION SYSTEM

15.1 GENERAL

All cars to be furnished under this Contract shall be equipped with variable-voltage, variable-frequency (VVVF) type propulsion control. The propulsion system shall be a service proven design.

15.1.1 Responsibility

The Contractor shall be responsible for the coordination and proper installation of all components of the propulsion system, and for its interrelation with other car systems, to ensure the successful functioning and proper performance of the completed car in accordance with the requirements of the Specification.

15.1.2 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 existing traction power supply system. The Contractor shall observe the voltage ranges established in Section 7.2 in the design and manufacture of the transit cars and their apparatus.

A. With third rail voltages as described in Section 7.2, the following performance standards shall be met by a six-car train, with new wheels and on level, tangent track:

1. With a passenger load of 24,000 lbs. (160 passengers) per car, the following standard shall be met:

a.	Initial accelerating rate	2.8 mphps +0.2, -0

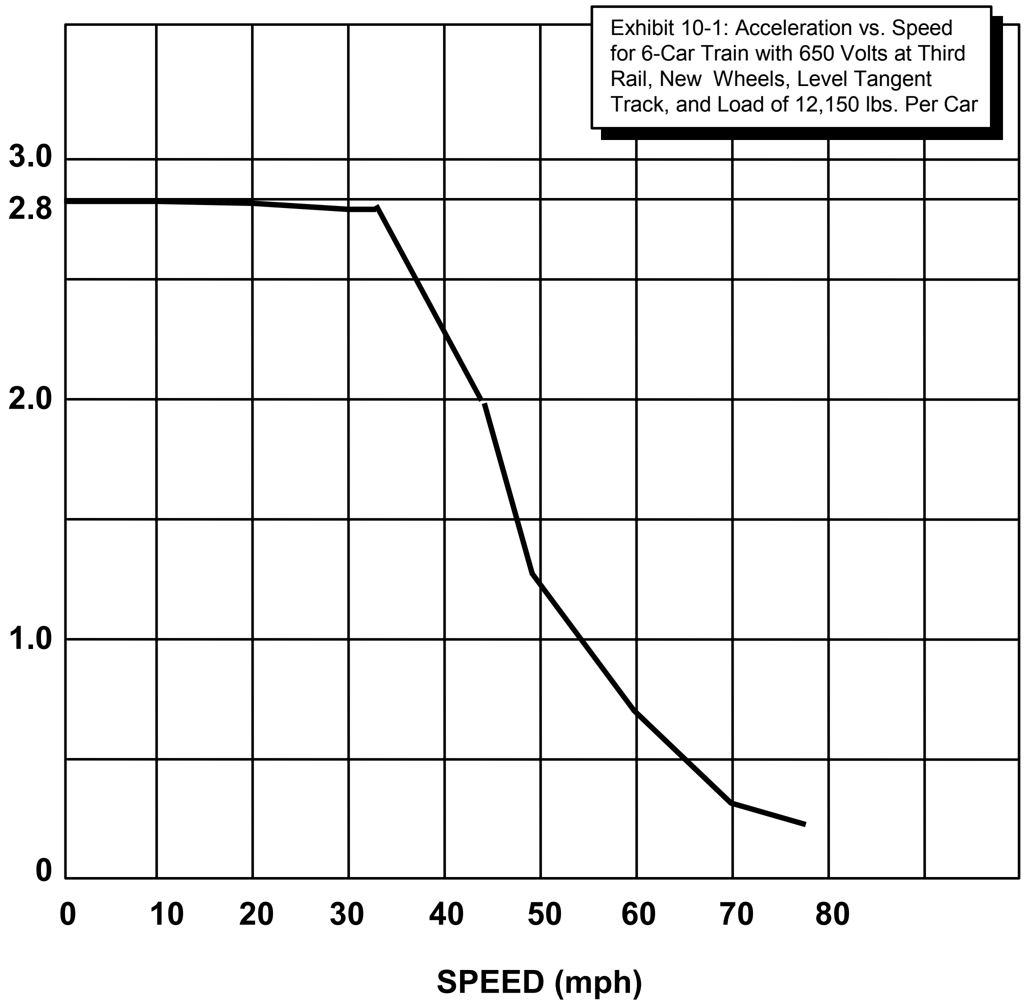
2. With a passenger load of 12,150 lbs. (81 passengers) per car, the following standards shall be met:

a.	Initial accelerating rate	2.8 mphps +0.2,-0
b.	Time to reach 50 mph	23 seconds or less
c.	Time to reach 75 mph	75 seconds or less
d.	Distance traveled in 50 seconds from a standing start	3,400 feet or more
e.	Distance traveled in 70 seconds from a standing start	5,500 feet or more
f.	Acceleration capability at 75 mph	0.25 mphps or more

B. In addition to the above minimum performance requirements, an eight-car train, with cars loaded to 12,150 lbs., shall have an acceleration vs. speed characteristic as shown in Exhibit 15-1, 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 the service life of, the car or any of its equipment.

Exhibit 15-1
Acceleration vs. Speed



D. The propulsion system shall provide dynamic braking capable of developing the following deceleration rates for car weights AW0 through AW3 (crush load):

Braking Level	Instantaneous Rate	Tolerance
B1	0.75 mphps	+/- 0.1 mphps
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

The specified instantaneous rates for braking levels B1, B2, B3, and B4 are those produced solely by the propulsion apparatus, and do not include any contribution from train resistance. Braking level B5 includes train resistance.

All braking rates specified are instantaneous values and do not include compensation for build-up or reaction times.

The braking rate request in levels B2, B3, B4, and B5 shall be speed tapered to produce, at 75 mph, 75% of the specified instantaneous rate, increasing linearly to 100% of the specified instantaneous rate as speed falls to 50 mph and below.

E. The propulsion system shall be closely coordinated with the friction brake system described in Section 16.

F. The propulsion and propulsion control system of the vehicles procured under this Contract shall maintain full functional compatibility with the Authority's existing 1000, 2000, 3000, 4000, and 5000 series cars.

G. The propulsion and electrical brake equipment shall be capable of making any number of consecutive non-stop trips between Metro terminals Addison Road/Franconia-Springfield, Shady Grove/Glenmont, Vienna-Fairfax/New Carrollton, Greenbelt/Branch Avenue, and Gallery Place/Huntington without exceeding the 1-hour ratings published by the manufacturer of the propulsion apparatus, under the following conditions: stopping at all stations for 15 seconds, observing all civil speed restrictions, turn-around time of 30 seconds at each terminal station, and carrying a load of 160 passengers with full performance acceleration and normal dynamic braking (B4) with either a receptive or non-receptive line. Continuous operation under these conditions shall not result in degradation, damage or reduced reliability from the Propulsion System when the maximum undercar ambient temperature and worst-case line voltage (in the range of 650-750 VDC) are utilized. A002 A003

H. Traction equipment shall be designed to allow an eight-car train of operating cars with a normal load (81 passengers), 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 A003

A003 dwell time of 15 seconds. This condition shall be met without exceeding the 1-hour rating published and demonstrated by the Propulsion Supplier.

I. When temperature rise has stabilized following continuous round trips defined in (G) above, a four (4) car train operating under the same conditions shall make one round trip with a propulsion failure / one car cut-out. During braking, the friction brake system shall be assumed to be working normally on the cut-out car, otherwise all positive and negative tractive effort shall be provided by the three active propulsion systems. This condition shall be met without exceeding the 1-hour rating published by the Propulsion Supplier and shall be
A003 demonstrated with simulations and type tests.

A003
J. Under no circumstances shall a failure of the traction power and friction brake system result in violation of the Authority's Automatic Train Protection system block design.

A003 K. In anticipation of the time when the Authority's entire fleet is equipped with AC propulsion, the design of the AC propulsion control system shall not preclude the removal of the DC motor emulation function in favor of an approach that takes full advantage of the AC propulsion system performance characteristics. The propulsion control software for the propulsion system provided under this Contract shall be structured to anticipate the eventual removal of the emulation function by the propulsion system supplier. This shall include provisions for the conversion of the existing Rate Request and Motor Connection Trainlines.

15.1.3 Adjustments

For the purpose of calculations, including adjustment of performance data obtained under conditions other than as defined in Section 15.1.2, standard Davis train resistance formulae shall be used. Flange friction and air resistance coefficients may be modified to make allowance for truck wheel base 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 1501)***

Propulsion system operating parameters, including tractive effort and jerk rate, shall be programmable to enable initial performance to be set and for maintenance purposes.

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 a portable test unit (PTU) as specified in Section 21.2.

The adjustment for wheel wear shall be implemented via a PTU. At a minimum, adjustment for wheel wear shall be possible to 1/4-inch increments of diameter from new to fully worn wheels.

15.1.4 Control

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.

15.1.5 Electrical Protection

All electrical protective apparatus and systems shall be subject to approval by the Authority and shall include the following ***(CDRL 1503)***: A002

A. Inverter phase overcurrent protection
B. Inverter phase current imbalance protection
C. Ground fault protection (i.e., return of nominal 700-volt propulsion system current via improper paths) A003
D. Propulsion overload (excessive line current) protection A003
E. Filter capacitor monitor
F. Transient voltage protection
G. Over- and under-voltage protection A003
H. 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 high-speed circuit breaker (HSCB) or 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.

Activation 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 pushbutton in the control cab or from the ATC. Resetting the apparatus shall be possible only while the train is stopped. The 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 requiring the removal of 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 and switches which can interrupt traction current shall be provided with arc chutes adequate to ensure 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.

15.2 VARIABLE-VOLTAGE, VARIABLE-FREQUENCY PROPULSION SYSTEM

15.2.1 General.

The variable-voltage, variable-frequency (VVVF) propulsion system shall be based on service proven
A002 IGBT or GTO technology. The propulsion control system shall use a 32-bit microprocessor-based system.

15.2.2 Configuration

The propulsion and propulsion control system shall be configured to provide control on a per-truck basis.

The propulsion/dynamic brake electronic controller shall be independent of and separate from the friction brake controller. The propulsion/dynamic brake controller shall continuously read and interpret the
A003 command trainlines to initiate and control appropriate action of the propulsion system in motoring and dynamic braking.

A003 The propulsion/dynamic brake controller shall also read and interpret the trainlines and load weigh signals independently of the friction brake controller.

The propulsion/dynamic brake controller shall communicate its status to the friction brake controller to ensure that the friction brake system provides the appropriate braking rates whenever:

A. A propulsion system fault has occurred.
A003 B. An emergency brake stop has beeninitiated.
C. The dynamic brake fade-out speed has been reached.
D. Dynamic Brake Feedback indicates less than the tractive effort requested.

The control electronics and power switchgear may be located in a single package or 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 that the electronic control unit is effectively sealed from the environment, and that suitable ports are supplied for connecting diagnostic equipment (PTUs) from within the vehicle. 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.

15.2.3 Duty Cycle Rating

Traction motor temperature rise for the worst-case continuous duty cycle shall be limited to that allowed by IEC 60349 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
A003 the duty cycle described in Section 15.1.2 (G).

The Contractor shall submit current and temperature calculations/simulations for the worst-case duty cycle and compare them to the ratings of the proposed equipment to illustrate compliance with the above requirements (show graphically and in a summary table, the actual stabilized temperatures versus the maximums for all critical components. In addition, the Contractor will perform the abnormal duty cycle A003
simulation condition described in Section 15.1.2(H) / 15.1.2(I) ***(CDRL 1504)***. A002

Critical RMS and peak currents predicted by the simulations shall be utilized to 'type' test the various pieces of equipment and the resulting temperature rise shall be compared to the simulated values. Corrective action shall be taken at the earliest time possible, if actual currents cause the equipment to be outside the declared limits. A003

During 'commissioning' of the prototype cars, the Contractor shall perform a duty cycle test on the line with the predicted worst-case profile to confirm the results of the simulation. The cars shall be loaded and shall operate as close as possible to the requirements set forth in 15.1.2. Where certain conditions A003
such as: line voltage, cannot be established because of the time of day or night during the test an engineering calculation shall be used to demonstrate the difference between the actual and worst-case. The Contractor may either measure the particular RMS or peak current of interest or shall measure the actual temperature rise of the equipment.

15.2.4 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.

Electromagnetic interference limits specified in Section 7.6 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.

15.2.5 Performance Characteristics

The propulsion system shall provide vehicle acceleration and deceleration as required by Section 15.1.2 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 7.4 and variation of the low voltage supply within the limits given in Section 14.1.3.

15.2.6 Electric Brake Capabilities

Dynamic 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 15.6.8.

Electric braking shall be continuously available from maximum car speed down to -5 mph, and shall be
A002 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 7.2, 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.

15.2.7 Direction Change

Direction change shall be provided by traction motor rotation reversal. A change of rotation shall be possible only when the car is at zero speed and the traction motor power circuits are de-energized.
A003 Failure of the reversing equipment signals to correspond to the direction trainline signal shall disable the propulsion and electric brake. Direction control shall be included in the Propulsion equipment FMEA.

A008
15.2.8 Wheel Spin Correction

The propulsion system shall control tractive effort in propulsion as required to correct wheel spin. The
A002 effectiveness of this feature shall be tested and demonstrated during the Slip-Slide testing specified in Section 16.8 of this Technical Specification.

15.2.9 Routine Switching

Switching for propulsion-brake mode changes and for direction changes, if required, shall be accomplished by suitably rated solid-state devices. The high speed circuit breaker or line breaker shall not be operated during routine power-to-brake and brake-to-power transitions.

15.2.10 Vehicle Monitoring System (VMS) Interface

Critical propulsion system and propulsion control input and output signals, 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 to the
A008 portable test device via the car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20. 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
A008 data for transmission to the VCU. The DAM shall meet the applicable reliability and safety design criteria as specified for the VCU in Section 20.5. The DAM shall convert the signals from its associated

system, analog or digital, to serial packages and store for transmission to the VCU via the car communications network. 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 (MID) character within the network so that communications between all units can be managed and controlled.

15.3 TRACTION MOTORS

15.3.1 General

Each axle shall be driven by a three-phase, squirrel-cage induction traction motor with a copper rotor cage. A self ventilated motor is preferred. The motor shall have characteristics such as to produce accelerations equal (+0%, -10%) to those developed by the Authority's existing cars, the motor characteristics of which are shown in Exhibit 15-2. The traction motor shall also develop tractive effort necessary to obtain the performance requirements specified in Section 15.1.2. The tractive effort levels shown in Exhibit 15-2, 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 on no less than one hundred car-sets of equipment. Successful record implies that the traction motor can be shown to meet or A003
exceed the Reliability requirements specified in Exhibit 5-1 when utilized with a duty-cycle at least as severe as WMATA's worst-case profile..

All traction motors shall be physically and electrically interchangeable between cars, as described in Section 7.5.

15.3.2 Mounting

Each motor shall be resiliently mounted to the truck frame and, unless otherwise approved by the Authority, shall drive through a suitable direct-coupled gear drive as specified in Section 15.4.

15.3.3 Duty Rating

The traction motors shall be rated in accordance with the duty cycles (continuous and short-term A003
overload) defined in Section 15.1.2 and shall be capable of meeting all the requirements of that section.

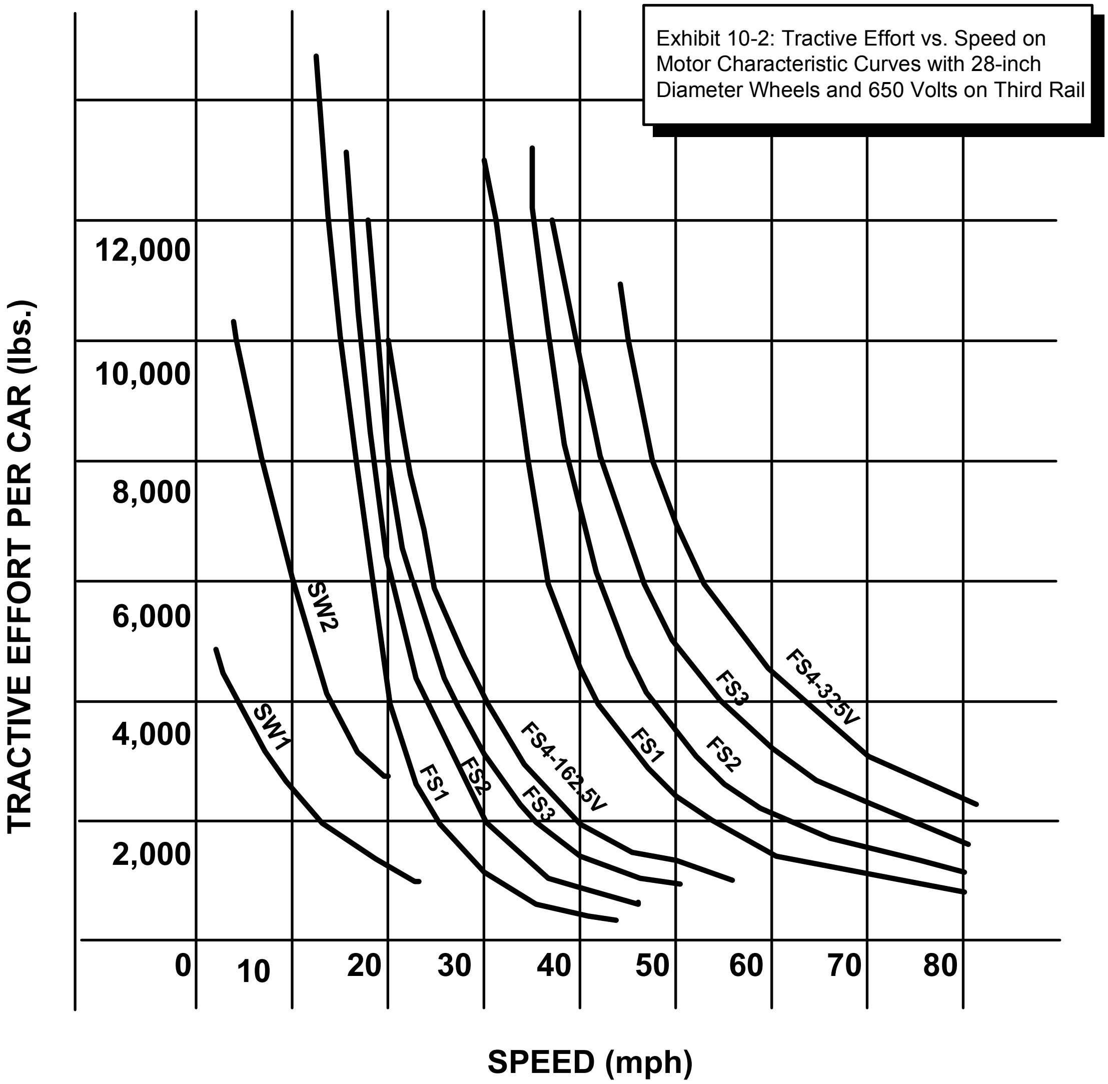
15.3.4 Load Sharing

The motor's characteristics shall allow all performance characteristics, including duty-cycle rating, to be A003
met with variations in wheel diameters of up to 1/4-inch between axles on a truck and up to 1/2-inch between trucks on a car.

15.3.5 Design Standards

The motors shall comply with BS DD ENV 60349-2, except as specified herein.

Exhibit 15-2
Tractive Effort Vs. Speed



15.3.6 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 11, Class H insulation system or better, or one class lower than the actual, for the continuous rating. Abnormal or short term overload conditions defined in Section 15.1.2 shall not result in the temperature exceeding the limits for the actual class. However, allowable temperature rise shall conform to Class F. Motor stator coils shall be vacuum pressure impregnated (VPI). The insulating resin used in the VPI process shall be silicone or an authority approved equal. The Contractor shall submit information on the proposed vacuum pressure impregnation process to the Authority for approval. ***(CDRL 1502)*** Impregnation processes other than VPI, thoroughly proven in traction service, may be offered as alternatives, subject to the approval of the Authority. A003

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 ***(CDRL T1551)***. If voids are found, then the sample size shall increase as directed on a case-by-case basis by the Authority. A002

15.3.7 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 snow, ice, leaves and debris. If installed, filters shall require cleaning no more frequently than once every 10,000 miles or 60 days. The traction motor ventilation system shall be subject to the approval of the Authority. A005

15.3.8 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. The ability to disconnect any motor from its gear unit while on the trucks below the car shal be incorporated into the design. A005

15.3.9 Design Speed

Motor design maximum speed shall be that corresponding to a vehicle speed of at least 75 mph with fully worn wheels. IEC 60349 definitions of “maximum speed” and “overspeed” shall be used.

15.3.10 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 15.1.2.

15.3.11 Bearings

Anti-friction bearings enclosed in a sealed grease cavity shall be provided. Grease cavities shall be large enough to hold a 3-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.

15.3.12 Motor and Rotor Balance

Motors shall be dynamically balanced to meet the requirements of NEMA MG 1-12.06 and IEEE 11-13.2.2. The rotors shall be dynamically balanced to within a maximum imbalance of 1.0 inch-ounce,
A002 even if a greater imbalance will satisfy the NEMA MG 1-12.06 requirements. Balancing methods shall be as approved by the Authority ***(CDRL 1505)***.

15.3.13 Marking

Terminals, leads, and motor frame shall be clearly marked for positive identification.

15.3.14 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
A002 using an insulating filler block of phenolic or polyester-glass. Alternative cable termination and fixation methods, proven in similar environments, may be proposed for Authority approval.

A003 Ground brush cables shall be arranged as described in Section 15.4.10 and 14.8.

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 8.15.1 for traction motor lead connector watertightness test requirements.

Traction motor cables shall employ stranding and construction in accordance with AAR S-501. Cable insulation shall be extra flexible, irradiated cross-linked polyolefin, 2,000V Class.

In any case, all wires, cables and hoses connecting between trucks and car body shall be routed in the vertical transition as close as possible to the truck's center of rotation to minimize flexing movements.

15.4 GEAR UNITS

15.4.1 General

Gear units shall be directly connected to the traction motors. Parallel drives shall be provided.

15.4.2 Mounting

Gear units shall be arranged to provide resilient attachment either to the axle or to the traction motor.

15.4.3 Specification

Gear units shall be service proven and capable of satisfactory operation with the proposed traction motors while conforming with the performance levels specified in Section 15.1.2.

15.4.4 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.

15.4.5 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.

15.4.6 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. The gear unit shall be A003
designed to prevent infiltration of moisture into lubricant from any and all sources.

15.4.7 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.

15.4.8 Inspection Openings

Inspection openings shall be provided. Covers shall be attached with bolts, gasketed, and designed to prevent loss of lubricant.

15.4.9 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; however, the filler plug may be non-magnetic if a magnetic inspection cover is provided. The type and or location of drain and filler plugs shall preclude damage to the plugs from obstacles on the track and any resultant loss of lubricant. Drain and filler plugs shall be lock-wired or shall incorporate another approved device to prevent their working loose during car operation.

15.4.10 Ground Brush and Cover

The gear unit shall carry three ground brushes and a brush holder to conduct ground current to the axles via a press-fit ground ring. If required by the gear unit design, the ground brush holder 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
A003 cover easily removed for access. Ground cables shall be adequately supported with cleats or clamps around the insulation and away from the connection lugs. See Section 14.8 and corresponding Exhibit 14-5 for grounding arrangement.

The brush assembly shall be designed so that the ground cable terminal can be attached thereto conveniently.

15.4.11 Speed Sensing

The 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 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, speed sensors, and speed-sensor mounting provisions shall be identical on "F" and "R" end trucks of both A and B cars to permit truck interchangeability. Dummy plugs or receptacles shall be provided for securing unused connectors 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 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, or 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.

All speed sensor cables shall be equipped with safety wires or harnesses to prevent them from damage in A007
the event that the connectors become loose.

15.5 WHEEL SLIP-SLIDE PROTECTION SYSTEM

15.5.1 General

The cars shall be equipped with wheel slip-slide protection (see Section 15.2.8 for spin protection
requirements). The slip-slide control shall detect all slips and slides whether they are random or A008
synchronous. It shall correct for tractive effort in excess of that which available adhesion will support during deceleration of the car, and shall prevent flat-spotting and other damage to wheel treads under all adhesion conditions at all speeds above 5 mph, 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 failure mode of the control shall be such as to render the wheel slip-slide system ineffective while allowing the friction brake to remain applied during a wheel slip-slide sequence. Failure modes which
produce invalid indications of a wheel slip or slide shall be tolerated, provided that apparatus is included A008
to detect such invalid signals and restore braking effort within 4.5 seconds of recognizing the invalid signal and that 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-slide correction shall be removed on a per truck basis if correction cannot be achieved in 4.5 seconds or if 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 control must be designed to operate in a manner such that it can pass the requirements of the test procedure stipulated in Section 15.8.8.3.

15.5.2 Function

Refer to Section 16.4.7.3.3(B) A008

15.6 ACCELERATION AND BRAKING CONTROLS

15.6.1 General

All acceleration and braking controls shall be designed to operate successfully in trains of up to eight cars. 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 Sections 15.5.2 and A008
16.4.7.3.3. 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 sources defined below.

15.6.1.1 Automatic Train Control (ATC)

The Automatic Train Control (ATC) system is described in Section 18 of this Specification. The ATC system shall interface with the propulsion apparatus furnished as part of the car in a manner as specified in Section 18 and as indicated in the Contract Drawings. The ATC system shall provide inputs to the propulsion 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 Protection system (ATP) or Automatic Train Supervision 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 Contract Drawings 97936-21 and 97936-22.

15.6.1.2 Manual Train Control (MTC)

In Manual Train Control (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 cut-out switch located in the Operator's cab.

15.6.2 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 Contract Drawings 97936-21 and 97936-22. The positions of the manual master controller shall be shown in Exhibit 15-3.

Exhibit 15-3
Master Controller Positions

Position Identification	Function		
	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	+0.75
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 braking.

In the “Auto/Store” position of the master controller handle, full service brake (B4) shall be applied when the mode-direction switch described in Section 15.6.3 is in either of its two manual positions. 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 during MTC operations shall be accomplished by placing the master controller handle in the “B4,” “B5,” or “Auto/Store” positions and pressing the emergency recharge pushbutton. During ATC operations, with the handle in the “Auto/Store” position, it shall be possible to recharge the emergency brake by depressing the emergency recharge pushbutton while the “overtravel” button is also depressed.

When operating manually, recharging of the emergency Brake Pipe shall be accomplished by placing the master controller handle in the “B4”, “B5”, or “Auto/Store” positions and by pressing the "Recharge" pushbutton. When operating under automatic train control with the handle in the “Auto/Store” position, it shall be possible to recharge by simultaneously depressing the "Recharge" pushbutton and the “overtravel” button. A008

15.6.3 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:

A. The switch can be moved between the “Man-Fwd” and “Man-Rev” positions only if the master controller is in the “B-5” or “Auto/Store” position

B. The switch can be moved to the “Auto/Store” position only if 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.

15.6.4 Control Lock

A control lock shall be provided in each control console which lock shall be operated by a control key (see Section 10.9.1). 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. The control lock shall be interlocked with the mode-direction switch such that the lock can be moved to the "Off" position only when the mode-direction switch is in the "Auto/Store" position, and the mode-direction switch can be moved only when the control lock is 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 it is impossible for contacts to 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 of a train 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	10.4
	Door trainline control	11.1
	Console door indication lamp	11.4.3
	Headlight, taillight and marker light selection	13.2.4
	Control console lights	14.6.2
A008	Wheel Slip-Slide Inhibit setup	15.6.5.7
	Snow brake setup	15.6.5.8
	Brake Pipe Recharge setup	16.3.2.2

Cab brake test lights	16.4.7.3.4
Communication system power	19.7

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 in Contract Drawings 97936-21 and 97936-22) shall be disconnected from the battery.

15.6.5 Acceleration and Braking Control Trainline Interfaces

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 15-4.

15.6.5.1 Train Direction

A forward wire and a reverse wire, either of which may be energized by battery voltage at any one time, 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. A003

The sensitivity of apparatus connected to trainline wires shall be such as to not respond to voltage levels less than 12 volts. A008

The friction brake control equipment shall monitor the following signals as a minimum to determine a train's present state of control and its possible response to indicator and interlock circuits. A008

15.6.5.2 Power-Brake Trainline

This wire (TL22) 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 nor inhibit the friction brake when a rate wire energization pattern calling for any level of braking is present on any car in a train. A008 A003

15.6.5.3 Rate Selection

Five wires (TL18, TL19, TL20, TL21, and TL76) shall be selectively energized with battery voltage to provide rate selection intelligence to the local car propulsion and braking systems as shown in Exhibit 15-4. A008

Energization patterns other than those listed specifically in Exhibit 15-4 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.

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.

15.6.5.4 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 15-2, based on the following motor connection trainline configuration.

15.6.5.4.1 Crawl

Energization of this wire shall produce sufficient tractive effort to produce a very slow speed for operation through a car washer. See Section 15.6.9. Response to the energization of this wire shall be predicated on the energization of the power-brake and direction trainline wires.

15.6.5.4.2 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.

15.6.5.4.3 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.

Exhibit 15-4
Trainline Energization Patterns

MTC** Command	NOMENCLATURE/ FIELD CONFIGURATION	RATE	TRAINLINES 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
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 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.

15.6.5.4.4 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.

15.6.5.4.5 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.

15.6.5.4.6 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 in Exhibit 15-2. Response to the energization of this wire shall be predicated on satisfaction of the control conditions for either series or parallel operation.

15.6.5.4.7 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 in Exhibit 15-2. Response to the energization of this wire shall be predicated on satisfaction of the control conditions for either series or parallel operation and energization of the FS-2 wire.

15.6.5.4.8 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 in Exhibit 15-2. Response to the energization of this wire shall be predicated on satisfaction of the control conditions for either series or parallel operation and energization of both the FS-2 and FS-3 wires.

15.6.5.5 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 amperes at 32 volts with an eight-car train.

The sensitivity of apparatus connected to trainline wires shall be such as not to respond to voltage levels below 12 volts.

15.6.5.6 Rate Common A008

This wire (TL17) shall be grounded to B- at the controlling ("keyed") cab to simultaneously provide rate selection intelligence to the local car propulsion and friction braking systems as shown in Exhibit 15-4. The removal of "ground" from this trainline wire shall remove power and shall result in braking at a B4 level irrespective of the status of the other rate selection trainline wires discussed in Section 15.6.5.3 and irrespective of the Power/Brake trainline discussed in Section 15.6.5.2.

A008

15.6.5.7 Wheel Slip-Slide Inhibit

In its normal state, this wire (TL72) shall be energized by battery voltage. Whenever either Emergency Stop button in the controlling ("keyed") cab is activated, the wire shall be de-energized. The de-energization of this wire shall inhibit the correction of detected wheel slip-slides.

A008

15.6.5.8 Snow Brake

This wire (TL73) shall be energized by battery voltage whenever the Snow Brake button has been activated in the controlling ("keyed") cab. The energization of this wire shall cause minimal but sufficient friction brake shoe forces to be applied to all brake discs for the sole purpose preventing snow and ice buildup during operation. Once activated, this trainline wire shall remain energized until the "key" is removed from the controlling cab.

15.6.6 Acceleration and Braking Control Circuit Protection

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. A008

Local car circuitry accepting inputs from any of the control trainline wires described in Section 15.6.5 shall be protected by an individual circuit breaker for each input. Each of the circuit breakers shall be A008 equipped with auxiliary contacts that are used to signal a 'tripped breaker' indicating light. The one exception shall be the 'Rate Common' trainine wire input. These breakers shall be arranged in a single panel located in the Operator's cab. A single indicating light on the rear bulkhead of the car shall be visible from both sides of the car, to indicate when any of the circuit breakers are tripped (refer to Exhibit 13-1). Circuit breakers shall be sized based on the current carrying capacity of the wiring that they protect.

In addition, an indicating light shall be provided on the cab console that will indicate when any of the A008 circuit breakers has tripped on that car. When the car is the lead car, this indicating light shall illuminate when one or more circuit breakers have tripped on the train using a trainlined wire (TL33).

15.6.7 Acceleration Control

The Contractor shall provide cars with solid-state VVVF control. The propulsion system shall use A005 service proven insulated gate bipolar transistors (IGBT) or gate turn-off thyristors (GTO) for control of acceleration and braking current. The cars shall 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 15.6.8. 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 15-2 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 shall 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 test runs between Silver Spring and Dupont Circle, which are described in Section 18.4.6. 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 shall 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 A005 any transition from power to brake, brake to power, or power to coast. 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 15.6.1 shall be adhered to at all times; however, to preclude 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 41 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.

A003 Fail-Safe Power Removal shall be included in the Propulsion equipment FMEA.

Related equipment shall be furnished as described below.

15.6.7.1 Input Filter

A propulsion input filter shall be provided to prevent damage to solid-state equipment from very large voltage transients likely to be present on the third rail due to such causes 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 high-speed circuit breaker.

The Contractor shall provide a means of guaranteeing that the capacitance of the input filter capacitor bank exceeds the minimum allowable capacitance for inverter operation and electromagnetic interference control at all times. The propulsion overload light under the car and at the controlling console of the train shall be illuminated if any of the fuses are open and propulsion in the car in question shall be automatically cut out. Alternate means to protect the capacitors and to ensure the continued effectiveness of the filter may be provided.

15.6.7.2 High-Speed Circuit Breaker

A propulsion high-speed circuit breaker (HSCB) shall be provided to interrupt full fault current and shall be located between the knife switch and the propulsion input filter. The opening speed of the HSCB shall be coordinated with the characteristics of the propulsion input filter and the relaying of rate of rise of inrush current so as to satisfy the inrush energy limitation of Section 15.6.7.1.

15.6.7.3 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 HSCB so that the HSCB can be closed or remain closed only when the switch is in the full open position. Closure of the 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 may be provided, subject to review and approval by the Authority. A009

Permanently connected indicator lights in strategic locations shall reliably show the charging state of the respective filter capacitors. A009

All doors and covers of boxes containing high voltage capacitors shall be labeled both inside and outside with decals warning of danger from charged capacitors, and providing instructions to operate the discharge switch, wait 15 seconds, and then verify that the capacitors are discharged prior to working near them.

15.6.7.4 Third Rail Sensing

Means shall be provided for sensing third rail potential independent of the voltage on the capacitor of the input filter whenever a 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, the auxiliary power converter input contactor, and any other line breaker, contactor, or switch that connects the third rail shoes to filters, and which therefore could keep the shoes energized, shall open whenever third rail current ceases as a result of a third rail gap or de-energized third rail or whenever third rail voltage falls below the minimum specified in Section 7.2. Opening of these devices in response to zero current shall occur within 200 milliseconds after detection of zero current. The line switch and auxiliary converter contactor shall not be opened while one of the control consoles in a train is activated so long as all equipment is functioning normally, current is flowing between the car and the third rail, and the third rail is energized to normal voltage levels. Dead-rail protection shall be included in the Propulsion equipment FMEA.

In addition to sensing of 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%.

15.6.7.5 Electronic Monitoring

Electronic monitoring shall be provided to detect abnormal conditions. Such monitoring shall include fault current interrupting breakers or alternative reliable means arranged to ensure 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.

15.6.7.6 Cooling System

While convection cooling is preferred, convection or forced air cooling may be used. However, external air shall not be used to cool live electrical components in the power modules.

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 230 VAC 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 of the car on which the failure has occurred.

Traction motor temperature shall be continuously sensed 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.

15.6.7.7 High Voltage Clearance and Creepage Distances

15.6.7.7.1 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 for "Normal Class" apparatus are as follows:

1. Equipment shall be housed in sealed enclosures

2. Convection-cooled electronic control apparatus shall be located inside the vehicle and shall be protected against dirt, moisture, and any contamination incidental to interior vehicle cleaning

3. Undercar control apparatus shall be housed in well-gasketed enclosures and cooled by well-filtered air or by convection

4. External terminal posts shall be well protected by tape or tight-fitting boots.

B. The clearance and creepage distance requirements for "Normal Class" apparatus are as follows:

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 7.2 as the nominal system voltage.

C. For Printed Circuit Boards where circuitry is exposed to line potential: 2.5 mm

15.6.7.7.2 Dirty Class Apparatus

All apparatus that is exposed essentially unenclosed, or is subject to build-up of ionized gases, will be classified as "Dirty Class."

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 7.2 as the nominal system voltage.

A003 C. For Conformally Coated Printed Circuit Boards (PCBs) where circuitry is exposed to line potential: 0.003 mm/V. Non-coated boards are prohibited.

15.6.7.8 Electromagnetic 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. Information on 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.

15.6.7.9 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.

15.6.7.10 Undercar Equipment

The Contractor shall install and wire all undercar equipment, especially traction equipment, in a manner that will minimize the magnetic field conducted, induced, or radiated by such equipment.

15.6.8 Braking Control

Dynamic regenerative/rheostatic braking shall be provided. The braking resistors on all cars 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 cut-out shall be provided to cut out regeneration on all cars in a train and cause all electrical braking energy to be dissipated in the carborne resistors. (This switch and trainline shall be separate from the ones for dynamic brake cut-out, which serve to prevent electrical braking altogether.)

B. A control shall be provided 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. A control shall be provided 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 electric braking effort due to such switching shall not cause introduction of friction braking.

D. Regenerated current shall pass through the HSCB (Section 15.6.7.2) 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.

Dynamic braking shall be automatic at all speeds, maintaining the rates commanded whether the braking commands originate in the MTC or the ATC system. All braking rates shall be available to MTC and 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. The dynamic braking control system shall have the capability to maintain net rates with new wheels for each level of service braking as described in Section 15.6.2 and in Exhibit 15-5.

Exhibit 15-5

Braking Levels	Tolerance	
	Instantaneous Rate	All Electrical Brake Except Inshot*
B1	-0.75 mphps**	±0.1 mphps
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 16-4 when blending electrical and friction brakes.

The apparatus supplying the electrical braking status signal shall be fail-safe in design, and no possible failure mode shall prevent the friction brake controller from receiving the "take-over" transition signal. A003 Dynamic Brake Feedback shall be included in the Propulsion equipment FMEA.

Jerk rate control shall be applicable to dynamic braking as well as propulsion.

All braking effort 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 15.1.2. 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 85% of that required on the married pair, and shall result in a white light condition.

The propulsion control system shall utilize the two air spring pressure transducer signals per truck (four total) for load weigh compensation of service brake force requests. The truck load levels shall be determined from the average of the two air spring pressures for each truck. The load weigh signal shall be reflective of actual air spring pressures until the instant the vehicle doors are closed. Following door closure, the load weigh signal level shall be held constant regardless of air spring pressure fluctuations.

The electrical brake system shall be so arranged that each level of braking outlined in Sections 15.6.2 and 15.6.5, 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.

The 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 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 electric brake systems use the same translation apparatus.

A rotary, modified shovel-style “deadman” emergency brake control shall be provided on the master controller handle, with the arrangement similar to that on the Authority’s existing cars. An electrically and pneumatically propagated emergency brake application shall occur whenever the handle is released, unless:

A. The master controller handle is in the "Auto/Store" position

B. The master controller handle is in the "B4" or "B5" position and brake cylinders have at least 75% of B4 pressure level

C. The master controller handle is in the "B4" or "B5" position and train speed is less than 2 mph.

15.6.9 Car Wash Speed Control

A "crawl" speed control pushbutton shall be provided in the Operator's auxiliary control and indicator panel for operation of trains through the car wash and for other similar purposes.. When this button is pushed and the master controller is in the "Coast" position, the traction motors shall be energized so as to accelerate to and maintain a speed between 2.5 and 3.0 mph

Circuiting shall be arranged so that the pushbutton must be held down to continue application of power. When the pushbutton 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.

15.6.10 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 22.30, 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 in 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 to allow 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 interface with the ATC system as shown in 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.

15.6.11 Arrangement of Control Components

Motoring 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 to 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, water and snow. If openings are required for ventilation, they shall exclude dust, water, 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 for 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. The Authority 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 one person can perform calibration.

15.6.12 Braking Resistors

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 load. 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 to the resistors may be submitted for approval by the Authority. Resistors and resistor groups shall be protected from wheel splash and flying objects. Safety guards shall be provided as described in Section 8.1.2. 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 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.

15.6.13 Contactors

All propulsion system contactors shall conform to the requirements of Section 22.30 and shall be capable of safely and repeatedly interrupting the maximum possible load current in the event of a control malfunction (not fault current) as well as any other current level that the contactor might need to interrupt in normal operation. 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 of a box cover. Access to the contact tips shall only require snap-off removal of the arc chute.

15.6.14 Control Logic

Propulsion system control logic shall consist of 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 pushbutton 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 LEDs 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 21.2. 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.

15.6.15 Traction Motor Current Measurement

Motor current data shall be accessible 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 15.2.10, to monitor regenerated current/power that is fed back to the third rail.

A003 If required for roll-back protection specified in 18.2.2.2, the propulsion system shall provide an output to ATP indicating when positive tractive effort is being applied to the axles.

15.6.16 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 that would be harmful to the equipment. When contact rail voltage rises above 430 volts, propulsion power shall be automatically restored.

15.6.17 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 5 feet of the transverse centerline on the left-hand side of the car. The main switch shall have four positions with connections as follows:

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 ensure as far as possible that when one blows, it will clear and not set up an arc.

15.6.19 Propulsion Cut-Out Switch

A Propulsion Cut-out switch shall be provided in the Operator's cab, located as specified in Section 14.6.3 and Contract Drawing 97936-12, to permit de-energization of the propulsion and electrical brake system o for the complete car. This switch, when operated, shall completely isolate the propulsion system from all A009 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.

15.6.20 Dead Car Indication and Annunciation

A red annunciator shall be provided to indicate when one or more cars in a train is not providing the requested level of tractive effort, and shall be located in the cab. The annunciator shall function in the control cab and shall also provide local indication in the car(s) not providing the requested level of propulsion effort.

15.7 PROPULSION ACCESSORIES AND WIRING

Wiring harnesses within control boxes shall be secured to tape rails at least every 8 inches with high temperature plastic tie wraps or approved equivalent. 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 1inch 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 and chafing. 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.

15.8 PROPULSION SYSTEM TEST PROGRAM

15.8.1 General

This section defines requirements for a comprehensive propulsion system test program to be developed and managed by the Contractor. The program shall ensure that the propulsion system and all of its components and subsystems meet all design and performance requirements. The tests specified are considered to be an absolute minimum.

Unless otherwise indicated, all costs associated with testing shall be borne by the Contractor. In the event of failure to meet the requirements of these Provisions in any test, the Contractor shall make necessary corrections and retest.

If further corrections or modifications affecting the item under test are implemented, the Contractor shall perform a complete retest at its expense to demonstrate compliance with the requirements of these Provisions.

WMATA reserves the right to reject any equipment that fails testing.

WMATA reserves the right to witness any or all of the tests. A written notice of at least 10 working days shall be provided to WMATA before each test, identifying the particular test and its date and location.

15.8.2 Test Program

15.8.2.1 Test Program Plan

The Contractor shall submit a Test Program Plan for approval. The Test Program Plan shall encompass all tests and inspections to be performed under this Contract, and shall include the following minimum requirements:

A. All tests and inspections shall be identified by reference to the appropriate section numbers of these Provisions.

B. A detailed schedule shall be submitted showing the date and location of each test.

C. Identification shall be provided of any requirements that the Contractor proposes to meet by means other than testing, such as documentation of previous successful testing or statistical data documenting proven product performance.

D. A test matrix shall be provided listing the sequence and relationships between the various tests.

15.8.2.2 Test Facility

The Contractor shall provide its own test facilities for all off-site testing. The Contractor shall provide its own test equipment and personnel for all testing. WMATA will make available test tracks and storage facilities as they become available, and Operators for on-site tests.

15.8.2.3 Test Procedures

The tests and adjustments to be performed on the propulsion equipment are grouped into three classifications: design qualification, and factory acceptance., and on-site acceptance.

A. Design qualification tests shall comprise system tests to be performed one time at a subcontractor's or the Contractor's property to demonstrate conformance of the system with the operation and performance requirements of these Provisions.

B. Factory acceptance tests shall comprise component, subsystem and system tests to be performed at a subcontractor's or the Contractor's facility on each functional component to demonstrate conformance with the Provisions.

For each test, the Contractor shall submit a test procedure for approval at least 45 days before the scheduled test date. The test procedure must be approved before the test is conducted.

Each test procedure shall contain, at a minimum, the following:

A. Test objective

B. Success/failure criteria in quantitative terms

C. Sequence of testing

D. Equipment and instrumentation required

E. Test setup

F. Test methodology

G. Data evaluation procedure

H. Procedure in the event of adverse test results when warranted by design and/or requested by WMATA.

I. Type of report or data to be issued.

With prior agreement from WMATA, the Contractor may submit for approval existing procedures that differ from this format, so long as traceability to design requirements is clearly delineated.

15.8.2.4 Test Reports

The Contractor shall submit a written report of each test within 15 days of test completion. Reports shall include all test data and analyses, and descriptions of any corrective actions taken.

15.8.3 Design Qualification Testing

15.8.3.1 AC Traction Motor

The traction motor test shall demonstrate compliance with the requirements of Sections 7 and 15. The AC traction motor shall be type tested in accordance with IEEE 11, IEEE 112, IEC 60349, and IEC A002 60034-14, as applicable ***(CDRL T1552)***. Within 18 months after Contract Award, two traction motors, randomly selected by the Authority, shall be subjected by the Contractor to this "type" test. In addition, one in every one hundred production motors shall also be "type" tested. As a minimum, the tests shall A003 include testing at minimum frequency, base speed, maximum slip-limited speed, maximum speed, audible noise, and temperature rise.

15.8.3.2 AC Auxiliary Motors

A002 *Moved to Section 3.*

A002 *15.8.3.3 Combined Systems Test*

A002 A009 The Contractor shall perform testing of combined systems ***(CDRL T1553)***. Included in this test shall be, as a minimum, the following systems: ATC, propulsion, friction brake, APS, LVPS, Battery Charger and Battery, Vehicle Monitoring, and other ancillary power and low voltage circuits and devices necessary to validate proper functioning, such as load weigh, speed sensors, etc. The VMS system shall be represented by actual hardware.

A009 The Contractor shall propose a suitable sequence of partial tests to ensure timely testing and validation, as well as complete coverage of all related systems parameters and interfaces before a final test on a completed vehicle is attempted on the Contractor's test track.

A009 The test facilities shall be capable of providing power and input signals covering the extremes of ranges, so as to simulate the full operational ranges as would be encountered in service, including abnormal situations (e.g. emergency braking, loss of signal, slip and spin, etc.). The test facilities shall also be capable of measuring and recording all data necessary to demonstrate that Contract requirements have been met and that proposed systems are compatible with the Authority's existing fleet.

As a minimum, the following tests shall be conducted:

- Performance standards verification tests (see Section 15.1.2)
- Performance verification under most severe voltage transients and rail gaps
- Line filter failure protection
- Regeneration transient test
- Regenerative efficiency test
- EMI tests
- Fault detection, clearance and annunciation

15.8.4 Specific Proof-of-Design Tests

In addition to other tests identified by the Contractor, the following specific proof-of-design tests shall be included in the Contractor's test program plan:

A002 A. <u>Ambient Temperature Test ***(CDRL T1554)***</u>: Determine the maximum temperature rise in equipment boxes, near heat-producing equipment. The test shall consist of at least 4 hours of simulated revenue service operation. The test shall ensure that temperatures do not exceed design limits for components.

B. Noise Tests ***(CDRL T1555)***: Perform tests to verify compliance with Section 24. Tests shall also verify compliance with pure tones and narrow band requirements. A002

C. Shock and Vibration Tests ***(CDRL T1556)***: Perform tests to verify compliance with Section 24. A002

D. Gear Unit Tests ***(CDRL T1557)***: The traction gear unit proof of design test shall be a 100-hour test on two gear units, selected at random by the Authority, and shall be mounted with torque load simulation. The test shall subject the unit to conditions that are in general 20% more severe than would occur under the most extreme operating conditions (i.e., torque increased by 20%). The test shall be started with the unit at room temperature 60 to 90 degrees F. A fan or other device may be provided so that in-service airflow conditions are simulated. The temperature rise measured in the oil sump shall not exceed the gear oil supplier's recommendations for maximum temperature consistent with the life between oil changes, as called out in the Contractor's maintenance manuals. The direction of rotation shall be reversed every 8 hours until the 100-hour test is completed. A002

During the test, the gear units shall display no signs of excessive heat, noise, or vibration. After completion of the test, the gear units shall be disassembled and all parts examined.

Gear tooth mesh shall be checked and recorded before and after the test. Any sign of deterioration of any part shall be investigated jointly with the Authority.

The test report shall include test records of running time, oil temperatures, vibration and sound level readings taken at such intervals as required to verify compliance with this Specification.

E. Dynamic Brake Resistors ***(CDRL T1558)***: Perform tests in accordance with IEC 60322. A002

15.8.5 Design Qualification Through Analysis

If tests required to demonstrate compliance with certain requirements are shown to be excessively expensive or potentially inconclusive, approval may be given to waive the requirements for certain design qualification tests, instead substituting analyses. A formal waiver request must be made for each instance, and approval will be at WMATA's option.

15.8.6 Waiver for Proven Equipment

If the component or subsystem in question is substantially identical in design to equipment extensively deployed in other transit applications, it may not be necessary to conduct design qualification tests on that equipment. A formal waiver request must be made, and the Contractor must provide the following data:

A. Identification of current locations of equipment installations and the quantities of equipment at each location, together with a contact name, address, and telephone number.

B. Description of all differences between the other installations and the requirements of these Provisions.

C. Test results for any relevant design qualification tests that have previously been conducted on the equipment.

Based on the data submitted, WMATA shall determine if the requirements for design qualification testing shall be waived. Specific requirements for each set of equipment shall be considered individually.

15.8.7 Factory Acceptance Testing

Each system that is separately assembled, housed, and wired into a unit prior to installation in the vehicle shall be tested at its point of manufacture, and a certified test report signed by the manufacturer shall be submitted to WMATA.

Tests shall include the following:

A002 A. <u>Traction Motor</u>: Each traction motor shall be tested by the manufacturer in accordance with IEC 60349, IEEE 11, or IEEE 112, as appropriate ***(CDRL T1559)***.

A002 B. <u>Propulsion System:</u> All units shall be tested against the requirements of IEC 60077, IEC 60322, and IEC 61287-1, as appropriate ***(CDRL T1560)***.

These tests shall ensure that each unit is produced to at least the same quality level as the unit presented for the First Article Inspection and in accordance with the standards listed in these Provisions and the approved tests plan for the equipment.

Routine test procedures shall be updated based on experience gained from subsequent testing or vehicle operation. If approved**,** tests may be simplified in areas where a high degree of confidence is developed.

Complete test log books shall be kept of all tests that are performed, divided by system or vehicle as appropriate. Any failures and subsequent corrective actions shall be noted. These records shall be made available to WMATA on request.

15.8.8 Performance Testing

15.8.8.1 Car Performance Testing

A002 See requirements of Section 16.6.8.

15.8.8.2 Drift Tests

A002 See requirements of Section 16.6.8.

15.8.8.3 Slip-Slide Test

A002 See requirements of Section 16.6.8.

15.8.8.4 Duty Cycle Confirmation Tests

As described in 15.2.3, the Contractor shall confirm by loaded vehicle tests, the validity of the RMS and peak currents or temperatures extracted from the duty-cycle simulations specified in 15.1.2 and

A003

subsequently used in the ‘type’ test of the critical propulsion components ***(CDRL T1561)***. The Authority may waive this test for some or all parts depending upon: 1) the design margin shown by simulation / type test is wide and has been approved by the Authority 2) compared to existing equipment with known rating and no history of high failure rates the new design is at least equal.

15.9 REFERENCED CDRLs

The following CDRL items are referenced in this section :

CDRL 1501	Performance Data Adjustment Calculations	
CDRL 1502	Information on Vacuum Pressure Impregnation Process for Motor Stator Coils	
CDRL 1503	Electrical Protection System Design Details	A002
CDRL 1504	Duty Cycle Calculations	
CDRL 1505	Traction Motor Ventilation System Design Details	
CDRL 1506	Information on Motor and Rotor Balancing Methods	
CDRL T1551	VPI Verification Test	
CDRL T1552	Traction Motor Type Test	
CDRL T1553	Combined Systems Test	
CDRL T1554	Ambient Temperature Test	
CDRL T1555	Noise Tests	
CDRL T1556	Shock and Vibration Tests	
CDRL T1557	Gear Unit 100-Hour Test	
CDRL T1558	Dynamic Brake Resistance	
CDRL T1559	Traction Motor Factory Acceptance Tests	
CDRL T1560	Propulsion System Factory Acceptance Tests	
CDRL T1561	Duty Cycle Confirmation Test	A003

15.10 REFERENCED STANDARDS

The following standards are referenced in this section:

AAR S-501	Wiring and Cable Specification
BS DD ENV 60349-2	Electric Traction – Rotating Electrical Machines for Rail and Road Vehicles – Electronic Converter-Fed Alternating Current Motors
IEC 60034-14	Rotating Electrical Machines – Part 14: Mechanical Vibration of Certain Machines with Shaft Heights 56 mm and Higher – Measurements, Evaluation and Limits of Vibration
IEC 60077	Rules for Electric Traction Equipment

IEC 60322	Rules for Ohmic Resistors Used in the Power Circuits of Electronically Powered Vehicles
IEC 60349	Electric Traction – Rotating Electrical Machines, Rail and Road Vehicles
IEC 61377	Electric Traction – Rolling Stock – Combined Testing of Inverter Fed Alternating Current Motors and Their Control
IEC 61287-1	Power Converters Installed On Board Rolling Stock – Part 1: Characteristics and Test Methods
IEEE 11	Rotating and Electrical Machinery for Rail and Road Vehicles
IEEE 16	Electric Control Apparatus, Land Transport
IEEE 112	Standard Test Procedure for Polyphase Induction Motors and Generators
NEMA MG 1	Motors and Generators

SECTION 16
FRICTION BRAKING SYSTEM

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SECTION 16
FRICTION BRAKING SYSTEM

16.1 GENERAL

All cars to be furnished under this contract shall be equipped with a friction brake system that is either a combination of hydraulic and pneumatic (compressed air) or entirely pneumatic (compressed air). All hardware shall be manufactured by and/or supplied/controlled through one subcontractor with a proven history of successful Friction Brake System design, product delivery, and service. The friction brake system shall be of proven design during substantial revenue service as equally severe as the Authority's service environment, if not more severe.

Service Braking shall be independently controlled on each car by an Electronic Control Unit while Emergency Braking shall be independently controlled on each car using a trainlined, pneumatic Brake Pipe commanded by an electrically trainlined Emergency circuit (TL82) and by manually activated attachments. Wheel slip-slide correction control shall be available from the friction brake system. Spin shall be controlled by the propulsion system per Section 15.2.8. Regardless of the level of brake A008
requested, under all conditions, each truck shall be individually controlled and regulated to promote safe operation through redundant means.

The friction brake system capacity shall be capable of providing the specified performance standards without relying on train resistance or electric braking to supplement any portion of the needed forces and without the need for speed restrictions unless operating with compromised functions considered safety-related.

16.1.1 Train Consist Operation

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.

The friction brake system shall be functionally compatible (both mechanically and electrically) with the Authority's existing fleets of railcars. Trainlined functions shall closely emulate, if not duplicate, those of the existing fleets.

16.1.2 Responsibility

The Contractor shall be responsible for systems integration of all propulsion (Section 15) and friction A008
braking functions, equipment, systems, and devices to ensure that vehicle system performance meets specification requirements. The contractor shall submit for Authority approval a stand alone systems integration plan describing, in detail, the hardware, software and functional interfaces that exist between the friction brake and propulsion systems ***(CDRL 1603)***.

The Contractor shall be responsible for proper installation of all components of the friction braking system and their interrelationship with other systems, and for the coordination of shared signals such as A008
brake blending and wheel slip-slide with the propulsion system.

The subcontractor shall be responsible for the review of the Contractor's design and installation of their equipment, its connections, and interfaces to ensure safe and proper functioning as required by this A008 specification. Prior to the installation of any equipment, the subcontractor shall provide written approval to the Engineer of the Contractor's design and installation which includes drawings for each type of railcar created and controlled by the subcontractor depicting all equipment. The subcontractor shall provide a periodic update of drawings, not less than quarterly, defining the latest configuration known to the subcontractor and certifying that the design/installation remains satisfactory.

The subcontractor shall be an integral part of the Contractor's design/coordination efforts relating to wheel slip-slide control, sources of tachometer signals from the axles, load-weigh signals, and blending of both friction and electric braking--taking into account vehicle speed, vehicle weight distribution, and the type of brake requested.

16.1.3 Performance Standards

The following performance standards shall be met with a six-car train on level, tangent track and with
A008 new wheels:

A008 A. Maximum Service Brake rate (B-5) shall be available under control of the load-weighing system:

<u>Rate on level tangent track</u>	<u>Linear increase from</u>
75 mph to 50 mph	2.25 to 3.0 mphps *
50 mph to 0 mph	3.0 mphps*

* All braking rates specified are nominal instantaneous values, not including compensation for build-up or reaction time. These instantaneous rates shall be in accordance with the tolerances specified in Section 16.4.3. See Exhibit 16-4.

A002 A008 B. Service friction braking shall be capable of developing the specified braking rate independently for any passenger load up to AW3 (34,800 lbs.) under control of the load weighing system.

A002 A008 C. Emergency friction braking shall be capable of developing the specified braking rate independently for any passenger load up to AW3 (34,800 lbs.), under control of the load weighing system:

Emergency brake rate on level tangent track (friction brake only) mphps	3.2 mphps at speeds below 50 mph with minimum instantaneous rate of 2.5 at 75 mph.*

* All braking rates specified are nominal instantaneous values, not including compensation for build-up or reaction time. These instantaneous rates shall be in accordance with the tolerances specified in Section 16.4.3. See Exhibit 16-4.

D. The friction brakes shall be capable of making one (1) complete round trip between Metro
A008 terminals Franconia-Springfield and Addison Road, Shady Grove and Glenmont, Huntington and Mt. Vernon Square, Vienna and New Carrollton, and Greenbelt and Branch Avenue, stopping at all stations, observing all speed restrictions, and maintaining a normal operating schedule as defined in Section 15.1.2(G) at the AW1 load level, with worn brake pads and

dynamic brakes inoperative, without damage or excessive wear to the friction brake system, including excessive pad wear that may result in an unsafe operating condition, at the B4 braking rate. The Contractor shall submit a detailed test plan and procedure for Authority approval to verify compliance with this requirement ***(CDRL T1665)***.

E. Friction braking equipment shall be designed to allow an eight-car train of operating cars (with a normal load) to move a train of eight dead cars in accordance with the requirements of Section 15.1.2(H). A008

F. It shall not be possible under any circumstances for a failure of the propulsion system, of the friction brake system, or of the shared signals between the two systems to result in a violation of the Authority's Automatic Train Protection system Block Design. A008

G. Additional performance, interface, and other requirements related to vehicle and braking performance are detailed in Section 15 – Propulsion. A008

16.1.4 Performance Calculations

For the purpose of design calculations and/or the adjustment of performance data, 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. The calculations shall be submitted to the Authority with sufficient detail to permit review and approval ***(CDRL 1601)***. A008

16.2 VEHICLE MONITORING SYSTEM (VMS) INTERFACE

The input and output signals from each critical friction brake system performance-dependent apparatus, together with its power supply voltage, shall be monitored; and these 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 to the portable test device via the car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. 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. ***(CDRL 1602)*** A008

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 20.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU via the car communications network. Serial data communication between the DAM and VCU shall be in accordance with Lon Works or other Authority-approved protocol. A008

The DAM shall be assigned a message identification character (MID) within the network so that communications between all units can be managed and controlled.

16.3 ACCELERATION AND BRAKING CONTROLS

A008 **16.3.1 Propulsion System Interface**

Friction Brake controls shall respond to the following as a minimum:

DESCRIPTION	REFERENCE SECTION
General Interface	15.6.1
Automatic Train Control (ATC)	15.6.1.1
Manual Train Control (MTC)	15.6.1.2
Manual Master Controller	15.6.2
Mode Direction Switch	15.6.3
Control Lock	15.6.4
Acceleration and Service Braking Control Trainline Interfaces	15.6.5
Power/Brake Trainline	15.6.5.2
Rate Selection	15.6.5.3
Coast Position	15.6.5.5
Rate Common	15.6.5.6
Wheel Slip-Slide Inhibit	15.6.5.7
Snow Brake	15.6.5.8
Control Trainline Protection	15.6.6

A008 **16.3.2 Brake Pipe Control Trainline Interfaces**

The trainline interfaces for the control of Brake Pipe, whether such control is initiated by either manual or automatic apparatus, are as follows:

A008 ***16.3.2.1 Emergency Brake***

This trainline wire (TL82) shall be energized by battery voltage whenever the appropriate electrical circuit logics have been satisfied in the controlling ("keyed") cab. The energization of this wire shall permit Brake Pipe to be "recharged" by allowing magnet valves to remain energized on each car once a predetermined amount of air pressure has been achieved.

De-energization of the trainline wire shall result in an immediate venting of Brake Pipe air pressure by the magnet valve on each car. Additionally, each car's vital Emergency Relay shall be de-energized which shall be interlocked with the propulsion system resulting in the removal of power.

A008 ***16.3.2.2 Brake Pipe Recharge***

This trainline wire (TL8) shall be energized by battery voltage whenever the Recharge button is depressed on the console of the controlling ("keyed") cab during Manual mode or in unison with the "overtravel" button during Automatic mode. The energization of this wire shall only be possible when the train is at "zero speed" and shall cause the Brake Pipe to be "recharged" by allowing a magnet valve to energize on each married-pair (as a minimum) which shall, in turn, feed Main Reservoir air unrestricted into Brake Pipe.

16.3.3 Friction Brake Status Trainline Interfaces A008

The trainline interfaces for the status of the friction brake system are as follows:

16.3.3.1 Brake Check (Applied) A008

A008

This is a summary loop circuit utilizing two trainlined wires (TL7 and TL70). When energized by a summary status of several relays per car (Front/Rear Trucks, Hand Brake, and White Light Indication), a vital "Brake Applied Relay" in the controlling ("keyed") cab shall be energized. The energization of this relay shall permit the Deadman Handle to be released with the master controller handle in either the B4 or B5 brake level positions without de-energizing the Emergency Brake trainline wire discussed in Section 16.3.2.1. Energization of the vital "Brake Applied Relay" shall also cause an amber "Brake On" indicator to illuminate on the controlling ("keyed") cab console.

16.3.3.2 Brake Released A008

A008

This is a summary loop circuit utilizing two trainlined wires (TL71 and TL79). When energized by a summary status of several relays per car (Front/Rear Trucks and Hand Brake), a vital "Brake Released Relay" in the controlling ("keyed") cab shall be energized. The energization of this relay shall work in conjunction with the “Power/Brake” trainline wire discussed in Section 15.6.5.2 to permit propulsion power to be generated. Energization of the vital "Brake Released Relay" shall also cause a green "Brake Off" indicator to illuminate on the controlling ("keyed") cab console.

16.4 FRICTION BRAKE FUNCTIONS/FEATURES

16.4.1 General

A008

The friction brake system shall primarily be an Emergency Brake system that also serves as a Service Brake back-up to the electrical braking system. The friction brake system shall function properly in coordination with the electric brake system and shall be inherently fail-safe in design, construction, and operation

All braking effort for Service Brake and Emergency Brake, shall be compensated for passenger load by a load-weighing system in order to produce a constant deceleration rate within the specified tolerances. The load-weighing system shall be fail-safe in design. It shall ensure that 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 both a "White Light" condition and a "Blue Light" condition as defined in Section 16.4.7.3.4.

A008

Coordination between the electric and friction braking shall be of the constant blending arrangement. A signal, proportional to the tractive effort request minus electric brake effort, shall control brake cylinder pressure to achieve the rate commanded. The apparatus supplying the electric braking effort shall be fail-safe in design, and no possible failure mode shall cause the signal to indicate a level of electric 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.

Following a stop imposed by the brake pipe pressure switch as described in Section 16.4.5.2.2 (pneumatic brakes) or by the second of the hydraulic accumulator pressure switches as described in Section 16.4.7.4.1 (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 on the cut-in pressure of the air compressor (pneumatic brakes) or the accumulator pressure just above the cut-in point of the hydraulic pump (hydraulic brakes).

16.4.2 Fail-Safe Design Principles

It is absolutely essential that the train protection braking, namely, Braking Level 4 and Braking Level 5,
A003 be absolutely fail-safe. These levels shall be considered to meet the fail-safe criteria stipulated if no
failure or series of related failures can occur which will cause the resultant brake force applied to be less
A008 than 75% of the braking force commanded by Braking Level 4 for a married pair of cars.

A002

In regard to fail-safe design criteria for the friction brake system, the criteria specified in Section 5.4 9 and the following are established as guidelines:

A. Self-detecting component failures that adversely affect the safe operation of the train at normal speed profiles 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,
A008 provided that sufficient checks are incorporated to detect welded relay contacts, stuck
armatures, or if the electronic circuitry meets fail-safe criteria.

F. In establishing fail-safe criteria for electronic circuitry, 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 that adversely affects the safe operation of a train at normal speed profiles shall prevent the release of brakes and the application of power at the next station (White Light). 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 16.2.

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.

16.4.3 Performance Tolerances

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
(2.2 mphpsps maximum) plus a maximum of 200 milliseconds dead time for friction brakes. During any A008
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. Friction braking shall be capable of maintaining net rates with new wheels for each level of A008
braking as described in Section 15.6.2 and in Exhibit 16-3.

Exhibit 16-3
Net Braking Rates

		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 in Exhibit 16-4
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 16-4 when blending electrical and friction brakes.

16.4.4 Compressed Air Supply

For each married pair, apparatus shall be arranged to store and to supply clean, cool, dry, oil-free compressed air for the friction brake system and for auxiliary pneumatic components of other car systems.

A008 Reservoir volumes and air compressor output flow shall have the capacity to operate a 4-car train
A009 maintaining normal performance levels at the optimal duty cycle of the air compressor as established by its manufacturer and approved by the Authority, not to exceed 50% on a single pair of cars.

16.4.4.1 Air Compressor Unit

16.4.4.1.1 Air Compressor

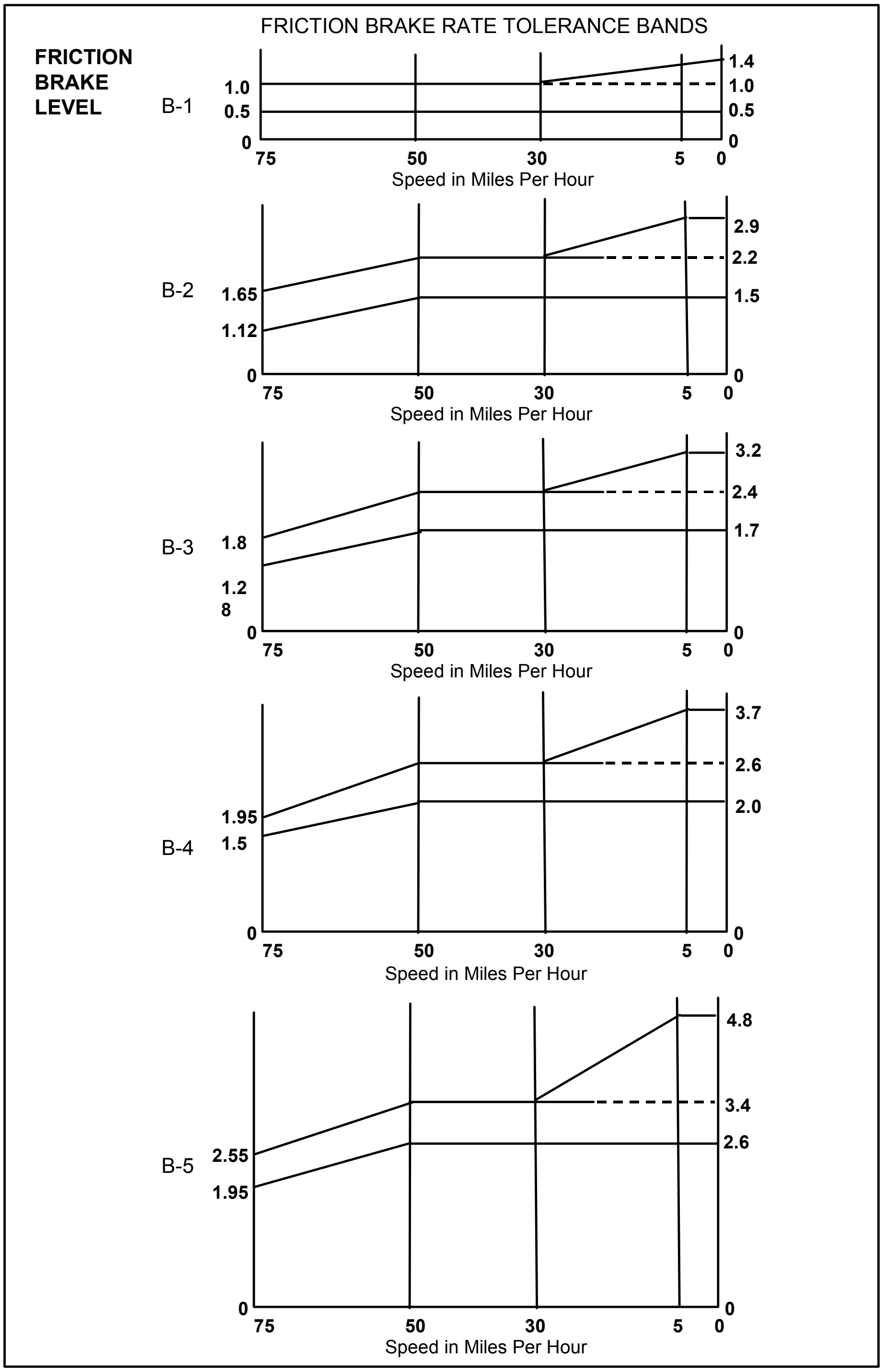
The air compressor shall be of a service proven design and shall be located on the "A-car". It shall be direct driven by a totally enclosed, fan- cooled, 230 VAC 3-phase motor of approved design, furnished complete with suspension frame. The suspension frame shall be so
A008 designed as to remain safely supported in the event of failure of suspension bolts or resilient mounting. All parts of the compressor shall be designed to produce minimum noise and vibration levels. The compressor shall be capable of quiet and safe operation at all third rail voltages specified in Section 7.2, 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.

The compressor shall produce compressed air for operation of the friction braking system, propulsion system (if required), suspension system, couplers, horns, and other accessories. The capacity of the compressor shall be sufficient to supply all compressed air requirements on a train composed of two married pairs of cars with the compressor on the other pair inoperative. In no case shall the delivery at the output of the air dryer 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, water, ice, and snow.

A008

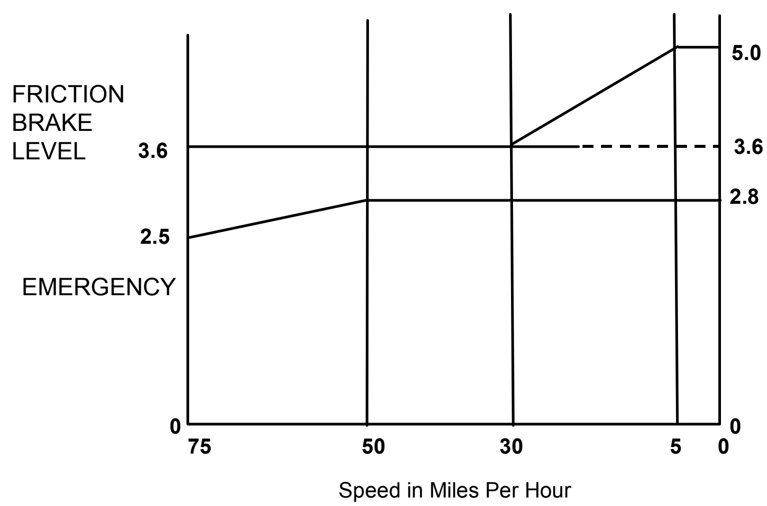
Exhibit 16-4
Friction Brake Rate Tolerance Bands



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 16-4
Friction Brake Rate Tolerance Bands (Continued)

FRICTION BRAKE RATE TOLERANCE BANDS



Deceleration Rates are in Miles per Hour per Second. Emergency Rate Includes Train Resistance.

16.4.4.1.2 Cooling and Drying Apparatus A008

The cooling apparatus shall consist of finned piping included in the air compressor unit and arranged to drain by gravity into the sump reservoir, which shall be included in the air compressor unit. Temperature of air as it exits from the dryer 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 A008 breaker panel, respectively. These heaters shall not share the same circuit breaker with the friction brake control.

16.4.4.1.3 Filter Dryer A008

Air shall be filtered by means of a high-efficiency, self-purging desiccant filter, twin-tower 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. Air entering the dryer shall first pass through an integral oil coalescor to preclude contamination of the desiccant, thereby reducing its life/longevity.

The filter dryer shall be a Graham-White Mfg. twin tower air dryer unit, or an Authority-approved equivalent.

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 A008 Authority for approval ***(CDRL 1604)***.

16.4.4.1.4 Safety Valves A008

A safety valve(s) shall be an integral part of the air compressor unit to protect against overpressurization of the Main Reservoir and associated apparatus in the event of malfunctions within the unit. Main Reservoir shall be limited to air pressures not exceeding 160 psig.

16.4.4.1.5 Control Circuits A008

Electrical control circuitry and wiring shall be integral to the unit and shall be protected by water-tight enclosures. It shall turn the air compressor "On" when Main Reservoir air pressure is less than 130 psig and shall turn "Off" the air compressor when Main Reservoir air pressure reaches 150 psig. The circuitry shall also provide the needed timing and control logic for the purging of the twin-tower air dryer desiccant and for the associated heaters.

16.4.4.2 Main Reservoir

A main reservoir air volume shall be furnished and may be achieved by installing a dual reservoir arrangement on the "A-car". The main air reservoir(s) shall be provided with a manual drain cock. The drain cock shall be constructed of noncorroding materials. The main reservoir(s) 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.

Except in the case of reservoirs made from 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:

$$D = \frac{0.6\ PR}{(S\text{-}0.6P)}$$

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 the requirements of the ASME Pressure Vessel Code and shall be stamped with ASME certification.

Main Reservoir air shall be distributed throughout the married-pair using appropriately sized pipe and flexible hoses in areas subjected to motion such as between the "A-car" and the "B-car".

16.4.4.3 Low Pressure Cut-Out

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" discussed in Section 16.4.7.3.4 shall be illuminated and the trainlined "Brakes Applied" indication shall not be given, thus forcing key-out prior to release of brakes following the next station stop (also described in Section 16.4.2). Key-out of a train composed of more than one pair of cars is not intended if compressors on other cars are able to supply adequate quantities of air to the afflicted pair through the Brake Pipe.

16.4.4.4 Supply Reservoirs

If a hydraulic friction braking system is employed, the supply reservoir and its associated apparatus may be eliminated.

If an entirely 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 friction braking only. When the air pressure in
A008 the supply reservoir is the same as the pressure at which the Air Compressor turns “on”, it shall be

adequate for five complete all-friction brake station stops from 75 mph with poor adhesion and slip-slide control functioning and shall satisfy the brake holding time requirement of Section 16.4.1. If friction brake safety is based on independent control of the front and rear trucks, then separate front and rear brake supply reservoirs and check valves shall be furnished on each car. The supply reservoirs shall be mounted without slope.

Except in the case of reservoirs made from aluminum or stainless steel, each air reservoir shall be drilled over its entire surface with telltale holes as described in Section 16.4.4.2. All air reservoirs shall meet A003
the requirements of the ASME Pressure Vessel Code and shall be stamped with ASME certification.

16.4.5 Brake Pipe

Each car shall be equipped with a single, trainlined Brake Pipe capable of passing air through the Couplers to adjacent cars. The Brake Pipe shall function as a fail-safe reference for the direct application and eventual release of Emergency Brake. When air pressure in the pipe exceeds a value of about 65 psig, Emergency Brake shall be released even though normal operating pressures in the pipe during Service Braking shall be within the range of 100-150 psig. When air pressure in the pipe is less than about 75 psig, it shall rapidly exhaust its remaining air pressure.

The Brake Pipe arrangement and valving shall permit one pair of cars to "recharge" the train at least three times consecutively and promptly with an adjacent pair whose air compressor is inoperative and whose main reservoir has at least 80 psig of air pressure. Following recharging, one married-pair shall be able to supply the adjacent married-pair whose air compressor is inoperative via the Brake Pipe without the train being put into Emergency Brake by a reduction in Brake Pipe pressure. It shall be possible for the Brake Pipe to supply the adjacent car with all the air that it can consume in normal functioning (including air suspension load compensation and friction braking under conditions of poor adhesion). Under such circumstances, it would be acceptable for Main Reservoir air pressure on the adjacent car to maintain lower pressure levels than normal. However, Main Reservoir pressure shall not be less than 100 psig.

16.4.5.1 Charging and Maintaining

To enable the train to take power, air pressure in the Brake Pipe shall initially attain 100 psig and then be A008
maintained at pressures greater than 100 psig in order to keep the Emergency Brakes released. Recharge and Maintaining shall be accomplished with the following arrangement of pneumatic valves.

16.4.5.1.1 <u>Low M.R. Pressure Shutoff Valve</u>

A shutoff valve shall disallow air to flow between the Main Reservoir and Brake Pipe when Main Reservoir air pressure is below 80 psig – an indication of a significant breach in the integrity of the compressed air supply.

This valve shall be designed to allow a train consist to recharge Brake Pipe by preserving the integrity of Brake Pipe function so that it may limp home to a repair facility.

16.4.5.1.2 <u>Charging Magnet Valve</u>

When energized by the Brake Pipe Recharge trainline wire (TL8) discussed in Section 16.3.2.2, the charging magnet valve shall provide an unrestricted connection between Main A008
Reservoir and Brake Pipe. Providing that the shutoff valve discussed in Section 16.4.5.1.1 is

"open" and that Main Reservoir air pressure is greater than Brake Pipe air pressure, air shall freely and rapidly flow into Brake Pipe.

16.4.5.1.3 Reverse Flow Check Valve

In the event that Brake Pipe air pressure is greater than Main Reservoir air pressure during recharge of the Brake Pipe, a check valve shall disallow air to freely and rapidly flow into Main Reservoir through the Charging Magnet Valve.

16.4.5.1.4 Maintaining Valve

When Brake Pipe air pressure reaches about 95 psig, a maintaining valve shall provide a restricted connection between the output of the Low M.R. Pressure Shutoff Valve discussed in Section 16.4.5.1.1 and the Brake Pipe, thereby circumventing the Charging Magnet Valve and the Reverse Flow Check Valve. When Brake Pipe air pressure drops below about 90 psig, the maintaining valve shall disallow air to flow.

When the valve is "open", it shall be possible for air to flow in either direction through the restriction. The primary purpose of the maintaining valve is to compensate for small quantities of air leakage in the Brake Pipe so that air pressure remains above 100 psig. The restricted flow of air shall be maximized while ensuring that the air in the brake pipe can be exhausted rapidly in the event of an emergency and that an Emergency Brake application is achieved.

This arrangement shall allow one or more married pairs with functioning air compressor units to slowly replenish Main Reservoir air pressure on a married pair that has a malfunctioning air compressor unit. The use of two differently sized restrictions may be incorporated in order to fulfill the requirements of Section 16.4.5.

16.4.5.1.5 Manual By-Pass Valve

A manual by-pass valve that is easily accessible from the side of the car shall be provided to permit pressurization of the Main Reservoir by the Brake Pipe when Main Reservoir air pressure is less than 80 psig. When "opened", the by-pass valve shall allow an unrestricted flow of air between the input of the Charging Magnet Valve and the input of the Low M.R. Pressure Shutoff Valve.

The by-pass valve shall be equipped with a "locking handle" that can be safety-wired in either the "closed" or the "opened" position. For the purposes of this procurement, the by-pass valve shall be safety-wired in its "closed" position.

16.4.5.2 Emergency Pressure Reduction

In order to apply the Emergency Brakes, air pressure in the Brake Pipe shall be less than about 65 psig. However, the air pressure shall be reduced to a level very near zero (0) psig to ensure that a full and irretrievable Emergency Brake application is achieved throughout the train consist.

A008 When Emergency Braking is requested via the master controller or the deadman handle in the controlling ("keyed") cab, the Emergency Brake trainline wire (TL82) discussed in Section 16.3.2.1 shall be de-energized. Within one second following de-energization of TL82, Brake Pipe air pressure on each car of the train consist shall drop below the level at which the brake system goes into emergency. When none of the cabs in a train consist is controlling ("keyed"), TL82 shall remain energized to allow the Operator to change controlling cabs without having to recharge. A008

Regardless of the status of TL82, any significant or rapid loss of air pressure in the Brake Pipe on a car shall propagate emergency pressure reduction in the Brake Pipe on all cars in a train consist. Emergency pressure reduction shall,

A. Interrupt the battery power feed from the Emergency Brake trainline wire (TL82) to critical and vital apparatus on each car

B. Independently apply full friction brake

C. Vitally shut off propulsion power on a per car basis

D. Vitally remove both battery power and ground from the rate trainline wires discussed in Sections 15.6.5.3 and 15.6.5.6 at their source in the controlling ("keyed") cab A008

E. Vitally interrupt an interlock within the Automatic Train Protection equipment.

The emergency pressure reduction and interlocking shall be accomplished with the following arrangement of pneumatic valves, pressure switches, and relays. Sizing and placement of the pneumatic valves and piping shall ensure 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 Brake within 3 seconds following actuation of any of the emergency valves in the first car of the train with TL82 kept artificially energized.

16.4.5.2.1 Emergency Magnet Valve

Each car shall be equipped with an emergency magnet valve. When energized by the battery power feed from the Emergency Brake trainline wire (TL82) discussed in Section 16.3.2.1, the emergency magnet valve shall disallow the exhausting of air from Brake Pipe. A008

Either the loss of the battery power feed from TL82 or its interruption by the car's vital Emergency Relay shall de-energize the emergency magnet valve, thereby allowing the unrestricted exhausting of air from Brake Pipe.

The emergency magnet valve shall be located in the underfloor area and shall be equipped with a silencer to keep exhaust noise to a minimum.

16.4.5.2.2 Brake Pipe Pressure Switch

Each car shall be equipped with a brake pipe pressure switch. The electrical contacts shall "open" when Brake Pipe air pressure is lower than about 75 psig. The electrical contacts shall "close" when Brake Pipe air pressure is 95-100 psig.

Opening of this switch shall interrupt the battery power feed from the Emergency Brake trainline wire (TL82) discussed in Section 16.3.2.1, thereby de-energizing the car's vital Emergency Relay. A008

16.4.5.2.3 Emergency Relay

Each car shall be equipped with a vital emergency relay. When energized by the battery
A008 power feed from the Emergency Brake trainline wire (TL82) discussed in Section 16.3.2.1,
the emergency relay shall,

A. Connect TL82 to the Emergency Magnet Valve discussed in Section 16.4.5.2.1

B. Enable propulsion power on a per car basis

A008 C. Enable both battery power and ground from the rate trainline wires discussed in Sections 15.6.5.3 and 15.6.5.6 at their source if that car's cab is controlling ("keyed")

D. Enable an interlock within the Automatic Train Protection equipment.

Either the loss of the battery power feed from TL82 or its interruption by the car's Brake Pipe Pressure Switch shall de-energize the emergency relay. If a hydraulic brake system is employed, interruption of the battery power feed from TL82 to the emergency relay shall also occur when either the hydraulic oil volume or the accumulator gas pressure in both accumulators is low as discussed in Section 16.4.7.4.1.

16.4.5.2.4 Pneumatic Vent Valve

Each car shall be equipped with a pneumatic vent valve that utilizes only Brake Pipe air pressure to function. The valve shall automatically actuate (open) using internally stored air to exhaust Brake Pipe air in response to rapid reductions in Brake Pipe air pressure equal to or exceeding a predetermined rate caused by uncoupling as well as by the activation of emergency valves on the car.

Once actuated, the pneumatic vent valve shall not close until both the Brake Pipe air pressure is reduced to a pressure very near zero (0) psig and the internally stored air is nearly depleted through its choked supply port. Automatic closure of all actuated pneumatic vent valves in a train consist shall occur within 20 seconds of an Emergency Brake actuation. In this way, the pneumatic vent valve is prepared for the next logical step of "recharge".

The pneumatic vent valve shall be located in the underfloor area and shall be equipped with a silencer to keep exhaust noise to a minimum.

16.4.5.2.5 Emergency Stop Button

Each cab area shall be equipped with two identical emergency stop buttons, one on the Operator's console and one on the Auxiliary Door Control panel. The emergency stop button shall be a two-position, detented apparatus that provides the normal means for an Operator to initiate an Emergency Brake stop while operating in Automatic mode. Depressing an emergency stop button in a controlling ("keyed") cab shall interrupt the cab control's battery
A008 power feed to the Emergency Brake trainline wire (TL82) discussed in Section 16.3.2.1.
This interruption, in turn, shall inhibit wheel slip-slide correction by de-energizing the Wheel Slip-Slide Inhibit trainline wire (TL72) discussed in Section 15.6.5.7.

When depressed, the pneumatic portion of the emergency stop button shall have sufficient capacity to rapidly and dramatically reduce the air pressure in the Brake Pipe separate from the electrically controlled Emergency Magnet Valve. If mounting space is limited, a pneumatically operated, high capacity Manual Vent Valve may be installed in the underfloor area of the cab that shall be actuated by either of the emergency stop valves.

16.4.5.2.6 Manual Vent Valve

In the event that low-capacity Emergency Stop Buttons are utilized in the cab of each car, a single high-capacity manual vent valve shall be installed in the underfloor area of the cab. The manual vent valve shall utilize only Brake Pipe air pressure to function and shall be controlled by the Emergency Stop Buttons.

Once actuated, the manual vent valve shall not close until the Brake Pipe air pressure is reduced to a pressure very near zero (0) psig. Automatic closure of the actuated manual vent valve shall occur regardless of the status of the Emergency Stop Buttons. In this way, the pneumatically controlled manual vent valve is prepared for the next logical step of "recharge". If one or both of the low capacity Emergency Stop Buttons is left in its "Emergency Brake (open)" position at the time "recharge" of Brake Pipe air pressure is attempted, the manual vent valve shall disallow the Brake Pipe air pressure to increase to any significant proportions.

The manual vent valve shall be located in the underfloor area and shall be equipped with a silencer to keep exhaust noise to a minimum.

16.4.5.2.7 Trainline Cut-Out Cock

Cut-out cocks with locking handles shall be provided in the trainlined Brake Pipe at the ends of each car.

16.4.5.2.8 Status Indicators

Light Emitting Diode (L.E.D.) indicators shall be provided in each cab to indicate the presence of B+ on TL82. These indicators shall be arranged so that an Operator can determine which friction brakes must be cut out in order to move a train in which some cars cannot be released from an emergency brake application due to an electrical malfunction.

One pneumatic pressure gauge at least 3 inches in diameter shall be provided in each Operator's cab near the Recharge Pushbutton to indicate Brake Pipe air pressure. The gauge face shall make use of color bands to indicate the range of normal working air pressure when the Brake Pipe is recharged.

16.4.6 Emergency Braking

Command of emergency braking shall be entirely by the reference air pressure in Brake Pipe discussed in Section 16.4.5. The resulting Brake Cylinder Pressure (BCP) on each truck in a car shall be independently regulated and shall be compensated for passenger load independently from that used for Service Braking. Under no circumstances shall the BCP exceed that stipulated in Section 16.4.7.1.

16.4.6.1 BCP Control Valves

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. Most of the BCP Control Valves for Service Braking may be used for Emergency Braking to optimize the utilization of various functions, providing their arrangement independently controls BCP on each truck in a car. In this respect, Emergency Braking shall be fail-safe. Any adjustments required shall be possible without removal of the valves from the car.

A dedicated application/release valve shall be utilized to control the feed of supply pressure to the brake cylinder piping. When Brake Pipe pressure is below about 65 psig, the valve shall immediately and distinctly connect supply pressure to the brake cylinder piping.

16.4.6.2 Load-Weigh Compensation

Upper and lower limits shall be established for the normal operating pressures of the air suspension when compensating for passenger load assuming evenly distributed carbody and passenger weights throughout the car. The lower limit shall be the air suspension pressure present with no passenger load (AW0). The upper limit shall be about 10 psig higher than the air suspension pressure present with a crush passenger load (AW3) to allow for variations encountered due to car floor height (leveling) adjustment variations as well as variations in carbody weight distribution resulting from the manufacturing process.

At a given end of the car, each of the air suspension pressures shall first be piped to a pneumatic comparator (Double Check Valve). The higher air pressure at the comparator shall be automatically selected and then piped directly to a BCP Control Valve for pneumatic, load-weigh compensation of that particular Truck. If the selected air suspension pressure is less than the established lower limit, a "default" value equal to the lower limit shall be assumed. If the selected air suspension pressure is greater than the established upper limit, a "default" value equal to the upper limit shall be assumed. If an air suspension pressure is within the normal operating pressures, its value shall be applied directly.

16.4.6.3 Wheel Slip-Slide Protection

To optimize the utilization of functions, the same wheel slip-slide protection function for Service Braking discussed in Section 16.4.7.3.3 shall be used by Emergency Braking to adjust Brake Cylinder Pressures on each truck, thereby maximizing deceleration for the available wheel-to-rail adhesion levels and preventing wheel flats.

16.4.6.4 Differential Pressure Switch

Each car shall be equipped with a differential pressure switch that directly compares the Brake Cylinder Pressure of one Truck to the other Truck. If the front and rear truck Brake Cylinder Pressures differ by more than the worst case scenario associated with passenger and carbody load imbalance combined for Emergency Braking, a vital relay shall be de-energized which, in turn, shall provide a "White Light" indication discussed in Section 16.4.7.3.4.

A008 De-energization of the vital relay shall simultaneously interrupt the "Brake Check (Applied)" trainline summary loop circuit (TL7 and TL70) discussed in Section 16.3.3.1.

16.4.7 Service Braking

Rate control of service braking shall be entirely through electric trainline circuits, which shall be of the fail-safe type, protected against trainline circuit faults. The levels of service braking outlined in Section 15.6.2 shall be made available to either MTC or ATC by the selective energization of the rate trainlines A008 discussed in Section 15.6.5.6. 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, as discussed in Section 16.3.5.3. The call for Braking Level 4 (B4 master controller position) shall, in addition to de-energizing the rate wires, open the rate common trainline.

Service Friction Brake shall cut in automatically when the electric brakes are inoperative without further operation of the master controller. Regardless of what the control logic may be commanding, Service Brake shall not interfere with the application of Emergency Braking and associated controls.

Electrical, mechanical, pneumatic, and hydraulic apparatus for Service Braking shall be located underfloor to supply, regulate, release, and signal pressure levels in the Brake Cylinder piping to the Trucks based on commands received from the Electronic Control Unit located in a passenger seatwell. Mechanical apparatus needed to convert the Brake Cylinder pressures into retardation forces shall be mounted on each truck in a manner that evenly distributes the forces to the wheels/axles.

16.4.7.1 Brake Cylinder 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 employed:

A. Pneumatic System: 100 psig.

A002

B. Hydraulic Brake System: 1,450 psig.

C. Pneumatic-over-Hydraulic System: The respective portions shall conform to the corresponding requirements of Paragraphs A and B above.

A second level of protection shall be provided to ensure that maximum allowable pressures are not exceeded in the event there is a failure in the first level of protection. Under no circumstances shall a failure in the second level of protection result in the loss of more than 25% friction braking effort on a married pair of cars.

16.4.7.2 BCP Control Valves

Magnet-valves shall be provided for each truck to modulate brake cylinder pressure at the request of the A008 Electronic Control Unit that includes wheel slip-slide detection/correction control. If necessary to meet the fail-safe requirements of Section 16.4.2, 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 controls to the A008 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-slide correction is actuated. Methods of combining these valves and pressure control valves may be used subject to approval by the Authority.

In the event that a pneumatic friction brake system is employed, an initial predetermined amount of brake cylinder pressure (inshot) shall be admitted to the brake cylinder piping when the electric brake is operating to assist in synchronizing the blending of friction with electric brake when the latter fades at the end of the normal service stop. This requirement shall not apply to friction brake systems in which slack adjuster design holds brake shoe clearance to 1/4-inch or less at the point of maximum gap.

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
A008 adjustments required shall be possible without removal of the valves from the car. Control systems shall be designed to allow a smooth transition between dynamic and friction braking. 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.

16.4.7.3 Electronic Control Unit

Friction braking control shall be combined as far as practicable, into a single integral control package and shall be constructed to include all the parts essential for friction braking and for signals shared with other systems. 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 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 1/4-turn locking connectors 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 located under the left rear back-to-back seat in a manner so as to provide accessibility for maintenance and shall be grounded to the carbody structure. All openings in the box shall be sealed sufficiently to exclude dust and moisture. If openings are required for ventilation, they shall preclude ingestion of dust and moisture. The control package shall be fully assembled and tested prior to installation in the car and connection to other car systems. Access to the interior of the box shall be through a non-hinged, easily removable cover without requiring the removal of other apparatus. Internal temperatures of all modules and components, including power supplies, shall be
A008 designed to provide a large thermal margin. No significant degradation of reliability shall occur during the design life of the equipment when the equipment is operated continuously where the under seat temperature is 130°F.

All friction 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, such compensation shall be provided via potentiometer on a circuit board, which is semi-permanently attached
A008 to the car, or by an otherwise Authority-approved method.

All control components requiring periodic calibration or testing, such as wheel slip-slide protection, load-weighing, electric brake feedback signals, 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.

16.4.7.3.1 Control Logic

Friction brake control logic shall consist of one or more 16-bit 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. A003

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 friction brake fault indicators when the friction brake 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 pushbutton 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 LEDs for indicating system states and faults.

Control logic and signals from the friction brake system shall be easily accessed from a portable test device per Section 21.2. Both analog and digital data must be readily accessible, and must have the ability to address all logic signals significant to analysis and diagnosis, including signals to and from relays and all external inputs and outputs. Unless otherwise specifically approved, the portable test device shall 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 control signal 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 friction brake system operation, accessing fault or other memory, and access to analog signals.

16.4.7.3.2 Load-Weigh Compensation

The air suspension pressures at the two ends of a car shall be individually sensed by pneumatic-to-electric transducers, and electronic circuitry shall be used to determine a single, average value representative of the passenger load in the car. This value shall be used both by the friction brake system and by the propulsion system to automatically adjust the levels of tractive effort needed to achieve the commanded rate. A008

Upper and lower limits shall be established for the normal operating pressures of the air suspension when compensating for passenger load assuming evenly distributed carbody and passenger weights throughout the car. The lower limit shall be the air suspension pressure present with no passenger load (AW0). The upper limit shall be about 10 psig higher than the air suspension pressure present with a crush passenger load (AW3) to allow for variations encountered due to car floor height (leveling) adjustment variations as well as variations in carbody weight distribution resulting from the manufacturing process.

At a given end of the car, each of the air suspension pressures shall first be checked for compliance with their normal operating pressures. If an air suspension pressure is less than the established lower limit, a "default" value equal to the lower limit shall be assumed. If an air suspension pressure is greater than the established upper limit, a "default" value equal to the upper limit shall be assumed. If an air suspension pressure is within the normal operating pressures, its value shall be assumed directly. The average of the two values shall then be determined.

The representative load values from each end of the car shall be averaged together to form a single, resultant value representative of the passenger load in the car. It is this value that shall be utilized by the propulsion system and by the Service Brake function. Variations in air suspension pressures due to the suspension dynamics of negotiating the right-of-way shall be ignored once the side doors are "closed" and the car is no longer at "zero speed". A change in the representative load-weigh value shall be instituted once the car is at "zero speed" and the side doors are "opened". Therefore, it is critical that the control of the air suspension have sufficient capacity to quickly compensate for passenger load during dwell at the stations.

Regardless of train speed, each of the air suspension pressures at each end of the car shall be continually monitored for malfunctions annunciated through the "Blue Light" and "White Light" indicators discussed in Section 16.4.7.3.4. The malfunctions shall consist of significantly low air pressure and significantly high air pressure. The low and high reference pressures used to make this determination shall be approved by the Authority.

16.4.7.3.3 Wheel Slip-Slide Protection

A. General

A008 The cars shall be equipped with wheel slip-slide protection (see Section 15.2.8 for spin protection requirements). The slip-slide control shall detect all slips and slides whether they are random or synchronous. It shall correct for braking effort in excess of that which available adhesion will support during deceleration of the car, and shall minimize stopping distance, prevent flat-spotting and other damage to wheel treads under all adhesion conditions at all speeds above 5 mph, 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 failure mode of the control shall be such as to render the wheel slip-slide system ineffective while allowing the friction brake to remain applied during a wheel slip-slide sequence. Failure modes which produce invalid indications of a wheel slip or slide will be
A008
A009 tolerated, provided that apparatus is included to detect such invalid signals and ensure that braking effort is not reduced for more than 4.5 seconds, and that the method of achieving the timing is inherently fail safe. Once activated, the time-out feature shall not reset until positive tractive effort has been reapplied to the car. Slip-slide correction shall be removed on a per truck basis if correction cannot be achieved in 4.5 seconds or if 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 control during all specified modes of braking and within the specified limits shall not be less than that necessary to meet the requirements of the stopping distances specified in Section 16.6.8.3 and shall operate in a manner such that it passes all requirements of the applicable test procedures.

B. Function

Slip-slide detection and correction 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 and adjustment for wheel diameter changes shall be automatic. A008

Upon detection of a slip or slide during Service Braking on a truck, electric brake control for that truck shall correct the slip or slide at all speeds above 3 mph unless it signals otherwise to the friction brake control through the dynamic brake feedback signal (or some other fail-safe means). Correction by Dynamic Brake in response to a slip-slide condition shall be monitored by Friction Brake via the speed sensors and associated signals from the Propulsion Electronic Control Unit. Should the Friction Brake control determine that the slip-slide condition on a Truck is not being corrected properly by the Dynamic Brake, it shall intervene by assuming total control for slip-slide correction on that Truck using a "Dynamic Brake Inhibit" signal to the associated Propulsion control. If the slip or slide is not corrected within 4.5 seconds or if train speed is 3 mph or less, slip-slide correction by both Dynamic Brake and by Friction Brake shall be inhibited throughout the remainder of the stop. Once 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. In the event the Friction Brake control had intervened, and no further slip-slides are detected for a period of 2 seconds following, the “Dynamic Brake Inhibit” signall shall be removed which shall result in electric brake reapplication at a jerk-limited rate. The 2-second delay in reapplication of electric brake shall be capable of adjustment over a range of 1 to 3 seconds. A008

Wheel slip-slide detection and correction shall be functional under all braking commands, except an Emergency Brake application initiated by either one of the Emergency Stop Pushbuttons in the controlling ("keyed") cab. The associated control and apparatus shall be so arranged that failure of any component shall not prevent development of a full Emergency Brake application. All components shall receive 37.5 VDC power from the friction brake system circuit breaker.

In the event that the Friction Brake for a Truck is lost, Dynamic Brake and its associated slip-slide control shall remain intact and active during legitimate braking commands. In this instance, the Dynamic Brake shall provide its own 4.5 second timeout. Appropriate indication of the failed condition shall be annunciated through the Vehicle Monitoring System (VMS). A008

C. Speed Sensing

The cars shall be equipped with accurate speed intelligence with the basic speed information coming from sensing devices mounted to the traction motor gear unit. 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. 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.

A008

The preferred speed sensor is 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.

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.

16.4.7.3.4 Brake Status Lights and Checks

A. 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 “Brake Off” status indicating light, which shall be illuminated when all friction brakes and handbrakes in the train are fully released. With the snow brake applied, and the brakes released, the green “Brake Off” indication shall be displayed. There shall also be an amber “Brake On” indication light, which shall be configured to illuminate only when all friction brakes in the train are applied to at least 85% of AW0 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.

A008 An exterior, amber, friction brake system fault indicating light shall be provided on the cab side near the ”R” end of each car, and shall flash when the Brake Cylinder Pressure on either Truck is less than 85% of an AW0 B4 level while commanding a B4, B5, or Emergency rate and electric brake is non-existent.

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 no indication shall be given in the event of any circuit failure. The relay corresponding to KABAR on the existing cars shall be a vital signal relay.

An interlock shall be provided such that if the summary "Brake On" indication and the summary "Doors 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 "Brake On" indication is recovered or the Operator keys-out and then 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 "Brake On" and "Doors Closed" indications. Restoration of the "Brake On" indication is to be the only means of releasing that interlock.)

B. White Indicator Light

An exterior, white, friction 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):

- Solid White: If a hydraulic friction brake system is employed, and the hydraulic pump is not fully functional or a predetermined loss of hydraulic fluid volume or gas in an accumulator is detected. A008

  If a pneumatic friction brake system is employed, and an apparent failure of the air compressor is detected as described in Section 16.4.3.

- Solid White: 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 the worst case scenario associated with passenger and carbody load imbalance combined for Emergency Braking. A008

- Blinking White: If failure of the load weighing system is detected. A008

C. Blue Indicator Light

If friction brake safety is based, in part, on the 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 shall be located above the "White Light" indicator that represents the front truck and the other shall be located below the "White Light" indicator that represents the rear truck. If friction brake safety does not depend on redundancy, then there shall be just a single blue light located beside the "White Light" indicator. Each blue light shall indicate faults in the brake equipment that it represents under the following conditions (as applicable):

- Solid Blue: If a hydraulic friction brake system is employed, then wherever there is an abnormally low condition of fluid level or pressure in the hydraulic accumulator. A solid blue light condition on both trucks shall cause venting of the brake pipe until the condition has been corrected or the faulty friction brake components/functions have been cut-out.

- Solid Blue: If friction brakes do not release on a truck when a release has been commanded (stuck brake).

A008

Any activation of the blue brake fault indicator shall cause an error to be recorded in a fault history log. Activation shall also cause the indicator to latch-in, regardless of any subsequent
A008 change in the condition that caused it, until the circuit is reset by “opening” and then “closing” the Friction Brake System control breaker on the car with the fault. The recorded error shall remain intact regardless of any subsequent change in the condition that caused it, until the log is reset on the car with the fault. It shall be possible to reset the log manually although the reliance will be on continual loop logging once the storage area has been filled.

An additional exterior Blue Light shall be located beneath the flashing Amber Indicator light
A008 stipulated in Section 16.4.7.3.4.A. It shall illuminate whenever either (or both) of the two Blue Indicator Lights on the "R" end of the car is illuminated.

16.4.7.3.5 <u>Adjustments</u>

Operating parameters for the friction brake control, 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 21.2.

The Friction Brake control equipment shall not require a manual adjustment feature for wheel wear. An automatic wheel-wear compensation feature determined through programming code inherent in the control program shall be provided which compares virtually-conditioned tachometer signals from each axle during "Coast" mode at speeds approximately above 10 mph. Adjustment factors that make each tachometer signal relatively equal in speed interpretation shall then be stored in memory for as long as the vehicle's 37.5 VDC power is supplied to the equipment. The control program shall make continual comparisons of the virtually-conditioned tachometer signals until an approximate
A008 speed of 45 mph has been reached based on the range of allowable wheel diameters (25-28 inches) that could exist. The loss of the vehicle's 37.5 VDC supply to the equipment shall cause whatever adjustment factors were stored in memory to be lost. Such an event shall serve as an indication to the friction brake control equipment that adjustment factors must be re-established and stored in memory. This feature will allow the maintainers to force the equipment to readjust after truing wheels. Under all situations, the virtual relationships between the tachometer signals shall error in a conservative/safe direction.

16.4.7.4 Hydraulic Friction Brake System

If a hydraulic friction brake system is employed, 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. The following apparatus shall be provided as a minimum, 16.4.7.4.1 Accumulators

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 brake station stops from 75 mph with poor adhesion and shall satisfy the brake holding time requirement of Section 16.4.1 before the low-pressure warning prevents restarting of the train. The five stops shall begin with an accumulator pressure just above the cut-in point of the hydraulic pump. These five stops shall be made with slip-slide control functioning and electric brakes inoperative.

The system shall have the ability to monitor and to signal through de-energization of a relay either the loss of hydraulic fluid volume or the loss of gas pressure from the accumulator (or both). A loss of either element shall be annunciated via a "White Light" indication as discussed in Section 16.4.7.3.4.

When the relays on both accumulators of a car open (de-energize), the feed from TL82 to the coil of the emergency relay shall be interrupted, thereby initiating an Emergency Brake. Opening of the relay on just one accumulator shall illuminate the "White Light" indicator and the related "Blue Light" indicator described in Section 16.4.7.3.4.

Hydraulic accumulators shall meet the requirements of the ASME pressure vessel code and shall be tested in accordance with these requirements.

16.4.7.4.2 Hydraulic Pump

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 hydraulic friction brake system, including full Service Brake stops from 75 mph with friction brakes only and with continuous operation of the slip-slide correction equipment 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.

Either a brushless DC motor or a 230 VAC 3-phase motor of approved design shall be supplied and shall be capable of continuous duty even though intermittent operation shall prevail. Accumulator capacities and pump output flow shall be sized to satisfy the fluid requirements of the married-pair without exceeding a 60% duty cycle during stressed operation.

16.4.7.4.3 System Filters

Filtration shall be provided to maintain a constant or decreasing system contamination level. System design must be compatible with the level of filtration selected. All filters shall be easily accessible and shall be of the disposable element type having a service life compatible with other car equipment service intervals.

16.4.7.4.4 Hydraulic Fluid Requirements

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 friction brake system.

16.4.7.4.5 Code Requirements

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 by-pass 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.

16.4.8 Power Knockout

The friction 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 16.4.7.3.4. A sealed bypass switch shall be provided in the Operator's cab (Section 14.6.3) to permit the train to move in the event of a circuit malfunction.

16.4.9 Disc Brakes/Calipers

Individually actuated disc brakes shall be installed outboard of each wheel of the trucks. The disc hubs
A008 shall be fastened to the wheels using Grade 5 bolts with an Authority-approved securing method. 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 discs and, in the case of pneumatically energized brakes, to minimize brake air cylinder volume for rapid control response under poor adhesion conditions.

Each friction brake caliper shall be supplied pressure 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.

16.4.10 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 electric 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 discussed in Section 16.1.3.D. A008

16.4.11 Handbrake

16.4.11.1 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 (AW3) 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.

The arrangement shall also permit the specified effect to be maintained should the air pressure in the carbody suspension be removed following application of the handbrake.

16.4.11.2 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.

16.4.11.3 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, as specified in Section 16.4.8. A008

Provisions shall be made to positively prevent force beyond design limits from being applied to the brake connecting linkage.

16.4.12 Pressure Gauges

One or two electrically controlled 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 Cylinder Pressure. If a hydraulic friction brake system is employed, a second electric gauge shall be provided that indicates hydraulic accumulator pressure for the "F" end truck.

The gauge face(s) shall make use of color bands to indicate the range of normal working pressures.

16.4.13 Pressure Test Fittings

Pressure test fittings shall be provided in 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. The fittings shall, 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.

16.4.14 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.

16.4.15 Cut-Out Handle Positions

All cut-out handles shall be arranged so that in the "open" position they will be parallel to the flow of fluid, and in the "closed" position they will be perpendicular to the flow of fluid. Cut-out handles shall
A008 be retained in a position that will not allow them to vibrate to the opposite position during revenue 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 the contact rail.

16.4.16 Flexible Connections

Vibration-eliminating flexible connections shall be provided on all piping between friction 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.

16.4.17 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 friction 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 electric 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.

16.4.18 Test Panel

A test panel shall be provided adjacent to the propulsion logic unit containing banana-type motor current and Brake Cylinder Pressure feedback connections. The Brake Cylinder Pressure wires shall be from the brake cylinder feedback transducers and shall be fused in the friction brake Electronic Control Unit. All wires shall be run underfloor. In lieu of fusing, current limiting may be used to protect the test point wiring.

Quick-disconnect connections for a Brake Cylinder Pressure test gauge for both front and rear trucks shall be provided in the left rear seatwell as specified in Section 8.5.

16.4.19 Maintenance Intervals

All friction brake system pneumatic or hydraulic equipment shall be designed such that overhaul is required no more frequently than at 5-year intervals.

16.5 BRAKE TEST RACKS

The Contractor shall furnish to the Authority the necessary electronic and pneumatic/hydraulic brake test racks designed for use with the friction brake system installed on the cars and built under the Contract in accordance with the requirements of Section 21. The test racks shall be arranged to permit all shop tests necessary on this apparatus to be made quickly and conveniently. The racks shall be delivered to a point to be determined by the Authority prior to the delivery of the first cars.

16.6 FRICTION BRAKE SYSTEM TEST PROGRAM

16.6.1 General

This section defines requirements for a comprehensive friction brake system test program to be developed and managed by the Contractor. The program shall ensure that the friction brake system and all of its components meet all design and performance requirements. The tests specified are considered to be an absolute minimum for Design Qualification Testing (DQT), Factory Acceptance Testing (FAT), and On-Site Acceptance Testing (OAT).

Unless otherwise indicated, all costs associated with testing shall be borne by the Contractor. In the event of failure to meet the requirements of these Provisions in any test, the Contractor shall make necessary corrections or modifications and retest.

Test procedures and reports shall be prepared and submitted in accordance with the provisions of Section 3 to which this section is considered an extension.

If further corrections or modifications affecting the item under test are implemented, the Contractor shall perform a complete retest at its expense to demonstrate compliance with the requirements of these Provisions.

The Authority reserves the right to reject any equipment which fails testing.

The Authority reserves the right to witness any or all of the tests. A written notice of at least 10 working days shall be provided to the Authority before each test, identifying the particular test and its date and location.

16.6.2 Test Program

16.6.2.1 Test Program Plan

The Contractor shall submit a Test Program Plan for approval. The Test Program Plan shall encompass all tests and inspections to be performed under this Contract, and shall include the following minimum requirements:

A. All tests and inspections shall be identified by reference to the appropriate section numbers of these Provisions.

B. A detailed schedule shall be submitted showing the date and location of each test.

C. Identification shall be provided of any requirements which the Contractor proposes to meet by means other than testing, such as documentation of previous successful testing or statistical data documenting proven product performance.

D. A test matrix shall be provided listing the sequence and relationships between the various tests.

16.6.2.2 Test Facility

The Contractor shall provide its own test facilities for all off-site testing. The Contractor shall provide its own test equipment and personnel for all testing. The Authority will make available test tracks and storage facilities as they become available, and Operators to drive the test trains for on-site tests.

16.6.2.3 Test Procedures

The tests and adjustments to be performed on the braking equipment are grouped into two classifications: design qualification and factory acceptance.

Design qualification tests consist system tests to be performed one time at a subcontractor's or the Contractor's property to demonstrate conformance of the system with the operation and performance requirements of these Provisions.

Factory acceptance tests consist of component, subsystem and system tests to be performed at a subcontractor's or the Contractor's facility on each functional component to demonstrate conformance with the Provisions.

For each test, the Contractor shall submit a test procedure for approval at least 45 days before the scheduled test date. The test procedure must be approved before the test is conducted.

Each test procedure shall contain, at a minimum, the following:

A. Test objective
B. Success/failure criteria in quantitative terms
C. Sequence of testing
D. Equipment and instrumentation required
E. Test setup
F. Test methodology
G. Data evaluation procedure
H. Procedure in the event of adverse test results when warranted by design and/or requested by the Authority.
I. Type of report or data to be issued.

With prior agreement from the Authority, the Contractor may submit for approval existing procedures that differ from this format, so long as traceability to design requirements is clearly delineated.

16.6.2.4 Test Reports

The Contractor shall submit a written report of each test within 15 days of test completion. Reports shall include all test data and analyses, and descriptions of any corrective actions taken. All test data 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.

16.6.3 Design Qualification Testing

16.6.3.1 System Pressure 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 ***(CDRL T1651)***. If a hydraulic system is A002
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 psig. After assembly on the car, a hydraulic system shall test A008

successfully at 150% of normal working pressure and a pneumatic system at maximum normal working pressure. Neither test shall create leaks or cause damage to equipment.

16.6.3.2 Friction Brake Rate Characteristics Test

A002 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 ***(CDRL T1652)***. 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 A008 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 16.1.3 on the Glenmont to Shady Grove portion of the Red Line will not be exceeded when making the test using "friction only" B4 brake rates for all braking.

16.6.3.3 Brake Unit Fatigue Test

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 A002 and force developed by braking torque in each direction ***(CDRL T1653)***. 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.

16.6.3.4 Braking System Capacity Test

The first production brake disc and caliper assembly shall be dynamometer or flywheel tested to verify A002 that the design can perform the specified operation over the Authority profile ***(CDRL T1654)***. The production brake shoe material shall be used and temperature limits specified in Section 16.1.2 shall not be exceeded. The test program shall be submitted to the Authority and their approval shall be required before the test is begun.

16.6.3.5 Brake System Endurance Test

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 A002 A008 required for rail transit service ***(CDRL T1655)***. Control of cycling shall be via the Electronic Control Unit, held at a temperature of 130°F per Section 16.4.7.3. 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.

16.6.4 Specific Proof-of-Design Tests

In addition to other tests identified by the Contractor, the following specific proof-of-design tests shall be included in the Contractor's test program plan:

A002

A. Ambient Temperature Test ***(CDRL T1656)****:* Determine the maximum temperature rise in equipment boxes, near heat-producing equipment. The test shall consist of at least 4 hours of simulated revenue service operation. The test shall ensure that temperatures do not exceed design limits for components.

B. Noise Tests ***(CDRL T1657)****:* Perform tests to verify compliance with Section 23.2. Tests shall also verify compliance with pure tones and narrow band requirements. A002

C. Shock and Vibration Tests ***(CDRL T1658)****:* Perform tests to verify compliance with Section 23.4. A002

16.6.5 Design Qualification Through Analysis

If tests required to demonstrate compliance with certain requirements are shown to be excessively expensive or potentially inconclusive, approval may be given to waive the requirements for certain design qualification tests, instead substituting analyses. A formal waiver request must be made for each instance, and approval will be at the Authority's option.

16.6.6 Waiver for Proven Equipment

If the component or subsystem in question is substantially identical in design to equipment extensively deployed in other transit applications with a similar or more severe duty-cycle rating, it may not be necessary to conduct design qualification tests on that equipment. A formal waiver request must be made, and the Contractor must provide the following data: A008

A. Identification of current locations of equipment installations and the quantities of equipment at each location, together with a contact name, address, and telephone number.

B. Description of all differences between the other installations and the requirements of these Provisions.

C. Test results for any relevant design qualification tests that have previously been conducted on the equipment.

Based on the data submitted, the Authority shall determine if the requirements for design qualification testing shall be waived. Specific requirements for each set of equipment shall be considered individually.

16.6.7 Factory Acceptance Testing

Routine tests shall be performed by the Contractor and subcontractors on each set of equipment. Tests shall be conducted at the point of manufacture on all assemblies prior to shipment. These tests shall ensure that each unit is produced to at least the same quality level as the unit presented for the First Article Inspection and in accordance with the standards listed in these Provisions and the approved tests plan for the equipment. The test reports of all routine tests shall become the property of the Authority.

Routine test procedures shall be updated based on experience gained from subsequent testing or vehicle operation. If approved, tests may be simplified in areas where a high degree of confidence is developed.

Complete test log books shall be kept of all tests that are performed, divided by system or vehicle as appropriate. Any failures and subsequent corrective actions shall be noted. These records shall be made available to the Authority on request.

Each system that is separately assembled, housed, and wired into a unit prior to installation in the vehicle shall be tested at its point of manufacture, and a certified test report signed by the manufacturer shall be submitted to the Authority.

Tests shall include those listed in the following subparagraphs.

16.6.7.1 Friction Brake System Performance Test

A002 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 Section 16 ***(CDRL T1659)***. Performance testing is to be run in conjunction with the tests required in Section 3. 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.

16.6.7.2 Brake System Functional Test

A002 The Contractor shall perform a complete functional test of the friction brake system prior to shipment of each pair of cars from its plant ***(CDRL T1660)***. Tests shall include, as a minimum, check of command and load-weigh signals, brake cylinder pressure settings, control and indicator checks, and leakage tests.

16.6.7.3 Handbrake Test

A002 A008 The handbrake on each car shall be tested ***(CDRL T1661)***. 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 load cell, the force needed to move the car with the handbrake applied. On the remaining cars a functional test shall be performed with new shoes.

16.6.8 On-Site Acceptance Testing

16.6.8.1 Car Performance Testing

A002 The Contractor shall make the necessary tests to prove compliance with the performance standards specified herein ***(CDRL T1662)***. As a minimum, the following tests shall be performed on the Authority's tracks: (1) train resistance tests with one, two, three, and four married pairs; and (2) performance tests with one, two, three and four married pairs.

For each test, the following values shall be recorded simultaneously for each car:

A. Acceleration (positive and negative)
B. Torque feedback (each truck)
C. Traction motor current (each truck)
D. Air Spring Pressures (particularly during Emergency Braking)
E. Slip-Slide System Operation
F. Brake cylinder pressure (each truck)
G. Third Rail Voltage (B-car only, at collector shoe)
H. Total line current drawn by each car

I. Speed
J. Propulsion and braking trainline signals (rate and motor connection)
K. System controller operating mode
L. Inverter operating mode
M. Time intervals
N. Distance intervals using a digital odometer to record 100-foot increments
O. 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. The 110VAC receptacles may be utilized to power instrumentation, provided a battery back-up is included to allow operation through rail gaps. 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. Weight ballast 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 or schedule is inadequate or unsatisfactory, an acceptable program or schedule shall be resubmitted within 15 working days. A008

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.

16.6.8.2 Drift Tests

To verify the coefficients used in performance calculations (see Section 16.1.4), the Contractor shall perform drift tests using trains of one, two, three and four married pairs ***(CDRL T1663)***. 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. A002

16.6.8.3 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 requirements of Section 16.4.7.3.3 ***(CDRL T1664)***. This test is to be performed using a wetting agent which will, when sprayed on the rails during tests, result in a reasonably accurate A008 simulation of conditions which would be produced by damp rail resulting in the necessary adhesion (approx. 8%) to achieve a 1.65 mphps deceleration rate (B2). 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.

A008 Tests shall be performed initially on a designated dry section of track that is reasonably straight and within ±1% of level. This pair will make six stops each from 30, 50, and 70 mph (three with blended brake and three with friction only braking) at a B4 brake rate request with dry rail conditions. A single EMERGENCY brake stop will be made from 50 and 70 mph using the Master Controller Handle EMERGENCY brake command. Time, speed, stop distance, and instantaneous deceleration rate will be measured for each stop. From this information, average deceleration rates and typical jerk rates may be calculated while distances may be verified. Data from the stops at each rate will be averaged. These averages will define the baseline stop performance at each of the three speeds.

The tests described above will then be repeated at the specified low-adhesion conditions. The sprayers
A008 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 50 mph stops at a B2 blended brake request. This mixture will become the test mixture.

The test mixture shall be used for slippery rail stops from 30, 50, and 70 mph using a B4 brake rate. Six runs (i.e., three blended and three friction only) at each speed will be made. All B4 slippery rail stops must be no more than 110% of the baseline stop distance performances at the three speeds of 30, 50, and 70 mph. Following successful testing at the B4 Service Brake level, a single slippery rail stop from 50
A008 and 70 mph shall be made using a Master Controller Handle EMERGENCY brake command. Each EMERGENCY slippery rail stop must be no more than 115% of the baseline stop distance performances from speeds of 50 and 70 mph.

The slip-slide equipment must effectively protect against wheel flats during the above test without creating objectionable or disconcerting jerking of the railcars throughout the majority of the stop. While "objectionable" and "disconcerting" are qualitative terms, a general consensus is that predominate jerk rates of 10 mphpsps for a duration of 0.10 second are neither objectionable nor disconcerting. The same is true for occasional jerk rates of 25 mphpsps for a duration of 0.05 second. The Authority will determine the acceptability of the "jerking" experienced during slip-slide correction.

Efficiency shall be tested both for electrical (where applicable) and for friction brake. Available adhesion shall be estimated respectively from motor current or brake cylinder pressure just prior to the beginning of each slip.

A008 The Contractor shall also include a means to verify the time-out feature performance in accordance with Sections 16.4.7.3.3A and B.

During these tests, a multiple channel recorder is to be used to record the following parameters as a
A008 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. Air spring pressures: each truck A008

The cognizant engineers from the Authority, the Contractor, the Propulsion supplier, and the Friction Brake supplier shall be present during the performance of the tests and shall be prepared to make the necessary adjustments to ensure the system meets the performance requirements. Preliminary test data shall be reduced to prove compliance with these requirements before the equipment is removed from the cars and copies of the test data shall be immediately provided to the Authority. A008

A final report that includes all data, data reduction, and analysis of results is to be prepared by the Contractor for approval by the Authority. A008

16.7 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 1601	Performance Calculations	
CDRL 1602	Description of Diagnostics System (DAM)	
CDRL 1603	Friction Brake and Propulsion Integration Plan	
CDRL 1604	Compressor Air Dryer Efficiency Demonstration Procedure	A008
CDRL T1651	Pressure Test	
CDRL T1652	Brake Rate Characteristics Test	A002
CDRL T1653	Brake Unit Fatigue Test	
CDRL T1654	System Capacity Test	
CDRL T1655	Brake Endurance Test	
CDRL T1656	Ambient Temperature Test	
CDRL T1657	Noise Tests	
CDRL T1658	Shock and Vibration Tests	A002
CDRL T1659	Brake System Performance Test	
CDRL T1660	Brake System Functional Test	
CDRL T1661	Hand Brake Test	
CDRL T1662	Car Performance Test	
CDRL T1663	Drift Test	
CDRL T1664	Slip-Slide Test	
CDRL T1665	Friction Brake Only Round Trip Test	A008

16.8 REFERENCED STANDARDS

The following standards are referenced in this section:

ASME	Boiler and Pressure Vessel Code for Unfired Pressure Vessels
JIC	Hydraulic Standards

SECTION 17
TRUCKS

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SECTION 17
TRUCKS

17.1 GENERAL

Each car shall be equipped with two motor trucks. Each truck shall be a four-wheel, inside frame, equalized, roller bearing truck 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 15.3 and 15.4, and two disc brakes per axle in accordance with the requirements of Section 16. 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 designed for use on an electric-railway passenger car. The design shall:

A Have been used successfully in mass transit passenger service on a fleet of at least 25 vehicles A008
for at least two years A009

B. Comply with all performance, strength, and ride-quality requirements of this Specification

C. Have 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 each end of a car and among the cars furnished under this Contract without requiring any modifications to the truck, except for the installation and removal of handbrake rigging. All cars furnished under this Contract shall have handbrake rigging installed on the front truck. 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

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 emergency detrucking shall be fastened with accessible bolts, pins or other approved, removable fasteners.

17.2 DESIGN CONSIDERATIONS

The qualities specified herein 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 A008
case of conflict the most stringent requirement shall prevail.

17.2.1 Safety

The design shall comply with the strength requirements of this Specification under all loading conditions described in Sections 17.4 and 17.10. The design shall be such that the stresses developed under absolute maximum load when running on minimum quality track under all operating conditions, including worn wheels, and at speeds up to and including 80 mph, do not exceed the yield strength of the material.

The vehicle suspension system shall be designed with suitable backup suspension or safety-stop means to reduce the likelihood of a catastrophic vehicle failure, derailment, collision or extension beyond the track clearance envelope in the event of a failure in the normal suspension element or system.

Each component of the truck (including axles, wheels, bearings, the truck-mounted brake system, suspension system components, and any other components attached to the truck by design) shall remain attached to the truck when a force equivalent to 2g acting on the mass of the component is exerted in any direction on that component.

The truck and its components shall be designed with consideration for the safety of personnel during shop maintenance activities. Sharp edges and pinch points shall be avoided where practical.

17.2.2 Service Life

The trucks shall be designed so that, in normal service under the stated conditions and with proper maintenance and servicing, their service life shall equal or exceed that of the carbody without any need for structural repairs or alteration.

17.2.3 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 5000 Series cars. The specified ride quality must be achieved at all speeds up to 80 mph. The Contractor shall be responsible for preparing the necessary test procedures for Authority approval and for conducting the test to determine ride quality (see Section 17.10.7). 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 shall be identical in both tests.

17.2.4 Maintenance Requirements

The truck design shall provide unobstructed access to all parts that require periodic inspection, lubrication, and/or removal and replacement without requiring removal of any other apparatus. Cables,
A009 wiring, piping, and hoses shall have convenient disconnect devices in places where required for the removal of truck from the carbody or major components from the truck assembly. 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 types of lubrication fittings shall be used to distinguish the lubrication points that require the use of differing lubricants.

Lifting eyes or other means approved by the Authority of sufficient strength (50% of yield strength shall not be exceeded) shall be provided at four points on the truck frame to permit level lifting and transport by shop crane of a fully assembled truck.

17.2.5 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 in 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.

17.2.6 Truck Side Bearing

Side bearings, if used, shall be coated with a material which meets or exceeds the expected life exhibited by Rulon J. A008

17.2.7 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 deflated.

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 inflated and brakes released.

17.2.8 Truck Dynamic Analysis

The Supplier shall perform detailed dynamic modeling of the entire vehicle, using a proven rail vehicle dynamic analysis package such as NUCARS or VAMPIRE. The analysis package used shall be subject to Authority approval, prior to use. This model shall include all appropriate degrees of freedom, masses, stiffness and damping elements for the vehicle. Modeling shall be performed initially with theoretical suspension parameters, and again when measured values become available, if these differ significantly from the predicted values. The model shall be validated by appropriate stability and curve negotiation testing on the first vehicle. ***(CDRL 1701)***

The model(s) shall accurately predict the ride quality, ground borne vibration, curving performance, lateral stability and derailment safety of the vehicle on Authority track. The vehicle condition shall be assessed using the following parameters:

A. with new and any worn wheel profile not condemnable by current Authority practice;

B. at all vehicle load conditions and operating speeds;

C. with a range of suspension characteristics consistent with those possible due to the prescribed maintenance recommendations.

Modeling of ride quality and ground vibration input shall demonstrate that the vehicle meets the requirements of this section with verified suspension and track characteristics.

Modeling of curving performance shall demonstrate that when the vehicle negotiates mainline or yard track at prescribed speeds, the requirements of this section are met when traversing curves or tangent track with irregularities.

Modeling of vehicle stability shall confirm that the vehicle does not exhibit any unstable limit cycle oscillations at any speed up to 10% above the maximum operating speed, and satisfies the requirements of this section.

Within an agreed to time frame the car builder shall furnish to the Authority a dynamic model that demonstrates that the final vehicle design complies with all requirements of this section. (CDRL 1701) Any changes made to the vehicle after this submittal must be reconfirmed and new modeling data must be submitted to the Authority.

17.2.8.1 Wheel Unloading

Under any operating condition over track within the limits of the governing track geometry standards (Section 17.3), the vertical load on any wheel of the truck, for a distance traveled along the track of 5 feet or more, shall not be less than 10% of the static vertical wheel load (that is, 10% of the vehicle load that would exist on that wheel when vehicle is stationary on perfectly level tangent track).

17.2.8.2 Vehicle Overturning

When negotiating a curve with uniform superelevation in steady-state conditions, no vertical wheel load shall be less than 60% of its static value on level tangent track. Compliance shall be demonstrated for two extreme conditions:

A. Static lean on maximum superelevation, as defined in Section 17.3

B. Static lean on negative superelevation corresponding to roll deflection at the maximum allowable speed in excess of balance speed.

17.2.8.3 Wheel Climb

Under any track irregularity condition permitted by the governing track standards, the ratio of lateral force (L) to vertical force (V) on any wheel should not exceed the Nadal limiting L/V ratio for a distance of 5 feet or more:

$$L/V = [\tan \delta - \mu]/[1 + \mu \tan \delta]$$

where:

δ = flange contact angle, and
μ = coefficient of rail head friction, a value of 0.5 shall be used.

17.2.8.4 Track Panel Shift

The total lateral force applied by any axle of the truck to the track should not exceed 50% of that axle's static vertical load for a distance traversed along the track of 5 feet or more.

17.2.8.5 Gauge Widening Forces and Ground-Borne Vibrations

The total dynamic lateral force exerted by a truck on a single rail shall not exceed 60% of the vertical force exerted by that truck on that rail for a distance of 5 feet or more. The rail damaging forces and ground-borne noise and vibration levels shall in no case be higher than those generated by the Authority's 4000 Series cars. The Contractor shall demonstrate by calculation or test that vertical and horizontal track forces have been minimized ***(CDRL 1704)***. The Contractor shall be responsible for preparing the necessary procedures for Authority approval and for conducting the test to determine the existing track forces and ground-borne vibration of the Authority's 4000 Series cars. 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 shall be identical. A002

17.2.8.6 Truck Rotation and Stability

The Contractor shall provide a truck assembly that will resist hunting (nosing) at all speeds from 0 up to 80 mph under worst-case conditions, including component wear and aging. The vehicle will be regarded as unstable when the criteria of UIC Standard 515 regarding stability are exceeded, or the vehicle bodies, trucks or axles exhibit continual undamped oscillations in any axis or mode. The truck assembly shall 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. Truck stability and turning stiffness shall not cause abnormal wheel or rail wear.

17.2.8.7 Truck Swiveling Index

The truck swiveling index (TSI) shall be in the range of 0.04 to 0.08 for all conditions of wear pads at swiveling surfaces, when defined as follows:

$$\frac{T}{2 \times Q \times d}$$

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 that truck drawings are submitted for approval. ***(CDRL 1702)***

17.2.8.8 Natural Frequency

The natural frequency of the suspension subsystem shall be separated from the natural frequency of the carbody by at least 3Hz. A007

17.2.9 Primary Suspension

The Contractor shall provide service-proven primary suspension systems. The vertical resonance frequency of the primary suspension system shall be separated from that of the carbody by at least 3 Hz. 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 lbs. per inch for chevron, clouth, or similar suspensions, and shall in no case exceed 135,000 lbs. per inch for donut-
A007 type suspensions.

A003 The primary suspension shall have a minimum useful life of 12 years.

17.2.10 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 under all car-loading conditions when any or all air springs are inoperative. Air-spring pressure with the vehicle at AW0 weight, as specified in Section 7.3, 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 nonadjustable and shall be attached to the truck in a fail-safe manner.

Lateral stops are required to restrict carbody motions. The lateral stops shall incorporate 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 the truck and shall be readily accessible from one side of a vehicle when the vehicle is on level track The location of the cut-out cocks 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 (cut-in) 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 (subjected to a hydrostatic pressure test at 1.5 maximum working pressure), and stamped in accordance with the ASME Boiler and Pressure Vessel Code. Stresses associated with the pressure-vessel function shall be included in the above stresses. The reservoirs shall contain telltale holes, if required, in accordance with the requirements of Section 16. 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 16.

All air reservoirs must provide drainage at their lowest point.

17.2.11 Leveling (Height Control)

Height-control valves shall regulate the inflation of the air springs 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 (±3/16-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. Check valves shall be provided 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.

17.2.12 Corrosion Protection

The truck shall be designed to preclude 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 ***(CDRL 1705)***. A002

17.3 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.

C. Average miles of operation per year: 100,000

D. Station Stops per mile, average: 0.85

E. Rail: 115 RE canted 1:40

F. Minimum Horizontal Curve: Refer to Section 7.1.

17.4 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.

A002 The Contractor shall provide a stress analysis. The stress analysis shall include the calculated stresses, allowable stresses and safety margins for all truck structural components under all anticipated loading conditions and load combinations. The stress analysis may consist of a finite element analysis (FEA) supplemented as necessary by conventional calculations, and shall be submitted for review with the truck
A002 drawings ***(CDRL 1706)***.

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 to the carbody bolster through structural members, positive stops, or other rigid, mechanical safety
A008 devices or combinations thereof. 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 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 same strength requirement applies to any brackets by which the rods are attached to the truck, the truck bolster, or the carbody, as well as to the members to which these brackets are attached.

Truck-lifting hooks and other members used to attach the truck to the carbody shall be designed to provide a safety factor 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 17.10 shall not exceed the following levels:

A. For static load tests (Section 17.10.1): 40% of yield strength of material.

B. For overload test (Section 17.10.2): Yield strength of material.

The fatigue design of the truck frame and bolster shall use the test loads defined in Section 17.10.3. 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 17.10.3. A005

For welded structures, the fatigue stress range shall be within the allowable fatigue endurance limit obtained from AWS D1.1, Section 2.24, as provided in Figure 2.10 "Design Stress Range Curves for Categories A to F, Non-Redundant Structures (Non-Tabular)". Curves for categories C or D for other attachments should be used, as mutually agreed. A005 A009

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.

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.

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 the requirements of Section 22.4 for steel plate and Section 22.5 for castings. All welding shall be in accordance with welding and brazing requirements specified in Sections 22.5.4 and 22.22. All cast steel welds shall be inspected to MSS SP-55, "Quality Standard for Steel Casting." Steel plate welds shall be inspected to AWS D1.1, Section 2 A009 requirements. Non-destructive sampling provisions for inspection of welds specified by Section 22.22.4 shall be applied to both cast steel and plate steel weldments.

17.5 DESIGN FEATURES

17.5.1 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 17.4.

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 top 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.

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 that permit these dimensions to be readily checked. The Contractor shall furnish seven sets of plugs or other gauges required for this purpose (see Section 21, CDRL 2105).

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.

17.5.2 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:

A002

A. Magnetic particle inspection to ASTM E709 of all critical areas of the castings by personnel certified to MIL-STD-410 ***(CDRL T1758)***. 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.

A002

B. Radiographic inspection meeting the requirements of ANSI/ASTM E94 using reference radiographs to ASTM E446 ***(CDRL T1759)***. A sampling frequency shall be selected and submitted for approval. Severity level III of ASTM E446 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 25 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 ***(CDRL 1707)***. A002

Prior to beginning truck manufacture, the Contractor shall submit for approval an inspection and acceptance plan that includes, as a minimum, the requirements specified herein ***(CDRL 1708)***. 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. A002

17.6 WHEELS

Wheels shall be multiple wear, Class C, and made of wrought steel in accordance with AAR M-107 and APTA SS_M-012-99 Standard for the Manufacture of Wrought Steel Wheels for Passenger Cars and Locomotives. The wheel manufacturer shall be AAR certified. 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 Authority's existing 5000 series cars shall be used. Wheelsets shall be interchangeable with the existing 5000 series fleet. The reference drawing for the wheel is Contract Drawing 97936-018. Disc mounting provisions shown in 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. Shop and mounting processes shall be AAR certified. Wheel sets shall be concentric within 0.005-inch total indicated run-out when rotated in their bearings.

The thread design shall be as shown in Contract Drawing 97936-018. Wheels shall be marked in accordance with AAR standards for rim stamping and coated with approved anti-rust coating.

17.7 AXLES

The axle manufacturer shall be AAR certified. Axles shall be hollow and made of alloy steel tubing AISI 5150 meeting all AAR M-101 Grade G requirements, and shall conform to the requirements of drawing 18350301, latest revision. A009

Axles shall be designed for multiple use, allowing for repeated assembly and disassembly of the wheels without permanent damage, in accordance with standard Authority maintenance intervals. A007

Inspection per the requisite AAR M-101 requirements shall be submitted to the Authority for approval ***(CDRL T1760)***. A009

17.8 JOURNAL BEARINGS

17.8.1 General

Journal bearings shall be an AAR-approved NFL design, roller type, and grease lubricated. Seals shall be HDL type, adequately installed to assure axle's and bearing's intended life. 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.

17.8.2 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 (as installed under a car) and even numbers applied to the right side. Number plates with raised, painted numerals shall be applied to the truck frames at locations which are clearly visible when viewed from the side of a completed truck assembly.

17.9 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 truck's construction, including manufacturing inspections, except where these are covered by standard specifications. ***(CDRL 1703)*** The Contractor shall thereafter notify the Authority of any changes thereto, and shall obtain Authority approval before placing such changes in effect. The procedures employed in the manufacture of the first truck to be successfully tested shall not be changed in any respect without the concurrence of the Authority.

A006

17.9.1 Press Records

All wheels and journal bearings shall be mounted on the axle in accordance with the practices set forth in the AAR Wheel and Axle Manual and journal bearing manufacturer installation instructions. AAR Rule 1E1, Wheel Press Practices and Rules 2C1 to 2C12, Wheel Mounting Press Practices shall be observed. The final seating tonnage (spike) shall be recorded as a part of a complete wheel fit pressure diagram. All press diagrams (wheels, bearings and gearboxes) shall have clearly defined acceptance (or rejection) limits and shall be presented in a form approved by the Authority ***(CDRL 1712)***. All press records (wheels, bearings and gearbox) shall be approved by the Authority prior to installation of any wheelset on the trucks ***(CDRL T1758)***. The Authority reserves the right to witness any or all of the pressing operations as deemed necessary.

All interference fits and pressing tonnage values for wheels, bearings, and gearboxes shall be made available as a part of wheelset assembly drawing. Authority approval of this wheelset assembly drawing (submitted with CDRL 102) must be received prior to the commencement of manufacture of the wheels and axles.

17.10 TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 3. Qualification tests of all new, unproven or updated truck designs shall be performed on a representative specimen to demonstrate conformance to specification requirements. For trucks similar in design or application to previously manufactured trucks, the Authority may elect to waive any or all portions of qualification tests if design adequacy can be proven through engineering analysis of previously completed equivalent testing and/or by successful service of the truck.

The first truck shall be subjected to tests in accordance with the requirements of Sections 17.10.1, 17.10.2 and 17.10.3. The Authority will witness the static load and overload tests, and will witness the dye penetrant inspection required by the fatigue test. In addition, the Authority may observe the fatigue test at any point in its progress.

The Contractor shall perform tests of the primary suspension system in accordance with the requirements of Section 17.10.4 and shall submit the reports of these tests 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. The Authority will witness these tests.

No fewer than 150 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 7.1.

Height-control valve adjustments, measurement of carbody floor height, and air-spring heights shall be checked and recorded for each car.

17.10.1 Static Load Test

The purpose of the static load test is to verify that the maximum allowable stresses specified in Section 17.4 are not exceeded. ***(CDRL T1751)*** 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 17.4. If this stress level is exceeded, 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.

17.10.2 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:

A. The vertical component shall be equal to half the total empty car weight plus 50,000 lbs.

B. The lateral component shall be equal to 15% of the vertical component

C. The longitudinal component shall equal 15% of the vertical component

D. 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 the truck as approved by the Authority. ***(CDRL T1752)*** 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 shall be retested at the expense of the Contractor; and all trucks installed in the cars shall be in accordance with the corrected design.

17.10.3 Fatigue Test

A005 To demonstrate that the truck has adequate fatigue strength under dynamic loading, it shall be subjected to the number of cycles equivalent to the endurance limit of combined loading within the limits specified below. ***(CDRL T1753)*** 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 be l5% of the mean vertical load and shall 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 vertical transfer 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 that do not exceed those required by Section 17.4. Critical locations shall be approved by the 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, truck shall be dye penetrant and magnetic particle inspected in the presence of the Authority, and all defects clearly identified. 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. The Authority reserves the right to select other trucks for testing.

During the fatigue tests all loads and stresses shall be recorded, and the truck shall be visually inspected periodically to detect possible crack initiation and progression. If evidence of progressive cracking or failure is found, the Authority and the Contractor shall assess the cause, an appropriate correction shall be established, and the test shall be repeated at the Contractor's expense.

At the conclusion of the test, a magnetic particle and dye penetrant inspection for cracks shall be made in the presence of the Authority. If any crack is found, the design shall be corrected, the truck shall be retested at the expense of the Contractor, and all trucks installed under the cars shall be modified in accordance with the corrected design.

17.10.4 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. ***(CDRL T1754)*** These tests shall verify 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 17.2.5.

17.10.5 Equalization Tests

The following tests shall be conducted to verify equalization provided by the truck design ***(CDRL T1755)***:

A. The test car on level track, with air springs deflated, shall have one wheel on one truck jacked up 2-1/2-inches while contact between any other wheel tread 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 inflated 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.

If the results of these tests indicate that the required equalization is not attained, the truck design shall be corrected and retested until satisfactory results are attained, and all trucks shall be modified in accordance with the corrected design.

17.10.6 Rollover Resistance Test

To verify the rollover resistance 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. Jacking may also be used to simulate the superelevation. Lateral displacement and roll angle of the carbody shall be measured. If the test indicates that the degree of motion restriction required by Section 17.2.5 is not attained, the truck design shall be altered, the truck retested at the expense of the Contractor, and all trucks shall be modified in accordance with the corrected design. ***(CDRL T1756)***

17.10.7 Ride Quality Test

To verify conformance to the ride quality requirements of Sections 17.2.3 and 17.2.10, the first married pair of cars shall be subjected to road tests on the Authority's tracks. ***(CDRL T1757)***

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: (1) empty, and (2) with simulated full load (AW2). The Contractor shall provide instrumentation capable of measuring and charting the magnitude and frequency of the expected vertical, longitudinal, and lateral shocks, up to 1.0g and 15 Hz. Sensing units shall be located and applied directly to the car floor (with carpet and padding removed) above the intersection of the car's longitudinal centerline and the transverse centerline of both trucks, and also at the center of the car. Provision shall be made for recording: (1) vertical, lateral, and longitudinal shocks (vibrations) concurrently; (2) speed; and (3) distance in 100-foot increments. The entry of event markers on recorded data for these tests shall be possible.

The Contractor shall provide the weights used in simulating a full load.

After each group of runs, the instrumentation shall be relocated to one of the Authority's existing cars in the 5000 Series, the specific car to be chosen by the Authority. A series of runs at the same speeds, at the same loads, and on the same track shall be made with the 5000 Series car 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 case the comparisons 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 root mean square (RMS) accelerations in the vertical, lateral, and longitudinal directions recorded 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 (square root of the sum of squares) 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.

17.11 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 1701	Truck Dynamic Analysis	
CDRL 1702	Truck Swiveling Index	
CDRL 1703	List of Truck Construction Procedures	
CDRL 1704	Track Force Calculations and Test Procedures	
CDRL 1705	Corrosion Protection Plan for Truck Frame	A002
CDRL 1706	Stress Analysis	
CDRL 1707	List of Critical Areas and Welds	
CDRL 1708	Truck Inspection and Acceptance Plan	
CDRL 1709	Truck Pressing Acceptance / Rejection Limits	A006
CDRL T1751	Static Load Test Report	
CDRL T1752	Overload Test Report	
CDRL T1753	Fatigue Test Report	
CDRL T1754	Primary Suspension Test Report	
CDRL T1755	Equalization Test Report	
CDRL T1756	Stability Test Report	
CDRL T1757	Ride Quality Test Report	
CDRL T1758	Truck Frame Magnetic Particle Inspection Report	A002
CDRL T1759	Truck Frame Radiographic Inspection Report	
CDRL T1760	Axle Inspection Report	
CDRL T1761	Wheelset Pressing Records	A006

17.12 REFERENCED STANDARDS

The following standards are referenced in this section:

AAR C-II, Section 7.4	
AAR Manual	Section G: Wheels and Axles
AAR M-101	Axles – Carbon Steel, Heat Treated
AAR M-107	Wheels, Carbon Steel
ANSI/ASTM E94	Practice for Radiographic Testing
APTA SS_M-012-99	Standard for the Manufacture of Wrought Steel Wheels for Passenger Cars and Locomotives
APTA RP-M-009-98	Recommended Practice for New Truck Design

ASME	Boiler and Pressure Vessel Code for Unfired Pressure Vessels
ASME	Metals Handbook
ASTM E446	Standard Reference Radiographs for Steel Castings Up to 2 in. (5 mm) in Thickness
ASTM E709	Standard Guide for Magnetic Particle Examination
ASM	Metals Handbook
AWS D1.1	Structural Welding Code, Steel
MIL-STD-410	Nondestructive Testing Personnel Qualification and Certification
MSS SP-55	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components

SECTION 18
AUTOMATIC TRAIN CONTROL

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SECTION 18
AUTOMATIC TRAIN CONTROL

18.1 GENERAL

Each pair of cars shall be equipped with an Automatic Train Control (ATC) system as specified herein and as shown in the Contract Drawings. 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 provide a complete, safe, reliable and operational system.

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, as well as the applicable requirements of other sections of this Specification, shall be passed on to any such supplier. The ATC equipment shall 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 their storage in a data acquisition module (DAM) as specified in Section 18.8.

18.1.1 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 9.4.9.

The fail-safe design criteria for the ATC system shall be as specified in Section9.4.9.

The number of vital relays used in the ATP subsystem shall be limited to the absolute minimum required without compromising system safety and without sacrificing functionality of subsystem operation. A007

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.

18.1.2 Design Reporting

The Contractor shall submit a conceptual design description for approval (see Section 2.2) . 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.

18.1.3 Testing

The Contractor shall perform all tests in accordance with the requirements of Section 18.10.

18.1.4 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 5.1.

Materials and workmanship used in the manufacturing process shall be in accordance with the applicable requirements of Section 22.

The ATC system shall be manufactured in accordance with the approved drawings and procedures that serve as the production baseline. Changes from the production baseline shall not be made without prior approval of the Authority.

18.1.5 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.

All assemblies and component circuit boards shall be permanently inscribed with nomenclature to reflect its unique part number and application. The nomenclature shall be inscribed in the English (U.S.) language at one location for each board.

The ATC microprocessor-based subsystems shall be compact and self -contained, and shall use modular construction of plug-in circuit boards. Circuit boards of a particular type shall be uniquely keyed to prevent insertion of the wrong board into a wrong slot. The vital relay portion of the ATP subsystem, if such existed, shall be placed on the hinged or rolled out frame to allow access to the relay plate wiring. Connections to external devices shall be accomplished by means of approved connectors, the use of edge connectors is unacceptable. All circuit boards and board-mounted components shall be coated to prevent them from malfunctioning due to accumulation of electrically conductive dust. The coating shall be approved by the Authority. All circuit boards shall be mounted vertically. All circuit boards and each board-mounted component shall be permanently labeled. All components shall be mounted so as to facilitate maintenance or replacement without disturbing internal wiring or other equipment.

The Authority will utilize a philosophy of plug-in/plug-out maintenance. The maintainers will perform remove and replace operations on Line Replaceable Units (LRUs). The repair of circuit boards and electronic modules will be performed in the shop.

The design of ATC system shall be such that all electrical devices including such items as PC boards, relays, 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.

The back of the ATC cabinet shall be properly sealed to exclude water or grease finding their way to the ATC components through the door pocket.

18.1.6 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.

18.1.7 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.

18.1.8 Test Points

The Contractor shall provide a sufficient amount of test points and diagnostics for line maintenance encompassing troubleshooting and routine maintenance of the ATC system components, and shop maintenance encompassing repair of failed components and PC boards. The amount of test points and diagnostics for line maintenance shall be minimized to the extent of reliable detection of defective PC boards and electronic modules. The detection of defective components shall be possible without the disconnection of wires.

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.

Diagnostics, self test, and system health status indicators shall be provided as described in Section 18.5.

18.1.9 Environmental Requirements

The ATC system shall be capable of operating under ambient temperature range from -5° F to 105° F and relative humidity from 20% to 100%, including conditions of condensation. Refer also to Section 7.2 of this Specification.

According to the vibration criteria specified in Section 23.3, the ATC equipment shall not be exposed to a vertical or horizontal vibration 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.

18.2 AUTOMATIC TRAIN PROTECTION (ATP)

The Automatic Train Protection (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 5.2 and 5.4, 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, as shown in Exhibit 18-1.

Exhibit 18-1
Speed Commands

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 in Contract Drawing 97936-021.

18.2.1 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 in 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 in Contract Drawings 97936-024 and 97936-021. The coils shall not be connected to the speed command reception circuits during backup moves.

18.2.1.1 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

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: code	Pole changed energy drive to the code rate detectors at the rate carried by F1 and F2

Refer to Section 18.2.1.3 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.

18.2.1.2 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.

18.2.1.3 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.

18.2.1.4 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.

18.2.2 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 the ATP speed sensor signal with a signal of the independent speed sensor used for the speed indication for the operator.

18.2.2.1 Speed Sensors

Two speed sensors mounted on separate axles shall be provided for the ATP system overspeed protection function. One additional speed sensor shall be mounted for the ATO system function which provides a speed indication for the operator. All three sensors 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 sensor interface to the ATC subsystem shall be such that continuous speed detection exists between 0.5 mph and 99 mph.

The sensors used for overspeed protection shall not be used for any purpose other than ATP

The Contractor shall make all efforts to utilize a common type of speed sensors for ATP and ATO compatible with the existing propulsion/brake systems speed sensors.

18.2.2.2 Speed Measurement and Safety Precautions

The ATP subsystem shall detect motion when gear rotation is sensed by the ATP 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 protection shall function to detect rollback and brake the train to a stop within 10 seconds or 50 feet, whichever occurs first. A009

The speed comparison algorithm of the microprocessor ATP system shall generate an output signal to energize a vital relay , which indicates that the actual train speed is less than the limiting speed and that the speed comparison is performed properly. In the event of algorithm failure, or if the actual speed exceeds the speed limit (an overspeed condition), this vital relay shall become de-energized.

18.2.2.3 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-Cut-out 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
A008 0.5 mph. This zero speed signal shall be available for use by other vehicle subsystems.

The audible overspeed alarm shall be compatible with existing Authority cars.

18.2.2.4 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%.

18.2.2.5 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.

During the test the following five ATC functions are checked in all applicable modes:

A. Cab signal reception and decoding
B. Overspeed protection

C. Rollback protection
D. Motion sensor failure protection
E. Door operation

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.

18.2.2.6 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.

18.2.3 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.

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 in Contract Drawing 97936-024. Door control circuits in the controlling "A" car shall monitor these trainline wires to provide back-end status as shown in 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 <u>either</u> 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 <u>either</u> 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.

18.2.4 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 <u>any</u> 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 CUT-OUT 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 <u>all</u> 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 <u>any</u> 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 CUT-OUT 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 cut-out 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 cut-out mode, the ATP CUT-OUT indicator on the Operator's control console shall be energized. An ATP Cut-out 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 cut-out 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.

18.2.5 Braking Interface

A braking interface shall be provided to initiate and enforce Safety Brake applications. Safety (Full Service) brake applications shall be initiated by <u>any</u> 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 18.2.2.3.

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.

18.2.6 Microprocessor-Based ATP System

18.2.6.1 General

The ATP functions shall be carried out by a microprocessor-based system. The microprocessor and its support logic equipment shall perform all functions required by the design of the device for which it is used. In the event of a general failure affecting the microprocessor system, or any its communications links, the outputs from the system shall ensure that system adopts a safe state.

The microprocessor-based ATP subsystem shall be of a type that has been proven in revenue service in an environmentally similar transit system for a minimum of two years prior to reception of the bid. Any product improvements that the Contractor wishes to make in the offered equipment over and above the equipment, which has actual revenue experience, shall be subject to approval by the Authority.

18.2.6.2 Hardware

Hardware shall generally comply with the requirements of Section 22, except where stated in this section.

Logic units shall consist of a microprocessor and all necessary memory storing, interface, and control devices. The memory shall have adequate capacity (including a minimum of 30% spare capacity over the requisite initial system memory requirements) to meet system requirements, and shall consist of static Random Access Memory (RAM), Flash Memory, mask-programmed Read Only Memory (ROM), and Programmable, ultra-violet-erasable, or electrically erasable Read Only Memory (PROM, EPROM, EEPROM), intermixed as required. The microprocessor shall be supplied with the instruction sets and internal registers necessary for the execution of its programs. The external bulk memory storing devices including cassettes, disks, CD ROMS, and tapes for program execution shall not be allowed.

All systems that perform real-time control functions necessary for the safe and/or reliable operation of the rapid rail system shall provide integrity checks for all data and programs stored in PROMs, EPROMs, EEROMs, and any other memory devices. The check shall consist of a cyclic redundancy check (CRC) of the memory contents performed either as a background task, or on receipt of a periodically generated processor interrupt. Memory-related integrity checks shall be executed no less frequently than once every five minutes. In the event that an integrity check is failed, the unit shall immediately provide an indication that it has failed, switch all outputs to their most restrictive condition, and execute a processor halt instruction.

The erasure apertures of all erasable memory storing devices shall be covered by approved self-adhesive opaque labels. The labels shall clearly identify the memory content of the device, and the version number of the program and/or data it contains.

All systems performing real-time control functions necessary for the safe and/or reliable operation of the carborne signaling system shall provide verification of output status independent of the output port and its associated electronics. This verification port shall allow diagnostic software routines to recognize and identify specific output failures.

18.2.6.3 Inputs and Outputs

Inputs and outputs shall incorporate opto-isolated circuits, or other approved method to isolate external circuits from the internal components of the circuit boards.

The system shall have solid state outputs of suitable balanced power to drive relays, serial links and parallel inputs to other microprocessor systems, or other devices as required.

All systems shall include a quartz-crystal-controlled master clock for time various operations. Where applicable, the clock shall be continuously monitored by an approved method.

All microprocessor subsystems shall include a panel with light emitting diodes and/or liquid crystal displays indicating the state of the system to maintenance forces. The displays shall comply with requirements of Section 22.

All equipment, including modules and connectors shall be housed in such a manner as to preclude contamination from electrically conductive dust.

All equipment shall be capable of performing in the environment as specified in Section 7.2. Forced air cooling fans to circulate air through the modules, and over circuit boards are not permitted.

Integrated circuits subject to revision of software shall be mounted in approved sockets as specified in Sections 22.28.3 and 22.28.4.

Components shall not require special grounding practices during troubleshooting, or for the replacement of boards or modules.

18.2.6.4 Vital System Requirements

Microprocessor systems employed in safety critical systems or subsystems shall be considered vital. The requirement of this section must be complied with by those systems.

Each vital system shall monitor on a continuous basis (at least once a second) that it is capable of executing its instruction set correctly, that the executive software and the application logic have not changed since installation of the system, and that databases are valid and not corrupted. Systems that revert to a more restrictive state in the event of corruption are acceptable.

The system shall ensure that inputs are correctly recognized and not stuck in a less restrictive state, and that they are responsive to changes in the external input circuits.

The system shall ensure that inputs and internal variables are current, and not ‘stale’ data from previous operations.

The system shall ensure that output devices are driven correctly and are responsive to changes in output status of the microprocessor-based equipment. No de-energized output shall be spuriously energized.

Data exchanged between microprocessors shall be current and valid.

Failure of the system to meet any or all of the above requirements shall result in a shut down of the microprocessor and the reversion to a restrictive state of all outputs.

The microprocessor-based ATP system shall be equipped with its own regulated power supply. The power supply shall be used solely for the excitement of the system itself and not for the energizing of other systems or associated equipment such as input or output relays or circuits.

The equipment shall be protected against and shall not malfunction due to power fluctuations of the carborne low voltage power supplies, including but not limited to power dips and spikes, electrical noise, and radiation of externally generated electromagnetic energy.

In the event of a power interruption, the system shall automatically reset to its normal operating mode upon restoration of input power.

18.2.6.5 Safety Requirements

A002 A safety analysis of operation of the ATC system shall be submitted in compliance with a general requirements specified in Section 5.4 ***(CDRL 1811)***. A Mean Time Between Hazardous Events (MTBHE) of not less than 1 x 10^9 Train Operating Hours shall be established for the microprocessor-based subsystems

18.2.6.6 Electromagnetic Interference and Compatibility

The ATC system shall be electromagnetically compatible with all other carborne subsystems and with the ambient electromagnetic environment. None of ATC subsystems or any other carborne subsystems shall cause or be impacted by electromagnetic interference with each other. The EMI/EMC requirements are specified in Section 7.6 of this Specification.

18.2.6.7 Software

Software, as a safety critical element of the ATP subsystem, shall meet both general requirements specified in Section 22.29.2 and the requirements outlined for vital systems in Section 18.2.6.4. A Vital Software Validation Report ***(CDRL 1801)*** shall be added to the standard package of Software Quality Assurance Documentation, which shall be provided by the Contractor according to the requirements of Section 22.29.5.

Vital software validation shall be based on series of tests proving a fail-safe feature of software design.

18.3 Automatic Train Operation (ATO)

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 ensure full compatibility with the Authority's existing cars.

18.3.1 Automatic Speed Regulation

The automatic speed regulation equipment shall use solid-state digital logic circuits for speed measurement, speed comparison, and cab display drives.

18.3.1.1 Speed Sensing

The ATO speed sensor shall be identical to the ATP speed sensors and shall be installed on one of the "A" car axles in an identical manner to the ATP speed sensor installation. Refer to Section 15.4.11 for locations of speed sensors.

18.3.1.2 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 14.6.2, Exhibit 14-1.

18.3.1.3 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 14.6.2, Exhibit 14-1.

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.

18.3.1.4 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 resulting 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.

18.3.1.5 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.

18.3.1.6 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.

18.3.2 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 pushbutton 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 in 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 pushbutton.

Actuation of the TRAIN BERTHED pushbutton shall cause the TRAIN BERTHED output of the PSS equipment to be energized and remain energized until the Program Station Stop is reset.

18.3.2.1 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 pushbutton.

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 18.3.2.4.

18.3.2.2 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, weather tight 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.

18.3.2.3 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 18-2.

The frequency assignments are shown in Exhibit 18-3.

Exhibit 18-2
Data Received from Specific Station Stopping Markers

Marker	Function
2,700-Foot Marker: 1st Member	• Always tuned to F1 • Initiates PSS • Initializes “Type A” stop logic • Indicates 2700 feet from platform centerline
2nd Member	• Conveys grade information. Tuned to one of five frequencies: F6, F7, F8, F9 or F10
1,200-Foot Marker: 1st Member	• Always tuned to F2 • Initiates PSS in absence of 2,700-foot marker • Indicates 1,200 feet from platform centerline
2nd Member	• Sets the type of stop logic • Tuned to one of four frequencies: F6, F7, F8, or F9 (Tuning is controlled by the wayside station control logic as required.)
484-Foot Marker: 1st Member	• Always tuned to F3 • Sets the grade storage logic to zero grade • Initiates PSS in the event of a turnback move • Indicates 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	• Always tuned to F4 • Resets the Skip Stop logic • Indicates 160 feet from the platform centerline

Exhibit 18-3
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

18.3.2.4 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.

18.4 Automatic Train Supervision (ATS)

An Automatic Train Supervision subsystem shall be provided to interface with the Authority' existing ATS System. The ATS subsystem shall consist of train-to-wayside communication and train length determination equipment.

18.4.1 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 Pushbutton Right	
Manual Pushbutton 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 pushbutton; 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 PUSHBUTTON RIGHT, from the operating cab right side door button; MANUAL PUSHBUTTON 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 Pushbutton Right
27	Manual Pushbutton 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

18.4.2 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 in 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.

18.5 DIAGNOSTIC REQUIREMENTS

The ATC subsystem shall be provided with a comprehensive set of diagnostic capabilities, including internal health monitoring routines and diagnostic indications. Self-detected faults shall be displayed locally on the front of the equipment, and interface to the Vehicle Monitoring System (VMS) subsystem A008 and portable test unit providing fault identification data to that equipment.

Subsystem faults shall be self-detecting to the maximum degree possible (at least down to the circuit board or module level) and diagnostic and health status shall be indicated on either LCD displays, LED indicators, LED segment displays, or displays of similar technology. The displays shall be clearly visible from the front of the ATC equipment and shall be clearly labeled. Alternatively the display shall spell out in text form the nature of the fault. The displays shall not be coded, and shall be easily understood by a maintainer without reference to a manual or troubleshooting guide.

A diagnostic system which uses two levels of detection is acceptable, that is the initial indication of a fault can be responded to by the Train Operator or maintainer pushing a button on the ATC equipment to initiate a more intensive diagnostic or self test routing. The results of this test shall be displayed on the equipment display units and available via the portable test unit so that the line replaceable unit at fault is A008 identified.

18.6 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.

18.7 MICROCOMPUTER

Microcomputers used to perform Automatic Train Control functions shall conform to the requirements of Section 22.29. The Contractor shall submit to the Authority for approval software quality assurance
A003 document in compliance with the requirements of Section 22.29.5. ***(CDRL2211)***

18.8 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 these data shall be stored with time and date stamping in a data acquisition module (DAM). The DAM shall be independent module from the ATC system which will act as a VMS data bank for the ATC system.

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 to the portable test device via the
A008 car communications network and the local RS232 port and transmitted by the car communications network to the central vehicle monitoring system equipment specified in Section 20.6. 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 20.5. The DAM shall convert the signals from its associated system, analog or digital, to serial packages and store for transmission to the VCU viathe car
A008 communications network. 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 (MID) character within the network so that communications between all units can be managed and controlled.

18.9 COMPONENTS AND HARDWARE

All components and hardware used in the ATC system shall meet the requirements specified in Section 22.

18.10 TESTS AND INSPECTIONS

18.10.1 General

This section provides a general description of the tests and inspections that 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 3.

18.10.2 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. ***(CDRL 1803)*** Detailed test procedures for conducting these tests shall be submitted for approval no later than 90 days after approval of the plan. ***(CDRL 1804)*** 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.

18.10.2.1 Development Tests

Development tests shall be conducted during the design phase to ensure proper interface with the Authority's existing ATC system. ***(CDRL T1851)*** 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.

18.10.2.2 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. ***(CDRL T1852)*** 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.

18.10.2.3 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. ***(CDRL T1853)*** 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.

18.10.3 Factory Tests and Inspections

The Contractor shall develop a factory test plan ***(CDRL 1805)*** and factory test procedures ***(CDRL 1806)*** 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.

18.10.3.1 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.

18.10.3.2 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.

18.10.3.3 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.

18.10.3.4 Test Reports

Test reports shall be submitted for each test required by the approved test plan. ***(CDRL T1854)*** 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.

18.10.4 Installation

18.10.4.1 Plan

The Contractor shall submit a detailed installation and test plan for approval no later than 180 days after award of the Contract. ***(CDRL 1807)*** 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.

18.10.4.2 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. ***(CDRL T1855)*** 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. ***(CDRL 1808)***

18.10.4.3 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.

18.10.5 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. Tests shall also be performed to ensure the compatibility of the ATC system on the 6000 series cars with the rest of the WMATA fleet.

18.10.5.1 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. ***(CDRL 1809)***

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. ***(CDRL 1810)***

18.10.5.2 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 21.2 and shall conduct the Daily Safety Test described in Section 18.2.2.5. ***(CDRL T1856)***

18.10.5.3 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. ***(CDRL T1857)***

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 Cut-out

C. Test results and corrective action taken shall be entered in the Car History book.

18.10.6 Qualification Demonstrations

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). ***(CDRL T1858)*** Diagrams depicting track routing and profiles will be made available upon Contractor request.

18.10.6.1 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.

18.10.6.2 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.

18.10.6.3 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.

18.10.6.4 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

18.10.6.5 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 18.3.2.

18.10.6.6 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.

18.11 REFERENCED CDRLs

The following CDRL items are referenced in this section:

	CDRL 1801	Vital Software Validation Report
A003	CDRL 1802	Not used
	CDRL 1803	Design Test Plan
	CDRL 1804	Design Test Procedures
	CDRL 1805	Factory Test Plan
	CDRL 1806	Factory Test Procedures
	CDRL 1807	Installation & Testing Plan
	CDRL 1808	System Test Procedures
	CDRL 1809	Static & Dynamic Test Plan
	CDRL 1810	Static & Dynamic Test Procedures
A002	CDRL 1811	Safety Analysis of ATC System
	CDRL T1851	Development Test Report
	CDRL T1852	Compatibility Test Report
	CDRL T1853	Qualification Test Report
	CDRL T1854	Factory Acceptance Test Report
	CDRL T1855	System Test Report
	CDRL T1856	Static Test Report
	CDRL T1857	Dynamic Test Report
	CDRL T1858	Qualification Demonstration Test Report

CDRL 2211 Software Assurance Plan A003

18.12 REFERENCED STANDARDS

AAR Signal Manual

SECTION 19
COMMUNICATIONS

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SECTION 19
COMMUNICATIONS

19.1 SCOPE

19.1.1 General

This section specifies the functional and design requirements for the carborne communications system. Subsystems include train radio, public address (PA), passenger intercom and next station signs.

A new Comprehensive Radio Communications System (CRCS) is being installed to provide radio support for Rail Operations, Bus Operations, Transit Police, and Systems Maintenance. The complete system-wide mobile radio facilities will consist of a simulcast, trunked radio system operating in the 490 MHz UHF band that provides continuous two-way communications, without environmental restrictions, between Central Control and Trains. The carborne mobile radio communications equipment specified herein will communicate with the fixed base stations located at above ground tower sites. Radiax cable and bi-directional amplifiers will be located throughout the WMATA underground system to support radio communications for trains while they are in the tunnels. The CRCS is expected to be fully operational prior to delivery of the first prototype rail cars. A006

A. The fixed portion of the Revenue Train Operation subsystem consists of base stations, control facilities, repeater networks, and antenna arrays. The antenna arrays are used in conjunction with other mobile radio subsystems by the use of appropriate filters to provide the necessary isolation between subsystems.

B. The radio system is arranged in a half-duplex configuration with a push-to-talk operational mode. A006

C. A total of 15 channel pairs are used to support voice radio transmissions for rail and other WMATA operations. These channels operate as a trunked radio system in which the frequencies are shared among all users. A006

19.1.2 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.

19.2 FUNCTIONAL DESCRIPTION

19.2.1 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.

19.2.2 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's public address (PA) system.

19.2.3 Public Address Functions

The Public Address System shall provide the following functions:

A. Central Control Announcements: Personnel at Central Control shall be able to speak directly over the train PA 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 PA system.

A volume control shall be provided near the power amplifier or other location approved by the Authority to simultaneously adjust the volume of all passenger compartment loudspeakers located throughout the car (not including the Passenger Call System loudspeakers).

19.2.4 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 pushbutton associated with any call station shall connect the call station to a cab loudspeaker and alert the Train Operator. The pushbutton 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 pushbutton 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 pushbutton is depressed.

When the momentary action pushbutton in the cab designated "Talk Intercom" is depressed, the Operator shall be able to address all activated call stations. When this pushbutton 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" pushbutton is depressed, the lamp in the "Reset Intercom" pushbutton on the Operator's cab and the lamp in the pushbutton at the passenger call station shall be extinguished and the connection to the call station shall be released.

A total of four intercoms on a train shall be capable of being operated simultaneously without appreciable degradation in communications with the Operator, regardless of train length.

19.3 CARBORNE CONTROL SYSTEM

19.3.1 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 (PA) system, trainwide passenger call system, radio transmitter/receiver and DC to DC power converter for the radio, with all necessary cabling and accessories. A006

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 for a screw-on gooseneck microphone stand as well as all controls and displays required for train communications. See Section 19.3.3 for additional details on the A006 communications panel.

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 in 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 19.5.3 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:

A006 1. Transmitter power output indication

2. Transmitter audio isolation

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 pushbutton. When this pushbutton 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" pushbutton and shall be lit when a call button at a passenger call station is activated and remain lit until the "RESET" pushbutton is depressed.

4. Talk Intercom: Nonlocking pushbutton. The Train Operator must depress and hold this pushbutton in order to reply to a "passenger call." When the pushbutton is released, the Operator shall hear the passenger over the cab loudspeaker.

A006 5. Radio Squelch: Rotary clutch-type potentiometer provided as part of the radio control head. 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.

A006 6. Radio Volume Control: Rotary clutch-type potentiometer provided as part of the radio control head. Control shall provide continuous variation from 10% to 100% of maximum volume at the cab loudspeaker.

7. Talk-Public Address: Nonlocking pushbutton. The Train Operator must depress this pushbutton 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 pushbutton is depressed. The radio attenuation circuitry shall be designed such that any failure of this circuit results in full radio output.

8. Radio-Public Address: Nonlocking pushbutton. This pushbutton 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.

9. Radio Transmit: Large nonlocking pushbutton. In order to talk over the mobile radio, this pushbutton must be depressed and held to key the transmitter.

The Radio Transmit pushbutton 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.

10. Automatic level control shall be provided.

11. PA Speaker Volume Control: Rotary clutch-type potentiometer. Control shall provide continuous variation from 10% to 100% of maximum volume at the PA system loudspeakers.

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 in Contract Drawing 97936-011.

I. All surface mount potentiometers shall be of the clutch type and shall be linear or audio taper, as appropriate.

19.3.2 Availability of Functions

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 in 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 A006
connection to the UHF radio, in the same manner.

B. The interposing relay contacts for communications shall be silver plated and rated for no less than 5 amperes.

19.3.3 Panel Layout

The layout of the full control panel in the cab of existing 4000 and 5000 series cars is contained in A006
Contract Drawing 97936-009. As part of the WMATA Comprehensive Radio Communications System Program, the communications panel in existing rail cars is being removed, modified and reinstalled. This work is required to enable the rail vehicles to operate with the new 490 MHz digital trunked radio infrastructure.

The rail car communications panel modifications incorporated by ARINC to support the WMATA CRCS are include the following:

- Replacement of operator control panel top plate
- Elimination of existing radio volume and squelch rotary controls
- Elimination of radio frequency pushbutton & rotary selector switches
- Elimination of radio central call pushbutton

- Required internal component relocation
- Integration of Astro Digital Spectra W4 control head into new panel
- Integration of ARINC-modified remote control head cable
- Retained rail vehicle intercom and public address
- Retention of common microphone
- Retained radio to rail car public address patch with pad muting
- Newly designed DC/DC power converter

The communications panel is used by the train operator to control the radio, the rail vehicle public address, and the train intercom. On existing rail cars, the VHF radio is controlled by using a pushbutton and rotary switch on the communications panel for selecting the frequency, rotary knob potentiometers for controlling volume and squelch, and a pushbutton for the train call signal. The modified panel for the CRCS UHF radio incorporates the Motorola Astro Digital Spectra W4 control head into the top panel assembly. The control head replaces the discrete radio controls used for the conventional VHF radio. The prior discrete operator controls for radio are eliminated with the functions provided on the Motorola control head. A single microphone is still used for radio, intercom and public address communications. The pushbuttons on the panel are used to select which of these systems is active.

Form, fit and functionality with this design is required for the 6000 Series Rail Cars. Therefore, the Contractor shall procure the communications panels ARINC.

19.4 UHF RADIO EQUIPMENT

19.4.1 General

Radio equipment shall have a fully solid state receiver, transmitter, and power supply. All equipment, including the transmitter, shall operate at the voltages specified in Section 19.7 and shall be designed for
A006 continuous service and shall be resistant to shock, vibration and moisture.

Radio equipment shall operate on frequencies in the 482 to 512 MHz UHF band.

A006 19.4.2 Radio Transmitter/Receiver

A006 The radio equipment shall be a Motorola ASTRO Digital Spectra Mobil Radio with a W4 Control Head in a remote mount configuration.

A006 19.4.3 Radio Power Supply

An ARINC DC/DC power converter shall be provided to power the radio. The power converter shall meet the following specifications:

A. Type: Wall mount enclosed, isolated input/output > 2500 VDC

B. Input/output: Galvanically isolated

C. Construction: Ruggedized for rail vehicle use

D. Input voltage: 22 - 45 VDC [37.5 VDC nominal]

E. Output voltage: 13.8 VDC

F. Load regulation: 2% from no load to full load

G. Output current: 13 Amps nominal, 15 Amps peak

H. Output ripple & noise: Less than 25 mV

I. Protection: Short circuit, over-voltage, reverse polarity

J. Temperature range: -10 to +50 C, operational

19.4.4 Location

The transmitter/receiver shall be located in a dust-free enclosure, readily accessible for maintenance. The design of the CRCS 490 MHz digital train radio system requires the use of a separate radio, as opposed to the previous configuration of having two communications panels share a common radio for the A-B married pair. This necessitates the use of a separate antenna on the roof of each cab. The Astro Digital Spectra radio body shall be installed in the vicinity of the Operator's Cab, along with an interconnect cable to connected the radio body to the remote radio head in the communications panel. The DC-DC power converter shall also be mounted in the Operator's cab. A006

19.4.5 Antenna

The antenna shall be a low profile type, Sinclair Excaliber Model 321-A*6 or approved equal, with an operating range of 470 – 512 MHz. The antenna shall be surface-mounted on the roof of each car, consistent with the location of the new antennas on 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. A006

The antenna shall be constructed to withstand the Authority's car-washing machines without damage to the antenna or its attachment to the carbody.

19.5 PUBLIC ADDRESS EQUIPMENT

19.5.1 Loudspeakers

19.5.1.1 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 19.5.2.

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. 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.

19.5.1.2 Exterior

The exterior loudspeakers shall have an axial free-field sound pressure of 121 dBA re 0.0002 dynes/sq.cm. 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 19.9 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 carbody. 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.

19.5.2 Amplifiers

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.

19.5.3 Microphone

The cab microphone shall be of the dynamic type, meeting requirements of Section 19.3.1.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.

19.6 NEXT STATION SIGN

Two high resolution, multi-color LCD 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.

A008 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. The sign controller shall interface via the car communications network and the local RS232 port with laptop computer based portable test devices that will allow functional testing of the each sign and fault isolation to the line replaceable unit.

19.7 INSTALLATION CONSIDERATIONS

19.7.1 Location

A006 The radio and the associated power supply shall be installed in the Operator's cab in a location approved by the Authority. 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 8.11.6.

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.

19.7.2 Wiring

All cabling and interconnections shall be in accordance with the requirements of Section 22. There shall be no splices between terminals, except as noted in Section 22.18.9.

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.

19.7.3 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.

19.7.4 Speaker Phasing

Speakers in the passenger section of a car shall be made to function in phase.

19.8 POWER REQUIREMENTS

19.8.1 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.

19.8.2 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. PA 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.

19.9 STANDARDS

19.9.1 Duty

All communications equipment shall be rated for continuous duty.

19.9.2 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.

19.9.3 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.

19.9.4 Other Standards

All RF and audio equipment shall conform with the following applicable standards:

A. EIA SE-101 – Amplifiers for Sound Equipment
B. EIA SE-103 – Speakers for Sound Equipment
C. EIA SE-105 – Microphones for Sound Equipment.
D. MS-3102 – Connector, Receptacle, Electric, Box Mounting, Solder Contacts, AN Type
E. TIA/EIA 603 – Land Mobile FM or PM Communications Equipment Measurement and Performance Standards

19.10 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 5.1. Qualification, installation and acceptance tests shall be planned, developed, scheduled, accomplished and documented in accordance with the requirements of Section 3.

19.10.1 Factory Tests and Inspections

In addition to the requirements of Sections 3 and 5.1, the Contractor shall develop and submit a factory test plan for the communication equipment. ***(CDRL 1901)*** 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. (***(CDRL 1902)*** The Authority shall be notified in writing, not less than 2 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. ***(CDRL T1951)***

19.10.2 Installation Tests and Inspections

Installation tests shall verify proper installation of equipment and continuity of circuitry. ***(CDRL T1952)*** 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.

19.10.3 Qualification and Field Tests

19.10.3.1 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.

19.10.3.2 Plans and Procedures

The Contractor shall prepare a detailed plan for conducting field tests and submit the plan for approval a minimum of 180 days prior to the scheduled delivery of the first cars. ***(CDRL 1903)***

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. ***(CDRL 1904)*** In addition, the Contractor shall obtain FCC certification for each transmitter installed in each car. Certification certificates will be furnished to the Authority prior to final acceptance. ***(CDRL 1905)***

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.

Field test report results shall be submitted after tests have been completed. ***(CDRL T1953)*** Test results and corrective action taken shall be entered in the Car History book.

19.11 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 1901	Factory Test Plan
CDRL 1902	Factory Test Procedure
CDRL 1903	Field Test Plan
CDRL 1904	Field Test Procedure
CDRL 1905	FCC Certification of Transmitters
CDRL T1951	Factory Test Report
CDRL T1952	Installation Test Report
CDRL T1953	Qualification Test Report

19.12 REFERENCED STANDARDS

See Section 19.9 for standards referenced in this section.

SECTION 20
VEHICLE MONITORING SYSTEM

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SECTION 20
VEHICLE MONITORING SYSTEM

20.1 GENERAL

This section defines requirements for the Vehicle Monitoring System (VMS). All equipment, including interface equipment, wiring to and from other systems and car communication network that is necessary to accomplish the functions defined below shall be provided. Exhibit 20-1 shows the VMS functional block diagram.

The Contractor shall select a communications system integrator and submit the communications system integrator's qualifications to the Authority for review. The Contractor shall ensure that the communication systems integrator integrates and makes compatible all subsystems utilizing the car communications network. and high-speed train line network. This includes, but is not limited to, the hardware interface and software protocol to ensure proper operation vehicle monitoring system, A008
including the vehicle control unit VCU, data acquisition module DAMs, the event recorder, as well as all A009
other visual and audio communications subsystems.

Each married pair shall utilize a car communications network to provide the communications channel between the VCU, DAMs of each subsystem, and network connection ports located at points throughout A008
the vehicle. The network shall be used to transfer the status of all points monitored in the subsystems A009
and their DAMs to the VCU. All diagnostics and fault logs maintained by each subsystem shall be available for download at any network port as well as at the local diagnostic connectors incorporated in each subsystem.

The contractor shall use open, interoperable network hardware compatible with IEEE 1473-L for physical device connectivity. For application logic, all networked devices shall be LonMark-certified, or as a minimum, shall comply with open, interoperable network requirements that conform to LonMark Guidelines. It shall be possible to install and replace any networked device using standard, commercial off-the-shelf network products and tools. No special or custom tools shall be required. All required tools shall be readily available, commercial off the shelf products.

It shall be possible to change the topology of the network by adding or removing devices at any time. The network shall automatically detect devices added or removed and automatically integrate them into the system without manual intervention, manual configuration or manual network setup. It shall be possible to store at least two complete network configurations for each unique car type or configuration.

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. DAMs, which contain a LonWorks- based interface and act as the VMS signal data bank for each major subsystem.

B. A VMS Central Unit (VCU), mounted in the "A" car of each married vehicle pair

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).

A009 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:

A. 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.

B. 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.

A009 One VCU shall be installed on each "A" car in the right front seat-well, in accordance with Section 8.5. The Authority prefers the VCU to use the car network to interface with the Operator's fault display units (FDUs). The VCU shall also contain a separate diagnostic port to function as a redundant communication link with the user interface portable laptop PC.

The VCU and DAMs shall be solid state, microprocessor-based, utilizing reliable EIA certified industrial grade hardware and EIA/IEEE-certified connectors. Windows-based open system architecture is preferable, and programming shall be done in a high-level language, such as C. The VCU shall have an RS 485 interface fully compatible with the VCU trainline network of the Authority's 5000 Series and renovated 2000/3000 Series cars.

The VCU shall 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. Under a self-test failure or system malfunction, the VMS shall indicate the failed LRU on the VCU Display Unit or via the diagnostic port. The VCU shall provide interfaces to the audio trainlines, digital trainlines, Communications Control Head (CCH), passenger intercom, handset, PA amp, radio,
A009 passenger information and route signs (via the local area network). All subsystem information, selected passenger information, and route signs must interface with the local area network.

A008
A009 The VCU shall interface with a laptop computer based portable test device via the local communications port on the VCU. If possible, the local communications port shall be compatible with a standard RS232 cable.

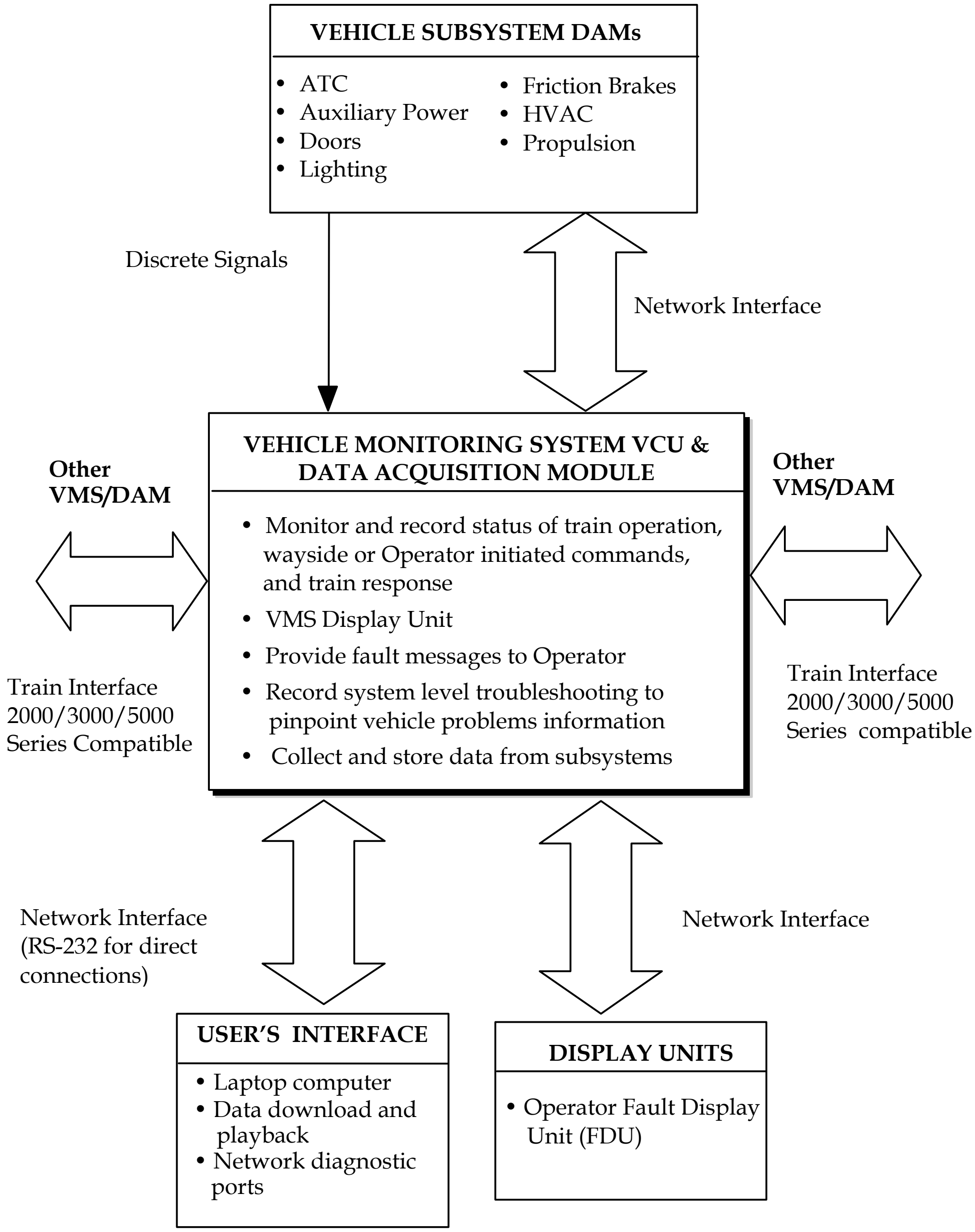
A008
A009 The VCU design shall be flexible enough to accommodate future adaptations of and expansions to the communications system. This shall include consideration for using the car communications network as the primary communication link with the portable test unit notebook computers. A proposed system block diagram, showing the general architecture and the location of all network interface ports shall be submitted to the Authority for review and approval. ***(CDRL 2001)***

The VCU shall interface with all microprocessor-based vehicle systems identified in Section 20.2.2 via the respective system's DAM. The DAM shall be microprocessor-based and shall be capable of processing and routing digital data from the various sources within a married pair to the VCU using the car communications network. It shall contain a communications interface to the VCU's high-speed data bus to permit subsystem data transfers to the lead VCU. The distribution of functions shall be implemented in computer software. The VCU shall maintain logs on the network's health. DAMs shall also provide the capability to set up and modify data acquisition and storage variables.

All subsystem DAMs shall interface with the systems master clock in the VCU. The VCU time and date shall be used by all the vehicle subsystem within the married pair. This time and date update will occur once a day when the vehicle is first powered. Fault indication shall be communicated within 2.5 seconds of subsystem detection to the Train Operator to support fault management actions. Time stamps on monitored signals and events shall reflect the time the signal or event occurred at the subsystem and not the time at which it was processed by the VCU. A009

In addition, the VCU shall have sufficient memory storage capacity to store 4,000 faults. Operation status information and fault data shall be available from all microprocessor-based subsystems within the train consist within 2.5 seconds of subsystem detection. The VCU shall record and identify faults as defined in a fault tree, which the Contractor shall develop and submit for the Authority's review and approval. ***(CDRL 2002)*** The fault tree shall, to the maximum extent possible, coincide with Authority's maintenance procedures. The development of the fault tree shall be discussed with Authority and the Engineer in detail in early design reviews. The fault data shall be used primarily by maintenance and operations support staff in troubleshooting specific vehicle failures, and by investigators in the event of an accident. A009

EXHIBIT 20-1 – VMS Functional Block Diagram



The FDU shall provide access to the logged failure events, conditions, and operating statistics. The Contractor shall develop a system-level maintenance philosophy that clearly defines the status and fault data to be monitored and displayed by the FDU. Information on all fault operators, status data, and screen displays shall be submitted to the Authority for approval. The system integration of data from all subsystems shall be the Contractor and Communications Supplier's responsibility. The Contractor shall display the specific fault data described in this Specification and any additional faults that are agreed to by the Engineer.

20.2 VCU FUNCTIONAL REQUIREMENTS

20.2.1 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 that is fully compatible with the VCU of the Authority's 5000 Series and renovated 2000/3000 Series cars. Each monitored vehicle system shall provide, via the DAMs, the necessary signals to the respective VCU on each vehicle pair to enable the operating status of the train to be determined. Exhibit 20-2 lists the minimum number of individual vehicle signals that the VCU shall monitor.

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 fully compatible with the 5000 Series and renovated 2000/3000 Series high-speed communications network. During the VMS design review, the Contractor shall provide a list of all VCU signals by name, supplier, and signal type. ***(CDRL 2003)*** Explanatory notes shall be provided as necessary. The final list of signal inputs to the VCU shall be subject to approval by the Authority.

20.2.2 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 20-2.

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 20.3.

Exhibit 20-2
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)
	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 20-2
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	T.L. 67	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.

20.2.3 Self Test

A008 The VCU shall perform self-diagnostics, and shall annunciate on the FDU in the Operator's cab either that 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 be 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 24-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 self-diagnostics determine that the VCU is not functioning properly, such failure shall be annunciated on the FDUs in the affected car and in the lead cab of the train.

20.2.4 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.

Manual downloading 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 minimum period of 30 hours.

A009

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 is retained. The Contractor shall submit details on shut-down conditions and the techniques for implementing them to the Authority for approval. ***(CDRL 2004)***

All data shall be time and date stamped and then stored for later download and analysis.

20.3 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 information shall be automatically halted upon detection of events such as excessive impact or other detectable catastrophic event. The data shall include all FRA mandated signals and other data as listed in Exhibit 20-2. Changes in monitored signals shall be capable of recording 20 changes per second no more than 750 milliseconds after the signal changes state. The final list shall be prepared by the Contractor and presented for approval during design review. ***(CDRL 2005)*** A009

B. Record events, event related data and other data as necessary in order to identify vehicle defects.

The above-listed recording functions may be performed by one or two units. If only one unit is used, that unit shall be fully environmentally hardened (i.e., fire, water and explosion proof). If two units are provided, the unit that records the FRA-mandated signals shall be environmentally hardened and shall remain fully functional after catastrophic vehicle accidents. The VCU shall retain 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 accident. A009

20.4 DATA REPORTING

All data retrieved from the VMS shall enable ad-hoc query for analysis by maintenance and engineering staff and shall facilitate the production of tabular reports, strip charts and graphs.

20.5 DESIGN CRITERIA

The design and installation of the VCU shall not degrade in any way the reliability and safety of vehicle systems. It is unacceptable for a failure in the VCU or in its wiring to cause a fault in the vehicle system. The trainlines 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 7.6.

B. Protection from damage due to transient over and under voltage conditions, as specified in Section 7.2.

C. Operation without equipment degradation due to environmental conditions, as specified in Section 7.4.

20.6 VCU HARDWARE REQUIREMENTS

20.6.1 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 22.29.

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 20.6.2, 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. Digital signals acquired directly by the VCU or its DAMs shall be capable of being monitored at a rate no less frequent than 2 msec and analog signals shall be monitored a t a rate that is no less frequent
A009 than twice the highest frequency component of the signal to be monitored. Signals acquired by subsystem DAMs via the car communications network shall meet the requirements of Section 20.3.

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. For signals
A009 acquired directly by the VCU or its DAM, 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.

20.6.2 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.

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 22.16 through 22.21.

A008
A009 B. Car Communications and Trainlined Network. A network data link shall be used for the following VCU interfaces:

1. DAM to VCU, Dual port memory is also acceptable

2. Unless otherwise approved by the Authority, the VCU to Operator's FDU link shall be implemented by the car communications network
3. VCU-to-VCU within a multi-vehicle consist (compatible with VCU trainline network of the Authority's 5000 Series and renovated 2000/3000 Series vehicles)

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 14.1.4. The power supply cable shall be protected by a suitable overcurrent device. In addition, the return of the VCU shall be connected to the battery ground.

20.7 VCU SOFTWARE REQUIREMENTS

20.7.1 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.

20.7.2 VCU Application Software

The VCU system baseline application software shall consist of the following six functions, as a minimum and be fully compatible with the 5000 Series and renovated 2000/3000 Series vehicles

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 be 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.

20.8 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.

20.9 FAULT MESSAGES

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:

A. "BRAKES IN EMERGENCY: Brake pressure < ___ psi on Car # ___."
B. "BRAKES NOT RELEASED: Car # ___ A or B Truck."
C. "BRAKES BINDING: Car # ___, Parking Brake Engaged."
D. "LOSS AIR PRESSURE: Car # ___, Compressor Failure."
E. "ALL DOORS NOT CLOSED: Door number ___, leaf ___ not locked."
F. "AUTOMATIC DOOR OPERATION DISABLED: Brake Loop Bypass Operated."
G. "NO WAYSIDE COMMUNICATIONS: Car # ___, Communication Failure."
H. "NO ATO: Car # ___, Tachometer Failure."
I. "PROPULSION FAULT: Inverter on Car # ___ failed."
J. "NO PROPULSION: Car # ___, Loss of Third Rail."
K. "ATC CUT-OUT: 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 design review. ***(CDRL 2006)***

20.10 VCU USER INTERFACE

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 LCD 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 64M. 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.

20.11 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.

20.11.1 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 an integral pointing device and 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.

20.11.2 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 alphanumeric 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.

20.12 TESTS

The VMS system shall be subject to performance, qualification, factory acceptance, vehicle level, and reliability testing per procedures generated by the Contractor and approved by the Authority (see Section 3, CDRL 302). All tests shall be documented and shall meet the requirements of Section 3.

20.13 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 2001	System Block Diagram
CDRL 2002	Fault Tree
CDRL 2003	List of All VCU Signals
CDRL 2004	Recommended Shut-Down Conditions and Implementation Techniques
CDRL 2005	Final List of Command and Operating Data To Be Recorded by the VCU
CDRL 2006	List of Fault Messages

20.14 REFERENCED STANDARDS

No standards are referenced in this section.

SECTION 21
SPECIAL TOOLS AND TEST EQUIPMENT

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SECTION 21
SPECIAL TOOLS AND TEST EQUIPMENT

21.1 GENERAL

The Contractor and subcontractors shall provide portable test devices, bench testers, software, and other test apparatus for the cars as specified herein. A008

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 shall be provided for the device itself.

B. Complete maintenance, calibration, and troubleshooting procedures (to the board level for Portable Test Devices and to the component level for Bench Testers) for printed circuit boards shall be provided for the associated carborne system. A003

C. Documentation for microprocessor-based test equipment shall include a hardware and software configuration list.

The above documentation shall be supplied in addition to and in accordance with the Maintenance Manuals required by Section 4.1.

In addition to the types and quantities of test devices specified herein, the Contractor shall provide all test devices required by the qualification and/or acceptance test programs. Under no circumstances will the Authority loan or make test apparatus available to the Contractor. A008

The Contractor shall be responsible for the integration of all test software and configuration of all computer based test equipment. A008

The Contractor shall also provide sets of special tools, as defined in Section 21.4. A008

21.2 PORTABLE TEST DEVICES

21.2.1 General Requirements

All periodic tests, calibration and trouble diagnosis required to maintain the vehicle systems specified below shall be accomplished through the use of laptop/notebook computer based portable test devices. The term portable test device (PTD) and the term portable test unit (PTU) shall be used interchangeably. A008

The Contractor shall provide 10 copies of all software and 50 laptop/notebook computers complete with all software installed. The Contractor shall be responsible for supplying all revisions to software from delivery through the warranty period. A008

Each laptop/notebook computer shall be functionally identical, unless otherwise approved by the Authority. All peripheral equipment including power adapters shall be interchangeable. A008

Portable test devices shall be provided for the following systems: A008

A. Automatic Train Control
B. Propulsion System
A008 C. Friction Brake System,
D. Low Voltage Power Supply System
E. Communications System
F. HVAC System
G. Side Doors
H. Destination Signs
I. AC Auxiliary Power System Inverters

All laptop computer based portable test devices and the design of carborne equipment shall make use of A005 the car communications network, as described in Section 20.1, and local RS 232 connectors to establish A008 all interfaces required for full utilization of the test devices. A RS 232 compatible DB-9 Female connector shall be provided at the sub-system equipment for use when the car communications network is not available. All systems shall use interchangeable RS 232 cables that connect to female DB-9 RS 232 connectors on the local system. The cables shall be of enough length so that a technician may safely rest the PTU device on a flat surface while troubleshooting the equipment. The farthest distance from any of the items listed in A through J above to a safe resting spot shall determine the length of all cables.
The first ten 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. ***(CDRL 2101)***

Power to operate the portable test devices shall be from either self-contained power packs or he car low- A005 voltage power supply via the test unit connectors. 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. No high-voltage connections (700 VDC) shall be required for any portable test device. Use of the portable test devices to perform periodic calibration or trouble diagnosis shall not require the removal, dislodging, dismounting, or disconnecting of any carborne component, card, wire, chassis, terminal, or cable. Each portable test device shall be designed such that it cannot initiate car movement while connected to the system.

A008 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 A008 or indicate 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 system might encounter during actual train operation, while simultaneously monitoring system responses to determine whether the system performs in accordance with design specifications. Requiring the test device operator to perform a visual check for system response, such as closure of a contactor, will be acceptable provided that (1) the visual check does not necessitate the removal of other components or equipment or the use of hand tools, and (2) does not require the 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 test device operator to fully check out and calibrate the system or subsystem under test, and shall indicate any removable component that has fully or partially failed. The device shall be capable of indicating the line replaceable unit (LRU) that 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 identify the defective component that requires replacement. Testing shall be automated to the maximum extent possible and shall 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 system or subsystem under test.

Unless otherwise specifically approved, portable test devices shall not require the connection of external apparatus for their operation. In cases where the use of external apparatus is approved by the Authority, terminals shall be provided to allow connection of the external apparatus to the portable test 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.

The Communications System may use a non-computer based portable test device, which shall be housed in a heavy-duty enclosure of sufficient strength for use in a transit shop environment. Non-computer based portable test devices shall meet the requirements above and shall integrate all necessary test signal generators and indicators. The enclosure shall have a removable cover, a suitable carrying handle, and shall include stowage space for the cabling required for unit hook-up. A008

The Authority will consider other non-computer based portable test devices deemed necessary by the Contractor on a case-by-case basis. A009

Laptop computer based portable test devices shall be suitable for use in harsh industrial environments and shall be shock- and vibration-resistant. A008

Laptop or notebook computers shall include microprocessors that are state-of-the-art at the time of delivery, as well as 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. A008

21.2.2 Unique Portable Test Device Features

In addition to the above general requirements for portable test devices, the following unique capabilities shall be incorporated into individual devices as listed below:

A. 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, overspeed protection equipment, door controls, program station stopping controls, and automatic speed regulation equipment.

B. 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.

C. The friction brake system test device shall monitor feedback signals to determine whether any electrical or electronic problems exist. 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, is faulty. The tester shall also test for spin/slide detection of all axles, including synchronous spin/slide conditions to the extent that the friction brake equipment physically reacts. A008

D. The communications test device shall be designed so as to measure actual sound levels at various points throughout the transit car. The test device shall be capable of verifying electrical signal levels and operation, and of calibrating the sound system on each married pair of cars to a set level. 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 a train.

E. The HVAC 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.

F. The door system portable test device shall automatically measure door currents and the 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.

G. The destination sign test device shall indicate whether sign problems are caused by the sign itself or the input signals to it.

H. The coupler test device shall test for circuit continuity from the coupler face through the
A008 connecting cable and for shorts between pins or connections.

21.3 BENCH TESTERS

21.3.1 General Requirements

Except as noted 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. Auxiliary Motors
G. Destination Signs
H. Heating and Cooling Control Logic
I. Communications (Control Panel, Public Address, and Intercom Systems)
J. Side Door Control (General, Local, and Chime)
K. Power Supplies (ATC, Lamp Dimmer, Console)
L. High Voltage Propulsion Components
M. Traction Motors (Variable Voltage, Variable Frequency, Vibration, Windings); two bench testers shall be provided
N. High Voltage Auxiliary Power Systems Components
O. AC Auxiliary Inverter.

The bench testers shall be capable of testing all modules of the system as a whole and of troubleshooting
A003 all circuit boards, transducers, relays and assemblies of the equipment 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
A002 incorporate a state-of-the-art microprocessor and shall include CD-ROM, 17-inch color monitor and the 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. The Contractor shall also ensure that detailed information is supplied on the theory of operation of the equipment being tested and that functional diagrams are provided of all boards in the equipment. This information should be included in the equipment Running Maintenance and Service manuals or the Heavy Repair manuals, as appropriate.

Complete maintenance, calibration and troubleshooting procedures for each of the above-listed carborne systems or equipment 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 or circuit board under test. Bench testers shall not be designed as simple "go/no-go" test devices; i.e., if a circuit board is A003
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 IBM-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. The tester shall be capable of running in fully automatic mode for a variable length of time that can be set by a technician, up to a maximum test cycle of at least 24 hours. Provision A002
shall be made to enter the model, serial number, date, and any pertinent data for test record purposes.

Unless otherwise specifically approved, bench test devices shall not require the connection of external apparatus for their operation. In cases where the use of external apparatus is approved by the Authority, A003
terminals shall be provided to allow connection of the external apparatus to the bench test device. Such external apparatus shall be considered part of the bench test device and shall be supplied with it.

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 a 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 test device. Similarly, the script may prompt the technician to observe and report/record the status of any audible or visible indicators associated with the item under test.

The bench testers shall be capable of distinguishing between properly operating and defective modules, and shall allow necessary adjustments to 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.

The Contractor shall submit a list of bench testers to be delivered under this 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 2102)*** Bench testers shall be delivered prior to acceptance of the sixth pair of cars. ***(CDRL 2103)***

21.3.2 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 below:

A. 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.

B. 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.

C. 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.

D. 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.

If the same vendor supplies than one subsystem, the bench testers for the relevant subsystems may be combined into a single unit.

21.4 SPECIAL TOOLS

Special tools are those tools that are not commonly available from commercial tool suppliers, but that 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 addressed separately in Section 21.3, all special tools used by the Contractor or subcontractors to assemble, test, calibrate, or align components and equipment shall be provided, as shall complete drawings of the special tools and parts lists for purchased parts.

The Contractor shall provide a list of all special tools to be delivered under the Contract. The list shall be arranged by vehicle system and shall 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 2104)***

A008 The Contractor shall provide sufficient quantities of special tools to supply eight maintenance shops. One set of special tools shall be delivered with the lead married pair of cars. The remaining sets shall be delivered no later than 6 months after delivery of the lead car. ***(CDRL 2105)***

21.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL 2101	Portable Test Devices and Required Documentation
CDRL 2102	List of Bench Testers
CDRL 2103	Bench Testers and Required Documentation
CDRL 2104	List of Special Tools
CDRL 2105	Special Tools and Required Documentation

21.6 REFERENCED STANDARDS

The following standard is referenced in this section:

ATA652	Computer Software Manual

SECTION 22
MATERIALS AND WORKMANSHIP

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SECTION 22
MATERIALS AND WORKMANSHIP

22.1 GENERAL

22.1.1 Quality

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.

22.1.2 Standards

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.

22.1.3 Marking

All materials intended for use on these vehicles shall be marked or stored so as to be readily identifiable, and shall be adequately protected during handling and storage. Rejected material shall be clearly marked and stored in an area specifically designated for that purpose.

22.1.4 Cleaning Agents

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.

22.2 JOINING AND FASTENING

22.2.1 Joining

22.2.1.1 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.

22.2.1.2 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.

22.2.1.3 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 22.6.4.

22.2.1.4 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.

22.2.1.5 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.

22.2.2 Fasteners

22.2.2.1 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 22.2.2.2.2. 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.

22.2.2.2 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.

22.2.2.2.1 <u>Inch-Standard Fasteners</u>

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.

22.2.2.2.2 <u>Metric Fasteners</u>

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.

22.2.2.3 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, per ASE J429, 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.

*22.2.2.4 Decorative and Appearance Faste*ners

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.

22.2.2.5 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.

22.2.2.6 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.

22.2.2.7 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.

22.2.2.8 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.

22.2.2.9 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.

22.3 STAINLESS STEEL

22.3.1 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.

22.3.2 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.

22.3.3 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.

22.3.4 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 2201)*** 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.

22.4 LOW-ALLOY, HIGH-TENSILE STEEL

22.4.1 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.

22.4.2 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 2202)*** 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.

22.5 STEEL CASTINGS

22.5.1 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.

22.5.2 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.

22.5.3 Quality of Structural Castings

All structural castings supplied shall be equal to or better than the design qualification castings in all respects. In addition, the inspections below shall be performed and a written report of the results of the
A008 tests and inspections shall be furnished for each lot of castings produced.

22.5.3.1 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.

22.5.3.2 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 2203)***

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.

22.5.4 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 22.22. 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.

22.5.5 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.

22.6 ALUMINUM

22.6.1 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.

22.6.2 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.

22.6.3 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.

22.6.4 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.

A006 B. The contact surfaces of aluminum alloy with aluminum alloy shall be painted with a two-part epoxy primer that is chromate-free.

C. The surfaces of aluminum alloy parts secured to steel parts shall be protected with a one-part polysulphide sealant, a corrosion-inhibiting paste or compound that is chromate-free, mica
A006 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.

A006 D. Stainless steel and carbon steel fasteners plated with zinc shall be coated with a corrosion-
A008 inhibiting paste or compound that is chromate-free 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.

22.6.5 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.

22.7 ELASTOMERS

22.7.1 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 7.4. 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.

22.7.2 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 22.24; the results of the testing shall be submitted to the Authority ***(CDRL T2251)***. The performance of only A002 these elastomers will not be bound by the performance requirements for elastomers outlined in Section 22.24.

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 1 ppm, an exposure time of 100 hours at 100°F, and a specimen elongation of 20%. The A008 elastomer shall not exhibit any cracks during the test period.

22.7.3 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.

22.7.4 Metal Parts

Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020 or 1045 hot-rolled steel.

22.7.5 Bonding

The joining of elastomeric pieces shall be done 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.

22.7.6 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.

22.7.7 Seals

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.

22.8 GLAZING MATERIALS

22.8.1 Safety Glass

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."

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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.

22.8.1.1 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.

22.8.1.2 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.

22.8.1.3 Dimension Tolerance

The overall dimensions of individual pieces as supplied shall be held within 0.060-inch of the dimensions ordered.

22.8.1.4 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.

22.8.1.5 Color

The color of the glass shall be as required by Section 8. 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.

22.8.1.6 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.

22.8.1.7 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.

22.8.1.8 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.

22.8.1.9 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.

22.8.2 Plastic Glazing

22.8.2.1 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.

22.8.2.2 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).

22.8.2.3 Material Physical Properties

Plastic materials used in the glazing of side windows and door windows shall meet the following requirements.

22.8.2.3.1 <u>Strength</u>

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.

22.8.2.3.2 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.

22.8.2.3.3 Weathering Test

The materials shall pass weathering test No. 16 of ANSI Standard Z26.1 ***(CDRL T2252)***. An accelerated weathering apparatus of Type D or E in ASTM G 23 shall be used in this test. A002

22.8.2.3.4 Color

The color of the plastic glazing shall be as required by Section 8. 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.

22.8.2.3.5 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 ***(CDRL T2253)***. The foregoing test is to be performed for initial product certification. A002

22.8.2.3.6 Chemical Resistance

Samples shall be prepared and tested according to Test 19, Article 5.19, of ANSI Z26.1 ***(CDRL T2254)***. 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. A002

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.

22.8.2.3.7 Adhesion of Coating Materials

A002 The abrasion resistant coating materials shall retain adhesion to the substrate materials when subjected to a 100 ft.-lb. impact as specified in Section 22.8.2.3.1. The coating must pass a standard cross cut adhesion test ***(CDRL T2255)***. 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.

22.8.2.3.8 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.

22.8.2.3.9 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.

22.8.2.3.10 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.

22.8.2.3.11 Optical Quality

A002 Optical quality of the plastic glazing materials shall be in accordance with Test No. 15, Article 5.15.2.2, of ANSI Z26.1 ***(CDRL T2256)***. 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.

22.8.2.4 Material Quality

22.8.2.4.1 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.

22.8.2.4.2 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.

22.8.2.4.3 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.

22.8.2.4.4 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.

22.8.2.4.5 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.

22.8.2.4.6 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.

22.8.2.4.7 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.

22.8.2.4.8 Documentation

The Contractor shall certify that the shipped material complies with the requirements in this Specification.

22.9 FLOOR COVERING

22.9.1 Rubber Floor Covering

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.

22.9.1.1 Inspection Criteria

This Section addresses defect items that may be cause for rejection, their allowable limits, and repair methods, where repairs are permitted.

22.9.1.1.1 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.

22.9.1.1.2 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.

22.9.1.1.3 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.

22.9.1.1.4 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.

22.9.1.1.5 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.

22.9.1.2 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.

22.9.2 Carpeting

22.9.2.1 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.

22.9.2.2 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
A002 when tested in accordance with AATCC Test 134 ***(CDRL T2257)***.

22.9.2.3 Edge Treatment

The edges shall be latexed to prevent raveling.

22.9.2.4 Color

The color and pattern of the carpet shall match samples, which are available upon request.

22.9.2.5 Protective Treatment

The pile yarn shall be permanently mothproofed. The carpet shall be processed to prevent mildew and other fungi.

22.9.2.6 Carpet Performance A006

The performance of the carpet shall be certified by the Contractor through the successful passage of the following tests ***(CDRL T2258)***:

Characteristics	**Test Method**	**Criteria**
Fiber Composition	AATCC Test Method 20A	Verify 100% wool fiber
Average Pile Yarn Weight	ASTM D418	56.25 ounces per sq. yd.
Tufts per Square Inch	ASTM D418	10 rows per inch, 216 pitch
Pile Thickness / Tuft Height	ASTM D418	0.205 inches
Tuft Bind	ASTM D1335	3.8 lbs. min.
Delamination Strength of Secondary Backing	ASTM D3936	2.5 psi
Wear Resistance	ASTM D5252	Rating of 3 minimum on the CRI-TM101 scale after 12,000 cycles
Shrinkage	GSA-FSS-DDD-C-0095	<1% max., Length or Width
Colorfastness to Acids and Alkalis	AATCC Test Method 6	Rating of 2 minimum for all reagents on the AATCC gray scale for color change
Colorfastness to Light	AATCC Test Method 16, Option E – water cooled xenon-arc lamp, continuous light	Rating of 4 minimum on the AATCC gray scale for color change after 40 AATCC fading units
Colorfastness to Crocking	AATCC Test Method 165	Rating of 4 minimum, wet and dry, on the AATCC color transference scale
Colorfastness to Oxides of Nitrogen	AATCC Test Method 164	Rating of 3 minimum on the AATCC gray scale for color change after 2 cycles
Colorfastness to Ozone	AATCC Test Method 129	Rating of 3 minimum on the AATCC gray scale for color change after 2 cycles
Electrostatic Propensity	AATCC Test Method 134	<3.5 Kilovolts @ 70ºF and 20% relative humidity
Radiant Panel Test	ASTM E648	CRF 0.5 W/sq.cm.
Smoke Density	ASTM E662	$D_s(1.5) \le 100$ $D_s(4.0) \le 200$
Toxic Gas Sampling	Bombardier SMP-800C	CO ppm <3,500 CO_2 ppm <90,000 NO_2 ppm <100 SO_2 ppm <100 HCL ppm <500 HF ppm <100 HBr ppm <100 HCN ppm <100

22.9.2.7 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.

22.9.2.8 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.

22.10 WOOD AND PANELS

22.10.1 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.

22.10.2 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 22.10.6 prior to the melamine-faced metal panel being laminated to the plywood core.

22.10.3 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.

22.10.4 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.

22.10.5 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.

22.10.6 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 x 10^6 lbf/in^2
2. Crossgrain: 3.1 x 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

22.11 SEAT CUSHION

22.11.1 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.

22.11.2 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

22.12 FIBERGLASS-REINFORCED PLASTIC

22.12.1 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 7.4, 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.

22.12.2 Construction

22.12.2.1 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.

22.12.2.2 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.

22.12.2.3 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 22.23. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color selected by the Authority.

22.12.2.4 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.

22.12.3 Strength Requirements

Independent laboratory test certificates shall be provided stating that the reinforced plastic material complies with the requirements of the following standards ***(CDRL T2259)***. Test specimens shall be conditioned in accordance with ASTM D 618. A002

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

22.13 THERMOPLASTIC SHEET

22.13.1 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 7, 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 8. 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.

22.13.2 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.

22.13.3 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	3.3×10^5 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

22.14 PIPING AND TUBING

22.14.1 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 ***(CDRL T2260)***. All leaks shall be repaired and the system recleaned and retested until leak-free. A002

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.

22.14.2 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 B16.18.

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
A002 supplier of the Contractor's air brake piping fabrication, installation, and design concept ***(CDRL 2212)***.
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 22.22.

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 2518, Standard 400. Approved copper tube shall also comply with any relevant requirements of AAR 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 M-. 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 16.

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.

22.14.3 Air Conditioning System Piping, Tubing, and Fittings

Air conditioning refrigerant lines shall be of seamless copper tubing conforming to ASTM-B-280-97. A009
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.

22.14.4 Brazing and Soldering of Piping, Tubing, and Fittings

All brazing and soldering shall comply with the applicable parts of Section 22.22, 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.

22.14.5 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^{o}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 cut-out cocks shall be designed to automatically depressurize the portion of the system which is being isolated by the cut-out cock.

22.15 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.

22.16 WIRE AND CABLE

22.16.1 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.

22.16.2 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 that 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 7. 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 W70, as appropriate for the application. A009

Stranding and conductor construction for wires and cables No. 20 AWG and smaller shall be in accordance with NEMA W70 or shall be 19-strand construction as appropriate for the wire size. A009

22.16.3 Insulation

*22.16.3.1 General Wiring Insul*ation

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.

A008 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. Cables for data transmission, where cable current is not a factor for the selection of the cable cross section, may be rated for a lower temperature as proposed by the Contractor and approved by the Authority. 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:

A009 1. Flammability: For cross-linked polyolefin, use test method per ICEA S-95-658. 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 22.16.6, 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 22.25.6 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.

A009 2. Heat Distortion – (Test Method per ICEA S-95-658) (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

A009 4. Moisture Absorption - Electrical Method (ICEA S-95-658): 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 per ICEA S-95-658): After 24 hours exposure to an ozone concentration of 0.03% by volume at 90°C, ±2°C, there shall be no insulation cracks. A009

6. Tension Set (Test Method per ICEA S-95-658); (Except that the specimen shall be stretched until the gauge marks are 4 inches apart.): Maximum: 30% A009

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° ± 2°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.

22.16.3.2 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 22.16.3.1:

A. For wire sizes No. 16 AWG and larger: abrasion resistant Teflon Polytetrafluoroethylene (PTFE) meeting MIL-W-22759/6B, or silicone rubber meeting AAR 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.

22.16.3.3 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 22.16.3.1 above, or Teflon Polytetrafluorethylene (PTFE) type EE per Military Specification MIL-W-16878/5.

22.16.3.4 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 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.

22.16.4 Multi-Conductor Cables

22.16.4.1 General

Multi-conductor cables, where approved, shall be constructed using wiring as described in Section 22.16.2 and 22.16.3. 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.

22.16.4.2 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.

22.16.4.3 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.

22.16.4.4 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.

22.16.4.5 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	–

22.16.5 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.

A002

22.16.6 Insulation Smoke Test *(CDRL T2261)*

***22.16.6.1 Sc**ope*

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."

22.16.6.2 Apparatus

A. Aminco-NBS Smoke Chamber and Recorder.

B. Aminco 6 tube, 90° 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.

22.16.6.3 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 ensure 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.

22.17 WIRING

22.17.1 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.

22.17.2 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." In addition, 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.

22.17.3 Wiring Layout and Installation

22.17.3.1 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.

22.17.3.2 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.

22.17.3.3 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.

22.17.3.3.1 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 22.7. 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 22.18.9.

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.

22.17.3.3.2 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 22.18.2. 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.

22.17.4 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.

22.17.5 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, 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.

22.17.6 Pulling Compound

Pulling compound shall be non-conductive, non-hygroscopic, non-odorous and shall not attract vermin.

22.17.7 Solder

Solder shall be in accordance with ASTM B 32, Grade 60B. A flux of non-corrosive type shall be applied immediately before soldering.

22.17.8 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.

22.18 WIRE AND CABLE CONNECTIONS

22.18.1 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.

22.18.2 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 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 ensure 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.

22.18.3 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.

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 a type that 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.

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.

22.18.4 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.

22.18.5 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.

22.18.6 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.

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.

22.18.7 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. A008

22.18.8 Grounding Return Connections

22.18.8.1 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. The Contractor may propose alternate grounding connection methods with proven service history in similar environments. A002

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 22.18.8.2.

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 2204)*** 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.

22.18.8.2 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."

22.18.9 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.

22.19 CONDUIT

22.19.1 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 C-80.1. The threads per inch and length of threading shall conform to ANSI B-20.1: 1983 on Pipe Threads.

Steel fittings shall be used to assemble steel conduit. Elbows, nipples, and couplings shall be made of the same grade of steel as that employed in the conduit. All fittings shall be treated, coated, and threaded according to the requirements for zinc-coated, rigid steel conduit and shall conform to Underwriters Laboratory Standard UL-6.

Flexible conduit, if used, shall be watertight and interlocking steel strip-protected, with an approved rust resistive coating.

22.19.2 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.

22.19.3 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.

22.20 CONDUIT FITTINGS AND JUNCTION BOXES

22.20.1 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 22.20.4.

22.20.2 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 22.23.4.

22.20.3 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.

22.20.4 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.

22.21 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.

22.22 WELDING AND BRAZING

22.22.1 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.”

22.22.2 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.

22.22.3 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.

22.22.4 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 2205)*** 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.

22.22.5 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.

22.22.6 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 2206)*** Specifications for purchase of welding electrodes, welding wires, and cover gases shall be submitted for approval before their application.

22.22.7 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 2207)***

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.

22.22.8 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 2208)**

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.

22.22.9 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).

22.22.10 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.

22.22.11 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.

22.22.12 Torch Soldering

All structural (not electrical) soldering, defined as heating below 840°F, shall follow the recommendations contained in the AWS Welding Handbook, Volume 2. 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 2209)***

22.23 PAINTS AND COATINGS

22.23.1 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.

22.23.2 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 ensure 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.

22.23.3 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.

22.23.4 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 22.23.3. 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.

22.23.5 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.

22.23.6 Interior Painting

All exposed interior surfaces, including molding and trim, shall be as specified in Section 8, 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 ensure 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.

22.23.7 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 and cleaned, and then painted in accordance with Section 22.23.3.

22.23.8 Acoustical Insulation

Acoustical insulating materials shall be applied to properly cleaned underframe, sides, ends, roof and floor sheets, as required in Section 8, 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.

22.23.9 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 22.23.5 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.

22.23.10 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.

22.24 FLAMMABILITY AND SMOKE EMISSION REQUIREMENTS

22.24.1 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 NFPA 130 – Standard for Fixed Guideway Transit Systems, 1995 Edition, or the latest issue of that
A008 document at the time of bidding, subject to the conditions cited in Section 22.24.3.

A matrix showing the total weight of all materials, where used, flammability, smoke emission and
A008 toxicity test identity, test facility, test requirements, and test results shall be submitted by the Contractor during detailed design review. ***(CDRL 2210)***

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.

22.24.2 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
A008 weight, and heating value in BTU/lb and BTU/hour. This information shall be included in **CDRL 2210**.

22.24.3 Flammability and Smoke Emission

Materials used in passenger vehicles shall be tested to demonstrate compliance with the requirements set
A002 forth in Section 22.24.1 ***(CDRL T2262)***. The procedures and performance criteria for flammability and smoke emission testing are given in Exhibit 22-1.

Exhibit 22-1
Requirements for Passenger Vehicle Material Fire Risk Assessment

Function of Material	Test Procedures	Performance Criteria
Seat Cushion	ASTM-D-3675 ASTM-E-662 ASTM-E-662	I_s 25 D_s (1.5) 100 D_s (4.0) 175
Seat Frame	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 175
Seat Shroud	ASTM-E-162 ASTM-E-662 ASTM-E-662	I_s 35 D_s (1.5) 100 D_s (4.0) 175
Upholstery	FAR 25.853 (vertical) ASTM-E-662	Flame Time: 10 seconds Burn Length: 6 inches D_s (4.0) (125 uncoated) (250 coated)
Seat Cushion Assembly ("Vandal-guard" type material	ASTM-D-3675 ASTM-E-662 ASTM-E-662	I_s 20 D_s (1.5) 100 D_s (4.0) 200
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 22.24.4)	ASTM-E-119	Pass (with a minimum 30-minute endurance period at AW3 loading A002
Flooring (Covering)	ASTM-E-648	CRF 0.5 W/cm^2

Function of Material	Test Procedures	Performance Criteria
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 200
Thermal Insulation	ASTM-E-162	I_s 25
	ASTM-E-662	D_s (4.0) 200
Acoustical Insulation	ASTM-E-162	I_s 25
	ASTM-E-662	D_s (4.0) 200
Elastomers, including articulation section diaphragm	ASTM-C-542	Pass
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 200
Exterior Shell, including non-metallic shrouding, equipment box covers, and articulation section panels, where applicable	ASTM-E-162	I_s 35
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 200
Battery Cases	ASTM-E-162	I_s 35
	ASTM-E-662	D_s (1.5) 100
	ASTM-E-662	D_s (4.0) 200
Wire Insulation	Flammability	Per Section 22.16.3.1
	ASTM-E-662	D_s (4.0) 200 (flaming)
		D_s (4.0) 75 (non-flaming)
		When tested in accordance with Section 22.16.6

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.

22.24.4 Floor Assembly Fire Resistance Testing Criteria

The Contractor shall test the floor assembly in accordance with ASTM E 119 to demonstrate a minimum 15-minute endurance rating ***(CDRL T2263)***. The test shall be run until failure as defined in the 1995 Edition of NFPA 130, Section 4-2.3.1 and ASTM E119. 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. A002 A008

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 172 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.

22.24.5 Not Used A002

22.24.6 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 ***(CDRL T2264)***. Materials shall meet the following maximum toxic gas release limits (ppm) as determined per BSS-7239. A002

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.

22.24.7 Electrical Fire Safety

Except when otherwise approved or where more restrictive requirements are imposed by this Specification, electrical equipment shall conform to NFPA 130.

22.25 AIR FILTERS

22.25.1 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.

22.25.2 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.

22.25.3 Low Pressure Air Filters

Replaceable media type filters shall use resin-bound, spun-glass fiber materials having an uncompressed thickness not less than 3-1/2 inches. It shall be non-absorptive of fluids and gases, shall be processed in such a manner that material density increases progressively from air inlet to air exit side, and shall be coated with not less than 24 grams per square foot of a dust-retaining, viscous adhesive film. This film shall be stable at temperatures up to 150°F. The filter medium shall be cut not less than 1/2-inch oversize to ensure adequate sealing between the edge of pad and its integral frame.

22.26 ELECTRICAL AND ELECTRONIC DESIGNS

22.26.1 Reliability Standards

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.

22.26.2 Ability to Repair

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.

PC Boards that cannot be tested according to the requirements of Section 21.3.1 (testing to the component level) and deemed "not repairable" by the Authority shall have their replacement source guaranteed for 20 years. This concerns fit and function of the respective boards to be replaceable without reconfiguring any other part of its parent system hardware or software. A009

22.26.3 Hardware

Refer to Section 22.2.2 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.

22.26.4 Wiring

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 22.16 through 22.21 for additional wire and wiring requirements.

22.26.5 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".

22.27 SEMICONDUCTOR STANDARDS

22.27.1 General

Semiconductors shall be selected to withstand all continuous and transient voltage and power demands present in the circuit application without damage or reduction in life. All circuit designs shall provide for the presence of high current switching equipment on the vehicle and the resultant induced voltages and currents in electrical equipment.

22.27.2 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.

22.27.3 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.

22.27.4 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.

22.27.5 Other Prohibitions

Electronic equipment shall utilize stock components and shall function properly with the component manufacture's full range of tolerances such that after-purchase screening or testing of components shall not be required.

Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

Germanium semiconductors shall not be used.

22.28 PRINTED CIRCUIT BOARD STANDARDS

22.28.1 General

Printed circuit boards shall be designed, constructed and inspected to IPC-2221, 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. A008

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.

A005 Printed circuit boards shall be mounted in the vertical plane with positive retention by keeper bars unless otherwise approved. These retaining mechanisms shall be simple, easily applied/removed without tools and shall remain attached to the card rack. PCBs shall be fully inter-changeable without adjustment by the use of digital circuits, stable components, and tight tolerance components as applicable. Potentiometers shall not be permitted. All electronic control units, PCBs, major components and assemblies shall be serialized and contain a bar code label.

22.28.2 Marking

All circuit boards shall be labeled with a part number, serial number, and descriptive nomenclature.

All components shall be labeled on the board with component drawing references and such other information as may be required to repair and troubleshoot the board. 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.

22.28.3 Component Mounting

Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration. Large components shall be supported in addition to the solder connections. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, spaced far enough away from the board so that resistor-produced heat will not discolor or damage the board.

22.28.4 IC and Device Sockets

IC and device sockets are prohibited except for components that must be removed for reprogramming or initial calibration procedures or devices that are available only in mounting in sockets. All socket applications are subject to 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:

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.

22.28.5 Conformal Coating

Both sides of the assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to MIL-I-46058 latest revision, or approved equal.

The 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.

22.28.6 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.

22.28.7 Circuit Board Connectors

Printed circuit board connectors shall be heavy duty, high reliability, two-part type with a history of successful service in rail applications and shall be approved by 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 22.16.5 for wire wrap used and connection requirements.

22.28.8 Testing

Sufficient clearance shall be provided between components to allow testing, removal and replacement without difficulty due to lack of space.

Test points shall be provided in appropriate locations on modules and printed circuit boards. A negative return test point shall also be provided. The test points 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.

22.28.9 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.

22.28.10 Multilayer Boards

A003 Multilayer PC boards and high-density surface mount components will be permitted. To ensure repairability by WMATA, the Contractor shall provide the following minimum documentation:

1. Assembly and detailed layout drawings.
2. Complete parts listing
3. Schematics and interconnection diagrams
4. Source control for any parts on the parts list that can not be directly ordered from an electronics catalog.
5. Theory of operation.

22.28.11 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.

22.28.12 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.

22.29 MICROPROCESSOR-BASED SYSTEMS

22.29.1 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 that allows access to data via a PTU for troubleshooting, and another that 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 22.30.10.

At least 30% additional memory space shall be installed and available for future modifications to program code, fixed data space, and temporary data space.

22.29.2 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.

22.29.3 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.

22.29.4 Programming

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 22.29.5. 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.

22.29.5 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 730. ***(CDRL 2211)*** 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 the following details: A002

   1. Computer description and operation
   2. Software architecture, basic program and functions

A002
3. Detailed flow information
4. Annotated compiler/assembly listing
5. Detailed memory map and listing
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. 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.

22.30 ELECTRICAL DEVICES AND HARDWARE

22.30.1 General

All electrical devices shall be transit industry-proven. Electrical connections shall use either captive screws or captive nuts, with crimped ring-type terminals.

22.30.2 Contactors and Relays

22.30.2.1 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:

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.

22.30.2.2 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.

22.30.3 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 that 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 pushbutton switches shall be per MIL-S-3950, MIL-S-8805, MIL-S-83731, or equal, as approved by the Authority.

22.30.4 Circuit Breakers

22.30.4.1 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.

All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI C37.13 and IEEE C37.14.

Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.

Electrically operated circuit breakers shall be arranged for operation from the low voltage DC supply.

22.30.4.2 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.

22.30.4.3 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.

22.30.5 Fuses

Fuses shall be used only where specifically called for in the Specification or where the use of circuit breakers is not technically feasible, and only with specific approval. Fuses may be considered in applications as follows:

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.

22.30.6 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.

22.30.7 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.

22.30.8 Transformers and Inductors

Transformers and inductors shall be derated 10% for current.

22.30.9 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.

22.30.10 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 5 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 5 years.

E. 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.

22.31 Lubrication Fittings

A005 Access to all lubrication fittings shall be possible through the use of standard, commercially-available grease guns and shall not require any disassembly of surrounding components.

22.32 REFERENCED CDRLs A005

The following CDRL items are referenced in this section:

CDRL 2201	Test and Inspection Plan for Stainless Steel in Weld Applications
CDRL 2202	Test and Inspection Plan for Structural Steel Applications
CDRL 2203	Sampling Frequency of Radiographic Inspections
CDRL 2204	Grounding Scheme
CDRL 2205	Sampling Plan for Full Penetration Weld Inspections
CDRL 2206	Contractor's Welding Procedures
CDRL 2207	Special Welding Procedures for Stainless Steel
CDRL 2208	Welding Settings, Shear Strength and Diameter Records
CDRL 2209	Torch Soldering Test Samples
CDRL 2210	Flammability and Smoke Emission Test Results
CDRL 2211	Software Assurance Plan
CDRL 2212	Air Brake Supplier Approval of Contractor's Piping
CDRL T2251	Elastomeric Tests
CDRL T2252	Plastic Materials Weathering Tests
CDRL T2253	Plastic Materials Abrasion Resistance Tests
CDRL T2254	Plastic Materials Chemical Resistance Tests A002
CDRL T2255	Plastic Materials Adhesion of Coating Materials Tests
CDRL T2256	Plastic Materials Optical Quality Tests
CDRL T2257	Carpeting Construction – Static Electricity Tests
CDRL T2258	Carpet Performance Tests
CDRL T2259	FRP Strength Tests A002
CDRL T2260	Piping Pressure Tests
CDRL T2261	Insulation Smoke Tests
CDRL T2262	Flammability and Smoke Emissions Tests
CDRL T2263	Floor Assembly Fire Test
CDRL T2264	Toxicity Tests

22.33 REFERENCED STANDARDS A005

Federal Spec.TT-P-664	Primer Coating, Alkyd, Corrosion-Inhibiting,Lead and Chromate Free, VOC-
Federal Spec. TT-P-38	Paint, Aluminum, Ready

NASM 21044	Nut, Self-Locking, Hexagon, Regular Height, 250 Degrees F, 125 KSI and 60 KSI
ANSI B1.1	Unified Inch Screw Threads
ANSI B1.13M	Metric Screw Threads – M Profile
ASME FAP-1-1990	Quality Assurance Program for Fastener Manufacturers and Distributors
IFI-0103	Fastener Standards
ASTM A502	Steel Structural Rivets
ANSI B18.1.2	Large Rivets
MIL-P-23469	Pin-Rivet, Grooved and Collar, Grooved Pin-Rivet, Swage-Locked (Lockpin)
ASTM B633	Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTMA666	Standard Specification for Annealed or Cold-Worked Austenitic Steel Sheet, Strip Plate, and Flat Bar
AAR	Specifications for the Construction of New Passenger Equipment Cars
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A736A	Standard Specification For Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbian and Nickel-Copper-Manganese-Molybdenum
ASTM A480	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
ASTM A588	Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 Mpa] Minimum Yield Point to 4-in. [100 mm] Thick
ASTMA710	Standard Specification for Age-Hardening Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Structural Steel Plates
ASTM A36	Standard Specification for Carbon Structural Steel
ASTM A6	Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A606	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A568	Standard Specification for General Requirements for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled
AAR M-201	

ASTM A27	Standard Specification for Steel Castings, Carbon, for General Application
ASTM E446	Standard Reference Radiographs for Steel Castings Up to 2 in. (5 mm) in Thickness
ANSI/ASTME E94	Standard Guide for Radiographic Examination
ASTM E709	Standard Guide for Magnetic Particle Examination
ASTM B26	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B85	Standard Specification for Aluminum-Alloy Die Castings
ASTM B108	Standard Specification for Aluminum-Alloy Permanent Mold Castings
ASTMB247	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
AA	Specification for Aluminum Structures
AA	Engineering Data for Aluminum Structures
ALCOA Tech. Report 524	Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles
ASTM D3182	Standard Practice for Rubber – Materials, Equipment and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets
ASTM D3183	Standard Practice for Rubber – Preparation of Pieces for Test Purposes from Products
ASTM D3190	Standard Test Method for Rubber – Evaluation of Chloroprene Rubber (CR)
ASTM D412	Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension
ASTM D573	Standard Test Method for Rubber – Deterioration in an Air Oven
ASTM D1149	Standard Test Method for Rubber Deterioration – Surface Ozone Cracking in a Chamber
ASTM C542	Standard Specification for Lock-Strip Washers
ANSI Z26.1	American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code
FRA 49 CFR 223	Impact Requirements
ASTM D673	Mar Resistance Of Plastics
ASTM G23	Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
ASTM D1499	Standard Practice Filtered Open-Flame Carbon-Arc Type Exposures of Plastic

ASTM D1003	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM E162	Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
ASTM E662	Standard Test Method for Specific Optical Density of Smoke Generated by Solid
Federal SpecSS-T-312	Tile, Floor; Asphalt, Rubber Vinyl, Vinyl-Asbestos.
AATCC Test 134	Electrostatic Propensity of Carpets
ASTM D1335	Standard Test Method for Tuft Bind of Pile Yarn Floor Coverings
ASTM D1336	Standard Test Method for Distortion of Yarn in Woven Fabrics
ASTM D1337	Standard Test Method for Storage Life of Adhesives by Consistency and Bond Strength
National Bureau of Standards	Carpet Wear Testing
MIL-P-8053	Plywood, Metal Faced
NBS PS 1	Construction and Industrial
MIL-C-7438	Core Material, Aluminum, for Sandwich Construction
NEMA LD-3	High-Pressure Decorative Laminates
ASTM D952	Standard Test Method for Bond or Cohesive Strength of Sheet Plastics and Electrical Insulating Materials
ASTM D790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D3574	Standard Test Methods for Flexible Cellular Materials Made from Olefin Polymers
ASTM D1055	Standard Specification for Flexible Cellular Materials – Latex Foam)
ASTM D618	Standard Practice for Conditioning Plastics for Testing
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTMD256	Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D785	Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
ASTM D648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position

ASTM D5420	Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight
ASTM D5628	Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (Tup or Falling Mass)
ANSI B31.1	Code for Pressure Piping
AAR 2518	Standard S-400
ASTM-A-53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
Fed Spec WW-T-799	Tube, Copper, Seamless (Use with Solder-Flared/CMPRS)
ANSI B16.22	Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings
ANSI B16.18	Cast Copper Alloy Solder Joint Pressure Fitting
AAR M-618	
Fed Spec QQ-B-654	Brazing Alloys, Silver
MIL-T-6845	Tubing, Steel, Corrosion-Resistant (530400), Aerospace Vehicle Hydraulic System 1/8 Hard Condition
MIL-T-8504	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
SAE J524	Seamless Low Carbon Steel Tubing Annealed for Bending and Flaring
SAE J356	Hose Clamps
SAE J533	Flares For Tubing
SAE J517	Hydraulic Hose
SAE J1273	Selection, Installation, and Maintenance of Hose and Hose Assemblies
SAE J343	Tests And Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies
SAE J1405	Flex-Impulse Test Procedures for Hydraulic Hose Assemblies
ASME	Boiler and Pressure Vessel Code for Unfired Pressure Vessels
NFPA 70	National Electric Code
ASTM B33	Standard Specification of Tinned Soft or Annealed Copper Wire for Electrical Purposes
AAR S-501	
AAR S-502	
AAR S-503	
AAR S-540	
NEMA WC3	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

ICEA S-66-524	Cross-Linked-Thermosetting-Polyethylene-Insulated
IEEE-383	Class 1e Electric Cables, Field Splices, & Conn.
ASTM D470	Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable
ICEA S-19-81	Rubber-Insulated Wire and Cable for the Transmission
ASTM D2671	Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use
MIL-W-22759	Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy
ASTM-D-3159	Standard Specification for Modified ETFE-Fluoropolymer Molding and Extrusion Materials
MIL-W-16878	Wire, Electrical, Solderless Wrap, Insulated, and Uninsulated
MIL-C-27072	Cable, Power, Electrical and Cable, Special Purpose Electrical, Multiconductor and Single Shielded
ASTM B298	Standard Specification for Silver-Coated Soft or Annealed Copper Wire
ASTM B174	Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors
MIL-W-81822	Wire, Electrical, Solderless Wrap, Insulated, and Uninsulated
AAR	Manual of Standards Section F S-538, Wiring Practice and Rolling Stock Standard
FAA Spec AC 43.13-1	Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair
MIL-M-81531	Marking of Electrical Insulating Materials
ASTM B32	Standard Specification for Solder Metal
MIL-T-55164	Terminal Boards, Molded, Barrier, Screw and Stud
MIL-T-7928	Terminal, Lug Splices, Conductors, Crimp Style, Copper
MS-25036	Terminal, Lug, Crimp Style, Copper, Insulated, Ring Tongue, Bell Mouthed, Type II, Class 1 (for 105 Degrees C Total Conductor Temperature)
MIL-C-5015	Connectors, Electric, Circular Threaded, AN Type, General Specification for
UL-6	Electrical Rigid Metal Conduit - Steel
ANSI C80.1	Rigid Steel Conduit - Zinc Coated
ANSI B-20.1	Safety Standard for Conveyors and Related Equipment
MIL-HDBK-132	Protective Finishes - For Metal and Wood Surfaces
AWS D1.1	Structural Welding Code, Steel
AWS D1.2	Structural Welding Code, Aluminum

AWS D1.3	Structural Welding Code, Sheet Steel
AWS	Handbook
ASTM A488/488M	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
MIL-W-6858	Welding, Resistance: Spot and Seam
ASME	Section IX & VIII, Part UHA
AWS B2.2	Brazing Procedure and Performance Qualification
Fed. Spec. TT-E-527	Enamel, Alkyd, Lusterless, Low VOC Content
ASTM D3675	Standard Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source
FAR 25.853	Airworthiness Standards: Transport Category Airplanes
ASTM E119	Standard Test Methods for Fire Tests of Building Construction and Materials
FED-STD-191	Textile Test Methods
ASTM D2724	Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics
BSS-7239	Boeing Specification Standard
NFPA 130	Fixed Guideway Transit and Passenger Rail Systems
MIL-HBK-217	Reliability Prediction for Electronic Systems
MIL-HBK 338	Electronic Reliability Design Handbook
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-275	Printed Wiring for Electronic Equipment
MIL-P-13949	Plastic Sheet, Laminated Metal Clad (For Printed Wiring Boards)
MIL-S-83502	Socket, Plug-In Electronic Components Round Style
MIL-S-83734	Sockets, Plug-In Electronic Components, Dual-In-Line Packages (Dips) and Single In Line Packages (Sips), General Specification for
MIL-I-46058	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies
MIL-C-55302	Connectors, Printed Circuit Subassembly and Accessories
IPC	General Guidelines
ANSI/IEEE 730	Standard for Software Quality Assurance Plans
ANSI/IEEE 1016	Recommended Practice for Software Design Description
ATA A652	Computer Software Manual
ATA 102	Computer Software Manual

CNCL S/S BY MIL-PRF-6106: Relays, Electromagnetic (TP15.31.2.1)

MIL-R-5757	Relays, Electromagnetic
IEC 947-4	Low-Voltage Switchgear and Control Gear, Part 4: Contactors and Motor-Starters
AAR	Communication and Signal Division, Signal Manual of Recommended Practice, Part 6.2.1, Recommended Design Criteria for Tractive-Armature, Direct-Current Neutral Relay
MIL-S-3950	Switches, Toggle, Environmentally Sealed
MIL-S-8805	Switches and Switch Assemblies, Sensitive and Push (Snap Action), General Specification for
MIL-S-83731	Switches, Toggle, Unsealed and Sealed Toggle, General Specification For
ANSI C37.16	Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors Preferred Ratings, Related Requirements, and Application Recommendations
ANSI C37.13	Low Voltage AC Power Circuit Breakers Used in Enclosures
IEEE C37.14	Low-Voltage DC Power Circuit Breakers

SECTION 23
NOISE AND VIBRATION

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SECTION 23
NOISE AND VIBRATION

23.1 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. 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. 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. 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, 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, 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.

23.2 AUDIBLE NOISE CRITERIA

23.2.1 Equipment Noise Prior to Installation on Car

Measurements shall be taken of equipment prior to installation on cars, as described below. ***(CDRL T2351)***

23.2.1.1 Traction Motors

The noise produced by each traction motor shall not exceed 93 dBA at a distance of 15 feet in any direction from the center of the motor, while the motor is 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, shall not exceed 89 dBA at a distance of 15 feet from the geometric center of the motor. ***(CDRL T2351)***

23.2.1.2 Propulsion System Gearing

The noise produced by each propulsion system gear box shall not exceed 85 dBA at a distance of 15 feet in any direction from the geometric center of each gear box, 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.

23.2.1.3 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 a distance of 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.

23.2.2 Equipment Noise After Installation on Car

Measurements shall be taken of equipment after installation on cars, as described below. ***(CDRL T2352)***

23.2.2.1 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.

23.2.2.2 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 a distance of 15 feet from the car centerline on the horizontal plane passing through the axles.

23.2.3 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 exceeds by 5dB or more the average of the two adjacent 1/3 octaves containing no pure tone or “tonal” noise.

23.2.4 Car Interior Noise Levels

Measurements shall be made of car interior noise levels, as described below. ***(CDRL T2353)***

23.2.4.1 Auxiliary Equipment Noise with Car Stopped

With all auxiliary equipment operating at simultaneously 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

23.2.4.2 Car Moving on At-Grade Ballasted Track

The noise level in the car interior (without passenger load) shall not exceed 72 dBA when measured at any point along the centerline of the car 4-1/2 feet above the floor and not less than 2 feet from the end walls of the car under the following conditions:

A. 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.

B. All vehicle systems are operating simultaneously at normal conditions.

C. The vehicle is operating without passenger load in any specified mode of acceleration, deceleration, or coasting,.

In areas immediately above trucks, the maximum noise level measured 4-1/2 feet above the floor and 2 feet from the side doors shall not exceed 75 dBA.

23.2.4.3 Car Moving in Subway

The noise level in the car interior shall not exceed 80 dBA when measured at any point along the car centerline 4-1/2 feet above the floor and not less than 2 feet from the car end walls under the following conditions:

A. 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.

B. All vehicle systems are operating simultaneously at normal conditions.

C. The vehicle is operating without passenger load in any specified mode of acceleration, deceleration, or coasting.

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 82.5 dBA.

23.2.5 Door Operation Noise

Noise produced by the operation of all side doors on one side of a car shall not exceed 75 dBA, on the fast meter scale, when measured at any point in the car 1 foot or more from the doors or door pockets and between 3 feet and 6 feet above the floor. ***(CDRL T2354)***

23.2.6 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 23.2.4. 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, during the design and development of the car, the calculations and preliminary tests required to determine that the sound insulation of the completed car will meet the requirements specified in Section 23.2.4. ***(CDRL T2355)*** 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.

23.2.7 Miscellaneous Equipment

The design of all equipment shall incorporate the use of damping, gasketing, resilient mounts, or similar noise-attenuating devices to minimize or eliminate rattling and resonance at all speeds up to 10% above maximum running speed. This requirement encompasses, but is not limited to, the design of 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 shall not exceed 40 dBA measured at a distance of 1 foot from each lighting fixture when all lights are operating simultaneously at normal conditions and are energized at rated voltage, Noise generated by the car public address (PA) system in the standby condition shall not exceed 45 dBA when measured at a distance of 1 foot from any loudspeaker when the PA auxiliary equipment is energized and operating and the car electrical systems are energized. Testing for this limitation may require an indirect test of loudspeaker acoustic sensitivity and electrical noise at the loudspeaker terminals. ***(CDRL T2356)***

23.2.8 Car Exterior Noise Levels

Measurements shall be made of car exterior noise levels, as described below. ***(CDRL T2357)***

23.2.8.1 Car Stopped on At-Grade Ballasted Track

When a two-car train is stopped and all vehicle systems are 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 train on either side. This requirement is intended to supplement Section 23.2.4.1 to discourage concentrations of noise-producing apparatus.

23.2.8.2 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 shall not exceed 68 dBA when measured at any point along the platform, parallel to the cars, 6 feet from the edge of the platform and 5-1/4 feet above the platform surface

23.2.8.3 Car Moving on At-Grade Ballasted Track

The noise level for a two-car train shall not exceed 86 dBA when measured on either side of the train 50 feet from track centerline on the horizontal plane passing through the axles under the following conditions:

A. The train is moving at all speeds up to 75 mph on tangent, at-grade, ballast-and-tie track with clean, smooth rail.

B. All vehicle systems are operating simultaneously at normal conditions.

C. The train is operating in any specified mode of acceleration, deceleration, or coasting,.

23.2.9 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 and installed on the car, and all components of each system must be operating during tests for noise level. ***(CDRL T2356)***

23.3 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:

A. 0.10-inch peak-to-peak amplitude, for the frequency range from 0 to 1.4 Hz
B. 0.01g peak acceleration for the frequency range from 1.4 Hz to 20 Hz
C. 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.

23.4 NOISE AND VIBRATION TESTS

All tests shall be performed and documented to meet the requirements specified herein and in Section 3. ***(CDRLs T2359 and T2360)***

23.4.1 Noise Tests

23.4.1.1 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.

23.4.1.2 Equipment Noise Test Procedures

Using sound level meter and analysis equipment as specified in Section 23.1, 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 23.2.

23.4.1.3 In-Vehicle Noise Test Procedures

Using sound level meter and analysis equipment as specified in Section 23.1, 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.

23.4.1.4 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 23.2. 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.

23.4.1.5 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 23.2.5 and 23.2.7. Noise level tests shall be performed on the first completed "A" car and "B" car to verify performance within the limits indicated in Sections 23.2.2, 23.2.3, 23.2.4, and 23.2.8. 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 23.2.

23.4.1.6 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 23.2.4 the supplier shall, using the procedures outlined in ASTM E336, 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 1foot 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 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 23.2.4.

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. 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.

23.4.2 Vibration Tests

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 23.3.

23.5 REFERENCED CDRLs

The following CDRL items are referenced in this section:

CDRL T2351 .... Equipment Nois

CDRL T2352 .... Equipment Nois

CDRL T2353 .... Car Interior Noi

CDRL T2354 .... Door Operation

CDRL T2355 .... Car Body Sound

CDRL T2356 .... Miscellaneous E

CDRL T2357 .... Car Exterior No

CDRL T2358 .... Auxiliary Equip

CDRL T2359 .... Noise Test Repo

CDRL T2360 .... Vibration Test R

23.6 REFERENCED STANDARDS

The following standards are referenced in this section:

ANSI S1.4	Specification for Sound Level Meters
ANSI S1.11	Octave Band and Fractional-Octave-B and Analog and Digital Filters
ASTM E90	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
ASTM E336	Standard Test Method for Measurement of Airborne Sound Insulation in Buildings.

APPENDIX A
ABBREVIATIONS AND DEFINITIONS

A.1 ABBREVIATIONS

AA	Aluminum Association
AALA	American Association of Laboratory Accreditation
AAR	Association of American Railroads
AATCC	American Association of Textile Chemists and Colorists
AC	Alternating Current
ADA	Americans with Disabilities Act
AFBMA	Anti-Friction Bearing Manufacturers' Association
AISI	American Iron and Steel Institute
ALCOA	Aluminum Company of America
ANSI	American National Standards Institute
AOQL	Average Outgoing Quality Level
APS	Auxiliary Power Supply
AQL	Acceptable Quality Level
AREA	American Railway Engineering Association (now the American Railway Engineering and Maintenance-of-Way Association [AREMA])
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
ATA	Air Transport Association of America
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection

ATS	Automatic Train Supervision
AW0	Empty transit vehicle weight
AW1	Empty transit vehicle weight plus passenger seated load
AW2	Empty transit vehicle weight plus passenger seated and normal rated standing load
AW3	Empty transit vehicle weight plus passenger seated and full rated standing load
AW4	Empty transit vehicle weight plus passenger seated and crush rated standing load
AWG	American Wire Gauge
AWS	American Welding Society
BCP	Brake Cylinder Pressure
BHP	Brake Horsepower
BSS	Boeing Support Standard
BTU	British Thermal Unit
CAD/CAE	Computer-Aided Design/Computer-Aided Engineering
CCITT	International Telegraph and Telephone Consultative Committee
CDR	Conceptual Design Review
CDRL	Contract Data Requirements List
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CGHAZ	Coarse Grain Heat Affected Zone
cm	Centimeter
C/O	Cut-Out
CPM	Critical Path Method
CRC	Cyclic Redundancy Check
CRF	Critical Radiant Flux
Cu. Ft.	Cubic Foot (or Feet)
DAM	Data Acquisition Module

dB	Decibels
dBA	Decibels – “A” scale
dBm	Decibels referenced to 1 milliwatt
DBTT	Ductile-to-Brittle Transition Temperature
DC	Direct Current
DOT	United States Department of Transportation
DQT	Design Qualification Test
DST	Daily Safety Test
DTE	Diagnostic and Test Equipment
ECCB	Environmental Control Circuit Breaker
ECP	Engineering Change Proposal
ECR	Environmental Control Relay
EDT	Eastern Daylight (Savings) Time
EEPROM	Electrically Erasable Programmable Read Only Memory
EIA	Electronics Industries Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPA	Environmental Protection Agency
EPROM	Electrically Programmable Read Only Memory
EST	Eastern Standard Time
ETFE	Ethylenetetrafluoroethylene
ETP	Electrolytic Tough Pitch
FAA	Federal Aviation Administration
FAI	First Article Inspection
FAR	Federal Aviation Regulation
FAT	Factory Acceptance Test

FCC	Federal Communications Commission
FDR	Final Design Review
FED-STD	Federal Standard
FDU	Fault Display Unit
FMEA	Failure Modes and Effects Analysis
FPM	Foot (or Feet) Per Minute
FPMM	Failures per Million Miles
FRA	Federal Railroad Administration
FRACAS	Failure Reporting Analysis and Corrective Action
FRP	Fiber-Reinforced Plastic
FTA	(1) Federal Transit Authority, United States Department of Transportation (2) Fault Tree Analysis
g	Gravity
HAZ	Heat Affected Zone
HPU	Hydraulic Power Unit
HRI	Hazard Risk Index
HSCB	High Speed Circuit Breaker
HVAC	Heating, Ventilation and Air Conditioning
HVDC	High Voltage Direct Current
Hz	Hertz
IACS	International Annealed Copper Standard
IC	Intercommunications
ICEA	Insulated Cable Engineers Association
ID	Identification
IEEE	Institute of Electrical and Electronic Engineers
IFI	Industrial Fastener Institute
IGBT	Insulated Gate Bipolar Transistor

ILD	Initial Load Deflection
I/O	Input/Output
IPC	Institute of Printed Circuits
ISO	International Standards Organization
JEDEC	Joint Electronic Device Engineering Council
LAHT	Low Alloy High Tensile Strength (steel)
lb	Pound(s)
lbf	Pounds Force
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LLRU	Lowest Level Replaceable Unit
LRU	Line Replaceable Unit
LVDC	Low-Voltage Direct Current
LVPS	Low-Voltage Power Supply
mA	MilliAmpere
MID	Message Identification
MIL	Military Specification (or Standard)
mm	Millimeter
mph	Miles per Hour
mphps	Miles per Hour per Second
MPS	Master Program Schedule
MR	Main Reservoir
MRB	Material Review Board
MS	Military Standard (or Specification)
msec	Millisecond
MTBHE	Mean Time Between Hazardous Events

MTC	Manual Train Control
MTTR	Mean Time to Repair
NBS	National Bureau of Standards
NDT	(1) Non-Destructive Testing (2) Nil-Ductility Temperature
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
OAT	On-site Acceptance Test
OD	Outer Diameter
OEM	Original Equipment Manufacturer
OFE	Oxygen Free Electronic
O&SHA	Operating & Support Hazard Analysis
OSHA	Occupational Safety and Health Authority, United States Department of Labor; Occupational Safety and Health Act
PA	Public Address
PCB	Printed Circuit Board
PCMCIA	Personal Computer Memory Card International Association
PDR	Preliminary Design Review
PHA	Preliminary Hazards Analysis
PHL	Preliminary Hazard List
PIV	Peak Inverse Voltage
PMP	Program Management Plan
ppm	Parts per Million
PQR	Procedure Qualification Records
PSD	Power Spectral Density

PROM	Programmable Read Only Memory
psi	Pounds per Square Inch
psig	Pounds per Square Inch Gauge
PSS	Programmed Station Stop
PTFE	Polytetrafluoroethylene
PTU	Portable Test Unit
QA	Quality Assurance
RAM	Random Access Memory
RE	Abbreviation denoting AREA type rail
RF	Radio Frequency
RFI	Radio Frequency Interference
RPM	Revolutions per Minute
RMS	Root Mean Square
RSW	Resistance Spot Welding
SAE	Society of Automotive Engineers
SCFM	Standard Cubic Feet per Minute
SCMM	Software Capability Maturity Model
SDD	Software Design Description
SI	International System of Units
SMT	Surface-Mounted Technology
S/N	Signal-to-Noise (ratio)
S-P	Severity and Probability
SQC	Statistical Quality Control
SPL	Sound Pressure Level
Sq. ft.	Square Foot (Feet)
Sq. in.	Square Inch(es)

Sq. yd.	Square Yard(s)
SSPC	Steel Structures Painting Council
SSPP	System Safety Program Plan
TCR	Temperature Control Relay
TFE	Tetrafluoroethylene
TIA	Telecommunications Industry Association
TL	Trainline
TOR	Top of (Running) Rail
TSI	Truck Swiveling Index
TWC	Train-to-Wayside Communication
UHF	Ultra High Frequency
UL	Underwriters' Laboratories, Inc.
UMTA	Urban Mass Transportation Administration
UNS	Unified Numbering System
UV	Ultraviolet
VAC	Volts Alternating Current
VCU	VMS Central Unit
VDC	Volts Direct Current
VH	Vickers Hardness
VHF	Very High Frequency
VMS	Vehicle Monitoring System
VOC	Volatile Organic Compound
VPI	Vacuum Pressure Impregnated
VSWR	Voltage Standing Wave Ratio
VU	Volume Units
W	Watt

VVVF	Variable Voltage, Variable Frequency
WMATA	Washington Metropolitan Area Transit Authority
WPS	Welding Procedure Specification

A.2 DEFINITIONS

"A" CAR – The even-numbered car of a married pair that houses the Automatic Train Control apparatus.

ACCEPTANCE – The formal written acceptance by the Authority that all work, or a specific portion thereof, under the Contract has been satisfactorily completed.

ADHESION, PERCENT – During rolling contact, the maximum value of the ratio between the longitudinal tangential force and the normal force at the wheel-rail interface.

AUTHORITY – The Washington Metropolitan Area Transit Authority.

ALIGNMENT, HORIZONTAL – The horizontal location of a track as described by curves and tangents.

ANCHORAGE – The attachment of the coupler, draft gear, and drawbar to the car underframe.

APPROVED – Approved by the Authority, unless otherwise stated.

APPROVED EQUAL OR EQUIVALENT – An item, material, or method offered as a substitute for that designated herein, for which approval in writing has been obtained from the Authority. The burden of proof that a substitute is, in fact, equal shall rest with the Contractor.

AUTOMATIC TRAIN CONTROL – The system for automatically controlling train movement, enforcing train safety, and directing train operations.

AUXILIARY EQUIPMENT – Any mechanism or structure, other than the vehicle body, traction motor, or propulsion equipment gearing, that performs a function at some time during the operation of the transit vehicle – e.g., heating and cooling subsystem, pumps, vehicle door mechanism, air compressor or hydraulic power unit, transit vehicle lighting.

"B" CAR – The odd-numbered car of a married pair.

BLENDING – In braking, a simultaneous application of dynamic and friction brakes with the effort of friction brake supplementing, as required, the electrical braking to achieve the required total brake effort.

BRAKING, DYNAMIC – Electrical braking in which the power generated by the traction motors, when driven as generators, is being dissipated by resistor banks on the vehicle and is providing retardation effort.

BRAKING EFFORT – Retarding force developed by the propulsion subsystem, braking subsystem, or a combination of both subsystems.

BRAKING, ELECTRICAL – Braking in which the power generated by the traction motors, when driven as generators, is either dynamic or regenerative.

BRAKING, EMERGENCY – An irretrievable braking effort to fully stop a transit vehicle at a higher retardation rate than is obtained with a full service brake application.

BRAKING, FULL SERVICE –The normal maximum braking effort employed to stop a transit vehicle in the absence of an emergency stop signal.

BRAKING, REGENERATIVE – Electric braking where the power generated by the traction motor, when driven as a generator, is conditioned and returned to the DC bus.

CAR – SEE TRANSIT VEHICLE.

COAST – The mode of operation of transit vehicle or consist in which propulsion (positive traction) and braking are inactive.

CONSIST – The quantity and specific identity of vehicles that make up a train.

CONSOLE – The control panel located in the cab directly in front of the operator's seat.

CONTACT RAIL – See Third Rail.

CONTRACT – The written agreementsexecuted by the Authority and the Contractor, covering the performance of the Work and furnishing of labor, materials, equipment, and tools, including work incidental to the procurement.

CONTRACT DATA REQUIREMENTS LIST (CDRL) – A matrix listing data (such as drawings, catalogs, reports, notices, and samples), services, and equipment that the Contract specifies must be provided by the Contractor. The matrix also indicates when and how often submittals and resubmittals are required.

CONTRACT SPECIFICATIONS BOOK – A document issued by the Authority that includes the Request for Proposals, Proposal Forms, General Provisions, Special Provisions, Technical Specification, and other forms and exhibits.

CONTRACTOR –The person or persons, firm, partnership, corporation, or any combination thereof, who, as an independent Contractor, has entered into a Contract with the Authority. As used herein, the terms "contractor" and "carbuilder" are synonymous.

COUPLER – A device for mechanically coupling transit vehicles together. This term is also applied to connectors, as in "electric coupler" and "pneumatic coupler".

CURRENT COLLECTOR – A transit vehicle-borne device used to transfer electrical power from the stationary contact rail to the transit vehicle.

DAYS – Unless otherwise designated, the word "days" means calendar days.

DEADMAN FEATURE – A device to detect inattention or disability of a train operator, which causes a brake application.

DEFECT – Malfunction or failure in the manufacture or design of any component or subsystem that causes a vehicle to cease operating or operate in a degraded mode.

DESIGN LIFE – The period of time for which the vehicle is intended to be safely and reliably usable for its original purpose. For this contract, this period shall be taken to be 35 years.

DRAFT GEAR – The energy-absorbing mechanism that attaches the coupler to the anchorage.

DWELL – The period of time measured from the instant a train stops at a station until the instant it resumes moving.

EXISTING CAR – As used throughout this specification, "existing cars" serves to identify all of the cars now in use on the Authority's property.

F-END – The cab end of either an "A" car or a "B" car

FAIL-SAFE – Equipment configurations that are implemented in hardware where each component has a known set of predictable failure modes that may be individually analyzed for their effect on equipment performance and function. Any failure or set of failures resulting from a single causative event must cause the equipment to revert to a safe state that is self-annunciating.

FAILURE – The inability of a system, subsystem, assembly, or component to perform its required function.

FAILURE RATE – The frequency of failure, expressed as failures per million miles.

GAP, RAIL – A section of the third rail isolated from the power source.

GAUGE, TRACK – The distance between the inside face of rails , usually measured 5/8-inch below the top of the centerline of heads of running rails and at a right angle thereto.

GENERAL TERMS – Whenever the words "acceptable," "approved," " submitted," "designated," "established," "permitted," "required," "satisfactory," or "unsuitable" "unacceptable," "unsatisfactory," or "unsuitable" are used they shall be understood to imply "by the Authority" or " to the Authority" unless the context clearly indicates a different meaning. Whenever the verbs "submit", "designate", "notify", "bear", "use", "furnish", "install", "comply", and other like verbs are used, without being preceded by a subject, it shall be understood that the subject is responsibility of the Contractor unless the context clearly indicates a different meaning.

HIGH VOLTAGE – SEE PRIMARY POWER.

INDICATED – As described in the specifications, as-built drawings or as required by the other Contract documents.

INTERFACE – The point at which one system component or subsystem comes into physical or functional contact with another.

INTERLOCK – A condition whereby one function is dependent on the operation of another function.

IRRETRIEVABLE – In braking, a condition imposed in which a brake cannot be released until a zero speed indication is attained.

JERK – The rate of change of acceleration or deceleration, normally measured in miles per hour per second per second.

LEAD CAB – The controlling cab in a train consist.

LEAD CAR – In the direction of travel, the forward- most vehicle of the consist.

LEFT HAND – Left side of the transit vehicle when one looks toward the F-end from inside the vehicle.

LOAD WEIGHING – A function that measures transit vehicle weight to permit control of tractive effort to achieve a constant effort-to-weight ratio.

LOW VOLTAGE – The voltage used for auxiliary systems on the vehicle, nominally 37.5 VDC.

LOWEST LEVEL REPLACEABLE UNIT – The lowest component or assemblage of components to which a malfunction can be isolated, and which normally can be replaced in its field application or in the workshop.

MARRIED PAIR (Two-Car Unit) – 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.

MULTIPLE UNIT – Two or more married pairs of cars.

NORMAL SERVICE CONDITIONS – Environmental conditions and operating parameters to which the cars will be exposed and must operate within each day, as outlined in these Contract Documents.

OPERATOR – The individual on board who is responsible for train operation in manual modes and overseeing train operation in any automatic mode.

OVERHAUL – Disassembly into component parts or subassemblies; replacement of worn and defective parts (with new or reconditioned parts as approved by the Authority); and reassembly into complete functional assemblies, in accordance with the OEM recommended instructions/procedures.

PERFORMANCE – The measure of output or results obtained by a component, system, person, team, and so forth, as specified.

PRIMARY POWER – High-voltage DC power supplied to the transit vehicle via the interface between the current collector and the contact rail.

R-END – The end of any vehicle which is opposite the cab end.

REDUNDANCY – The existence within a system or subsytem of more than one means of accomplishing a given function.

RELAY, VITAL – A relay whose function is necessary for the safe operation of the train and whose mode of failure is in the safe condition. Such relays must be approved by the AAR Committee E, Mainline Block Signals.

RELIABILITY – The probability of performing a specified function, without failure and within design parameters, for the period of time intended under actual operating conditions.

REQUIREMENTS – The criteria that must be met in designing the transit vehicle.

REVENUE SERVICE – Service on routes established for train use by the public.

RIGHT HAND – Right side of the transit vehicle when one looks toward the F-end from inside the vehicle.

ROLL, BODY – The number of degrees in an arc, having its base at top-of-rail height and at the centerline of the track, swept by a point in the center of the roof as the vehicle sways from side to side during normal running at any speed on level tangent track.

SERVICE LIFE – The actual time during which any vehicle serves its intended purpose of safely and reliably transporting passengers. The end of service life occurs when degradation of the structural integrity of the vehicle requires that it be removed from service.

SERVICE PROVEN – 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.

SLIDE, WHEEL – The condition is which the equivalent linear velocity of the wheel is less than the linear velocity of the transit vehicle.

SPECIFICATIONS – The directions, provisions, and requirements contained or referred to herein, together with all written agreements made, or to be made, that pertain to the manner of performing the Work, or the quantities of Work and materials, to be provided under the Contract.

SPIN, WHEEL – The condition in which the equivalent linear velocity of the wheel is greater than the linear velocity of the transit vehicle.

STOP, PROGRAMMED – The stopping of a train at a brake rate, which may be equal to or less than the full service brake rate under automatically programmed conditions at a designated point on the transit system.

SUBCONTRACTOR – Any individual, partnership, firm, or corporation who undertakes integrally on the Project the partial or total design, manufacture, or performance of one or more items of work under the terms of the Contract. As used herein, the terms "subcontractor," "supplier," and "subsupplier" are synonymous.

SUBSYSTEM – A subsystem comprises functional elements interconnected within a system to perform a specific function, such as door operations, communications, and lighting.

SUPERELEVATION – On a curve, the vertical distance, measured in inches, that the outer rail is above the inner rail.

TECHNICAL SPECIFICATION – The specifications, provisions, and requirements that detail the work and the materials, products (including the methods of manufacture, construction, assembly, and testing), and other requirements relative thereto.

THIRD RAIL – The rail alongside the track which carries electrical power for the operation of trains and includes supports, insulators, coverboards, and accessories.

TIME, DEAD – The time from the occurrence of a step change of the control signal to the beginning of change of the controlled variable.

TIME, REACTION – Time from the initiation of a step change of control signal to the first attainment of the new steady-state value of the controlled variable, within the designed accuracy.

TIME, RECOVERY – The time required for a system or condition to return to its original state (or some stated percentage of its original value) after being disrupted or de-stabilized.

TRACTIVE EFFORT – Propelling or braking force developed by the power and traction system and other subsystems.

TRAINLINE – The means of sending a signal to all transit vehicles in a consist via a continuous electrical or fluid circuit connected through appropriate coupling devices.

TRANSIT VEHICLE – A heavy rail car whose configurations and performance are described by this specification.

VEHICLE – See Transit Vehicle.

VITAL – A function or a unit which is critical to overall system safety.

WEIGHTS, ACTUAL – The measured weights of finished transit vehicles ready to run.

WEIGHT, ASSIGNED – The loaded transit vehicle categories assigned as the basis for system, design and for subsystem and transit vehicle testing.

WEIGHT, READY-TO-RUN – The weight of a car which is complete in all respects but without passengers or Operator; the AW0 weight.

WORK – The furnishing of all the products, materials, equipment, services and the performance of the contractual requirements in the Contract documents, including changes thereto.

ZERO SPEED – Vehicle velocity of less than 1 mph for more than 1 second.