



New York City Transit

**SUBWAY CAR PROCUREMENT
FOR THE
B DIVISION**

TECHNICAL SPECIFICATION

NEW CAR PROCUREMENT CONTRACT

R34211 (R211)

TECHNICAL SPECIFICATION

New York City Transit
Contract R34211

R211 Technical Specification

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Section 1

General Requirements and Scope

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1. General Requirements and Scope

1.1. Introduction

- 1.1.1. This section defines the requirements for the supply of heavy rail rapid transit cars, designated R211, including the project goals, general technical requirements, scope of supply, and compatibility requirements. A listing of definitions and abbreviations is included.
- 1.1.2. This section also provides requirements and guidance for the use of this Specification.
- 1.1.3. This Specification addresses the three types of R211 cars:
 - a) **R211A cars.** These will be the baseline NYCT cars defined in this Specification, as described in Section 1.3.1.
 - b) **R211S cars.** These cars will be for use on the Staten Island Railway (SIR), with the minimum of changes from the R211A cars needed for compatibility with the SIR infrastructure and operation, as described in Sections 1.2.3 and 25 – Staten Island Railway Cars.
 - c) **R211T cars.** These cars will be used to test the feasibility of open gangways on the NYCT system, with the minimum of changes from the R211A cars needed to accommodate open gangways, as described in Section 26 – Open Gangway Test Train.
- 1.1.4. In order to maintain design and configuration consistency, the Contractor may include wiring and equipment specific to one type of R211 car which is not required for all configurations.
- 1.1.5. The Technical Specification is hereinafter referred as the Specification or the TS. The reference to the clauses may be prefixed by the letters "TS" (for example, Clause 21.3.4 of the Technical Specification is written as TS 21.3.4). The use of the term "Section" shall be interpreted as referring to a section of the Specification.

1.2. Project Summary and Goals

1.2.1. The NYCT System

- 1.2.1.1. NYCT operations are divided into the A Division (numbered lines, formerly the IRT system) and the B Division (lettered lines, formerly the BMT and IND systems). NYCT fleets are not interchangeable between the A and B divisions, due to infrastructure differences.
- 1.2.1.2. The NYCT fleet currently comprises almost 6,300 cars, covering 12 distinct contract types, of which more than 3,500 are used on the B Division. Cars on the B Division are either 60 or 75 feet in length.
- 1.2.1.3. The B Division has six Maintenance Facilities (207 St, Concourse, Coney Island, East New York, Jamaica, and Pitkin) for maintenance and two Overhaul Facilities (207 St and Coney Island) for major overhauls, repairs, and Scheduled Maintenance System (SMS) work. A Central Electronics Shop (CES) repairs electronic equipment for all NYCT operating divisions.

1.2.2. The R211 Project

- 1.2.2.1. The R211A fleet will replace the R46 fleet and shall be able to operate anywhere on the B Division.
- 1.2.2.2. The R211A and R211T cars shall be compatible with existing physical infrastructure, NYCT Maintenance Facilities and signal systems, including the CBTC system, as required in Sections 2 – Design and Performance Criteria and 14 – Train Control System.

1.2.3. Staten Island Railway and R211S Cars

- 1.2.3.1. On Staten Island, the SIR operates a 14-mile route with 22 stations, providing 24-hour service over a primarily open air, grade separated alignment. The SIR has one maintenance shop. The current R44 SIR fleet comprises 64, 75 foot long cars. The R211S fleet will replace these cars.
- 1.2.3.2. The R211S cars shall be compatible with existing SIR physical infrastructure, SIR Maintenance and NYCT Maintenance and Overhaul Facilities, SIR's signal system, including the SIR Automatic Train Control (ATC) and Cab Signaling system, as required by Sections 2, 14, and 25.
- 1.2.3.3. NYCT B Division cars, with modifications, are able to operate on the SIR infrastructure. All references to the NYCT system in this specification shall be understood to refer to the B Division, or SIR as applicable. Requirements specific to the SIR system shall be defined in Section 25 - Staten Island Railway Cars.

1.2.4. Compatibility with Existing Fleets

- 1.2.4.1. All R211 Units shall be capable of mechanically and pneumatically coupling with existing car classes, through the use of mechanical coupler adapters where necessary, as described in Sections 4.4.4 (R211A and R211T) and Section 25.4.1 (R211S).

1.2.5. Design Goals

- 1.2.5.1. The following key goals shall drive the design and implementation of the R211 program:
 - a) **Safety and Security** – provide high levels of active (incident prevention) and passive (incident mitigation) safety, and provide security levels appropriate for NYCT operation.
 - b) **Operational Efficiency** – provide the highest levels of reliability and maintainability, with high fault tolerance and rapid recovery from fault conditions. Optimize station dwell times and capacities and provide adaptability through plug and play concept devices/technologies.
 - c) **Cost Reduction** – reduce life cycle costs considering initial procurement costs, maintenance costs, replacement costs, energy consumption, and inventory control.
 - d) **Customer Experience** – provide safe, reliable, and predictable service; maximize customer comfort with state of the art communications and information systems.
 - e) **Green Technology** – minimize weight, energy consumption, and emissions (including noise) while achieving the minimum environmental footprint within the technical requirements and constraints of the program.
- 1.2.5.2. The industrial design of the R211 cars is important to NYCT, and the Contractor's design shall be in accordance with the interior and exterior design concepts shown in Appendix E-1.
- 1.2.5.3. The Contractor's industrial design shall include consideration of International Best Practice and their prior project experience when addressing the factors listed below to achieve the design goals stated in 1.2.5.1:
 - a) Crowding – optimize passenger flow for ingress and egress (i.e. – location/placement of stanchions, depth of passenger seats).
 - b) Heat/Cold/Drafts – provide means to mitigate loss of conditioned air and optimize air flow and distribution; see Section 7 - Heating, Ventilation, and Air Conditioning for additional design details.

- c) Crime and Anti-Social Behavior – the Contractor shall propose layouts for CCTV cameras in the car’s interior that will optimize visibility (see Section 13 - Communications) and shall provide messaging and signage from worldwide experience targeting security for NYCT review.
- d) Customer Comfort – consideration of ergonomic factors in passenger interfaces (i.e. - seat shell contours, materials, stanchion design and dimensions). See Section 15 - Carbody Equipment and Interiors.
- e) Odors and Dirt – in addition to the requirements for fresh air changes and filtration specified in Section 7 - Heating, Ventilation, and Air Conditioning, attention shall be paid to interior design elements that minimize dirt and odor retention and are easy to clean using the standard NYCT cleaners listed in Appendix C-3 (Cleaners and other products approved for use on railcars and railcar parts).
- f) Personal Space – interior designs shall include means to minimize undesired physical interactions between customers. For example, USB charger layouts should minimize the potential for charging cords to hit or interfere with the seated customer.
- g) Information – in addition to the baseline requirements of Section 13 - Communications, the Contractor shall propose means, based on worldwide experience, of effectively transmitting information to the customer including but not limited to location, advertising, and messages.

1.3. Scope of Supply

1.3.1. The primary scope of supply is to design, build, test, and commission:

- a) The quantity of R211A cars defined and specified in the Contract Documents to replace the NYCT R46 fleet,
- b) The quantity of R211S cars defined and specified in the Contract Documents to replace the SIR R44 fleet, and
- c) A 10-car (two unit) Open Gangway Test Train to determine the feasibility of open gangways on NYCT’s B-Division.

1.3.2. The design of the R211A, R211S, and R211T cars shall be identical except where specific differences are required by this Specification, and all like subsystems and components shall be interchangeable between the three car types.

1.3.3. All cars delivered under this Specification shall be uniform to the extent noted in Section 1.3.2. Any changes made to systems or equipment shall be fully incorporated in all cars unless otherwise approved by NYCT.

1.4. Scope of Specification

1.4.1. This Specification defines the requirements for the performance, design, manufacturing, assembly, testing, delivery, and acceptance of heavy rail transit cars, to be configured in Units and designated as R211.

1.4.2. This Specification includes requirements concerning program management, compliance demonstration (design review, testing, and inspection), product support (documentation, training, and test equipment), and data submittals.

1.4.3. While this Specification makes every attempt to provide accurate information on the operating conditions for the cars, it is the responsibility of the Contractor to verify these conditions as described in Section 1.5.1.4, and to ensure that the design is compatible with them.

1.5. Contractor's Responsibilities

1.5.1. Design Integration

- 1.5.1.1. The Contractor shall have complete responsibility for the design and performance of the cars, including integration of design elements from other suppliers (e.g., brakes and propulsion), and management of all physical, functional, data, and other interfaces.
- 1.5.1.2. Integration of the complex systems on the car is critical to the success of the project. The Contractor shall dedicate experienced, knowledgeable staff to the mechanical, electrical, software, and communications integration efforts.
- 1.5.1.3. The Contractor shall provide written evidence that each Major Supplier has received a complete copy of this Specification as part of the Contractor's contract with the supplier. [CDRL].
- 1.5.1.4. If quantification of any interfaces or NYCT operating conditions (e.g. – high voltage transients) is considered critical design information, the Contractor shall conduct such studies as required on NYCT's infrastructure with the approval and cooperation of NYCT.
- 1.5.1.5. Any data obtained in the course of such studies shall be provided to NYCT for use by NYCT without limitation.
- 1.5.1.6. The Contractor shall provide NYCT with complete information affecting form, fit, and function, as well as all necessary interface and performance information to enable interchangeability and operational compatibility with future car orders.
- 1.5.1.7. The Contractor's integration efforts shall eliminate undesired redundant hardware and software, while providing optimum reliability, functionality, and diagnostic capability.
- 1.5.1.8. Throughout this Specification, references are made to the requirement that the Contractor shall be required to seek NYCT approval for certain design methods, approaches, and analyses; possible alternate methods and materials; proposed materials and workmanship; test procedures; submittal requirements; and other details of the program.
- 1.5.1.9. The absence of a specific reference or requirement for receiving NYCT approval of an item shall not relieve the Supplier from obtaining approval of the design, type of material, procedure, or method applicable to that item.
- 1.5.1.10. The Contractor shall proceed with the Work on the basis that NYCT approval in advance is required for everything associated with the Contractor's performance of the Work.
- 1.5.1.11. The Contractor shall provide a system to provide traceability to test results, test reports, and other artifacts that provide evidence of verification, or a means by which requirement validation status is maintained. [CDRL]

1.5.2. Material and Equipment Selection

- 1.5.2.1. Materials and equipment for the construction of the cars shall be selected to obtain the maximum strength and reliability, balanced against minimum weight and reasonable life cycle costs consistent with the requirements of this Specification.
- 1.5.2.2. All materials and equipment shall be of sufficiently robust design and implementation to survive continuous 24-hour service and repeated application consistent with duty cycles for that service. Components expected to withstand extensive handling including, but not limited to, door and window latches, touch screen displays, key switches, knobs, and buttons.
- 1.5.2.3. All materials and equipment furnished by the Contractor shall be new and shall be subject to inspection by NYCT.

- 1.5.2.4. The Contractor shall have complete responsibility for inspection and quality of material and workmanship (see Section 19 – Materials, Processes and Workmanship).

1.5.3. Consumable Parts

- 1.5.3.1. To the greatest extent possible, and except as otherwise specified, all consumable parts, such as hardware, lubricants, air hoses, contact shoes, brake shoes, etc., shall be interchangeable with similar elements on existing NYCT cars.
- 1.5.3.2. All consumable parts shall be available from at least two sources unless otherwise approved.

1.5.4. Documentation and Units of Measure

Documentation

- 1.5.4.1. All drawings, documents, reports, and other applicable items submitted to NYCT shall use the U.S. customary units of measure. Any documents including, but not limited to, drawings, test plans and test reports prepared initially in metric units shall have the corresponding U.S. customary units of measure recorded on the documents directly after the metric notation in parentheses.
- 1.5.4.2. Electrical/electronic symbols on all drawings from all suppliers shall conform to International Electrotechnical Committee (IEC) or American National Standards Institute (ANSI) standards.
- 1.5.4.3. All letters and reports shall be submitted in clear, idiomatic American English and shall not be a literal translation to English from another language.
- 1.5.4.4. All letters and reports shall be submitted on standard 8.5 × 11-inch paper. All drawings shall be prepared using the drawing size standards defined in NYCT Specification 8004-GENL-87 contained in Appendix C-35.
- 1.5.4.5. If the Contractor cites a reference document that is not readily available to NYCT, the complete reference or copies of the pertinent pages shall be provided.
- 1.5.4.6. All reference documents shall be in English. For non-English documents, both the original and the English translation shall be included in the submittal.

Measurement Standards

- 1.5.4.7. Each car system shall be designed and manufactured to a single measurement standard, either U.S. inch or ISO metric. U.S. inch and ISO metric parts shall not be mixed within equipment or sub-assemblies.
- 1.5.4.8. The mounting of all carbody and truck equipment shall be to U.S standard.
- 1.5.4.9. Metric sized hardware may be used only for the internal assemblies of components or equipment where it will not be removed during routine maintenance, testing, or adjustment, or to gain access for troubleshooting or maintenance.
- 1.5.4.10. Each unit, component, or group containing ISO-metric threads shall be indelibly identified, in a manner and conspicuous location approved by NYCT, to signify that the unit contains metric threaded fasteners.

1.6. Use of this Specification

- 1.6.1. All references in this Specification to the NYCT system shall be considered to cover both the main NYCT system and the SIR, unless it is clear from the context that only one applies.

- 1.6.2. This Specification is generally complete and comprehensive, but is not intended to describe all Work details to be performed and therefore must be supplemented by the Contractor's experience in building heavy rail transit cars, on its examination of the NYCT system, and with its detailed design and testing capabilities.
- 1.6.3. The cars provided under this Contract must comply with all applicable Federal, State, and Local laws, ordinances, and regulations whether or not such laws, ordinances, and regulations are specifically identified in this Specification.
- 1.6.4. References to commercial, industrial, and NYCT standards, specifications, regulations, and recommendations pertain to the revision in effect at the time of the Request for Proposal (RFP) release, unless specifically indicated otherwise.
- 1.6.5. In the case of a conflict between referenced standards and this Specification, the Specification shall govern.
- 1.6.6. If at any time the Contractor finds that any requirement of this Specification appears to be in error, or in conflict with the general intent of the Contract Documents or Specification, then it shall immediately bring the apparent problem to NYCT's attention, in writing. NYCT will determine whether the Specification needs to be modified.
- 1.6.7. References to sections within this Specification are provided for convenience. If errors exist, or references are incomplete, the Contractor shall immediately bring such occurrences to NYCT's attention, in writing, for clarification.
- 1.6.8. The Contractor shall be solely responsible for the detailed design of the cars and shall provide cars that are in all respects compliant with this Specification.
- 1.6.9. Where alternatives to any requirement of this Specification are proposed, such requests shall be made in writing, with full supporting justification. NYCT written approval shall be received by the Contractor before such alternatives are considered acceptable. See Section 20.2.7.
- 1.6.10. Acceptance of the substitution of a particular material, standard, or specification for a specific application does not automatically imply the acceptance of the same material for another application. Each substitution proposed must be submitted to NYCT for acceptance.
- 1.6.11. If the Contractor proceeds with any work affected by an apparent error or conflict, or an alternative approach pending NYCT approval, with knowledge of such apparent error or conflict and prior to correction, the Contractor shall do so at its own risk. The work so performed shall not be considered as work done and shall not be paid for under this Contract unless and until approved. No Excusable Delay will be allowed based on these conditions.
- 1.6.12. As used in this Specification, the singular shall mean and include the plural; the masculine gender shall mean the feminine and neuter genders; and vice versa.
- 1.6.13. Whenever in this Specification the words "required," "determined," "directed," "specified," "authorized," "ordered," "given," "designated," "indicated," "considered necessary," "deemed necessary," "permitted," "reserved," "suspended," "established," "approval," "approved," "disapproved," "acceptable," "unacceptable," "suitable," "accepted," "satisfactory," "unsatisfactory," "sufficient," "insufficient," "rejected," "condemned," or words of like import are used, it shall have the same meaning as if such words were followed by the words, in writing, "by NYCT" or "to NYCT," unless otherwise specifically stated.
- 1.6.14. Wherever the words "provided," "supplied," or "installed" are used in the Contract Documents in reference to work to be performed by the Contractor, they shall be understood to mean "furnished and delivered completed."

- 1.6.15. This Specification has been developed primarily in customary U.S. units of measure. International System of Units (SI) conversion units are listed in parenthesis for convenience. If a conflict occurs in a conversion, it should be assumed that the English measure is accurate.
- 1.6.16. This Specification contains a blend of performance, functional, and design requirements. Where a specific design is desired, it is stated, based on past experience on the NYCT system, or upon necessary interfaces with NYCT infrastructure or maintenance and fleet management processes.
- 1.6.17. Sections that define the requirements for equipment are arranged such that each provides:
 - a) **Introduction** – describes the scope of the section and a summary of the required equipment.
 - b) **Performance requirements** – defines the expected performance of the system, in measurable terms – e.g., strength, acceleration, brightness, and heating/cooling.
 - c) **Functional requirements** – defines the function of the system - e.g., door logic, brake control, and isolation.
 - d) **Design requirements** – defines specific design features - e.g., wheels and axles, and connectors.
 - e) **Maintainability requirements** – what is needed for NYCT to be able to maintain the equipment - e.g., special tools, maintenance intervals.
 - f) **Validation requirements** – describes obligations for design review, and testing - e.g., structural analysis and power laboratory testing.
- 1.6.18. Table 1-1 is provided for convenience as a guide to where the requirements for equipment and functions can be found.

Table 1-1 – Key Requirements Locator

Section	Requirements for:		
01	<ul style="list-style-type: none"> • General introduction to the Specification • Definitions and acronyms used in the Specification 		
02	<table border="0" style="width: 100%;"> <tr> <td style="vertical-align: top; width: 50%;"> <ul style="list-style-type: none"> • General design requirements • Compatibility requirements • Car, Unit, and Train configuration • Dimensions and clearances • Weight requirements • Operating environment and interfaces • Performance and functional requirements at a Car, Unit and Train level </td> <td style="vertical-align: top; width: 50%;"> <ul style="list-style-type: none"> • Train level crashworthiness requirements • Noise and vibration limits • Derailment mitigation, stability and ride quality performance • Electromagnetic interference and compatibility requirements • Safety and reliability requirements • Overall design requirements </td> </tr> </table>	<ul style="list-style-type: none"> • General design requirements • Compatibility requirements • Car, Unit, and Train configuration • Dimensions and clearances • Weight requirements • Operating environment and interfaces • Performance and functional requirements at a Car, Unit and Train level 	<ul style="list-style-type: none"> • Train level crashworthiness requirements • Noise and vibration limits • Derailment mitigation, stability and ride quality performance • Electromagnetic interference and compatibility requirements • Safety and reliability requirements • Overall design requirements
<ul style="list-style-type: none"> • General design requirements • Compatibility requirements • Car, Unit, and Train configuration • Dimensions and clearances • Weight requirements • Operating environment and interfaces • Performance and functional requirements at a Car, Unit and Train level 	<ul style="list-style-type: none"> • Train level crashworthiness requirements • Noise and vibration limits • Derailment mitigation, stability and ride quality performance • Electromagnetic interference and compatibility requirements • Safety and reliability requirements • Overall design requirements 		
03	<ul style="list-style-type: none"> • Carshell structure • Flooring • End masks (bonnets) • Finishing requirements • Structural analysis and testing requirements 		
04	<ul style="list-style-type: none"> • Couplers • Link bars • Coupler adapters 		
05	<ul style="list-style-type: none"> • Cab controls and equipment 		
06	<ul style="list-style-type: none"> • Side doors and controls 		
07	<ul style="list-style-type: none"> • Heating, ventilation, and air conditioning equipment 		

Section	Requirements for:	
08	<ul style="list-style-type: none"> • Lighting, interior and exterior 	
09	<ul style="list-style-type: none"> • Third Rail Collector Shoe Assembly and primary power circuits • Distribution of auxiliary power • Grounding scheme • Auxiliary inverters 	<ul style="list-style-type: none"> • Low voltage power supply • Storage battery and battery box • Low voltage distribution network and load shedding
10	<ul style="list-style-type: none"> • Propulsion system, including inverters, traction motors, gear units • Propulsion and brake controls 	
11	<ul style="list-style-type: none"> • Trucks and suspension 	
12	<ul style="list-style-type: none"> • Friction brake hardware • Air system, including compressor, air dryer, reservoirs, and piping 	
13	<ul style="list-style-type: none"> • Public Address and intercom system • Passenger information displays • Side destination signs, interior information sign, and end route sign • Train radio • Communications hardware • CCTV system 	
14	<ul style="list-style-type: none"> • Train control system, including CBTC 	
15	<ul style="list-style-type: none"> • Floor covering • Insulation • Windows • Exterior equipment • Interior linings, moldings, ceiling panels • Floor heater grilles • Cab partition and door • Body end doors 	<ul style="list-style-type: none"> • Equipment enclosures and electric lockers • Seats • Stanchions, grab rails, and windscreens • Advertising card and system map frames • Passenger emergency intercom stations • Graphics and information signs
16	<ul style="list-style-type: none"> • Trainline and network architecture 	
17	<ul style="list-style-type: none"> • Monitoring and Diagnostic System • Event recorder 	
18	<ul style="list-style-type: none"> • Software system design and management requirements 	
19	<ul style="list-style-type: none"> • Materials, processes and workmanship standards 	
20	<ul style="list-style-type: none"> • Project management requirements • Design review 	
21	<ul style="list-style-type: none"> • Reliability, maintainability, and safety requirements 	
22	<ul style="list-style-type: none"> • Operations and Maintenance Manuals • Illustrated Parts Catalog • Contractor’s Specifications and Drawings (as-built) • Training program • Spare parts 	<ul style="list-style-type: none"> • Parts and device identification (bar coding) • Special tools and equipment • Portable test equipment • Bench test equipment • Software workstation
23	<ul style="list-style-type: none"> • Quality Assurance requirements 	
24	<ul style="list-style-type: none"> • Testing and validation requirements 	
25	<ul style="list-style-type: none"> • Specific requirements for cars for SIR (such as ATC/ Cab Signaling) 	
26	<ul style="list-style-type: none"> • Specific requirements for Open Gangway Test Train 	

Use of Alternative Standards

- 1.6.19. Where alternative standards to those specified are proposed by the Contractor, the Contractor shall submit documentation for NYCT review and approval, including a written narrative comparing the specified standard to the proposed equivalent, demonstrating how the proposed standards are the equivalent of the foregoing standards and specifications. See also Section 20.2.7.
- 1.6.20. At a minimum, equivalency comparisons shall address all of characteristic and properties pertinent to the material(s) being considered, as used in the proposed application, as defined in the various section of this Specification, plus data related to the application of the material(s) in a similar environment as NYCT.
- 1.6.21. Where appropriate, cost estimates may be requested by NYCT.
- 1.6.22. Proposed substitute specifications shall be submitted in both English and the language of the country of origin, per Section 1.5.4.6.

1.7. Definitions and Abbreviations

1.7.1. Definitions

The terms used in the Technical Specification shall be construed as follows, except where it is clear by the context that another meaning is intended:

A Car - The car located at each end of a Unit. This car contains an operating cab and an automatic mechanical and electrical coupler at the No. 1 End. Whenever an A Car is referenced within the Specification, it is implied to pertain to both A1 and A2 Car types unless specified otherwise.

A1 Car - An A Car equipped with CBTC equipment as defined in Section 14 – Train Control System, or ATC equipment as defined in Section 25 –Staten Island Railway Cars, and with one unpowered truck, which has one free, or unbraked axle.

A2 Car - An A Car equipped with CBTC equipment as defined in Section 14 – Train Control System, or ATC equipment as defined in Section 25 –Staten Island Railway Cars, with both trucks fully powered and braked.

Acceptance - Review and acceptance, in writing, by the NYCT. See Article 207 for acceptance of Units.

ADA - The Americans with Disabilities Act of 1990. As used in the Specification, references to ADA requirements or compliance means the requirements for accessibility of Rapid Rail Vehicles and Systems for people with Disabilities, as specified in the regulations of the U.S. Department of Transportation, published at 49 CFR Part 38, Subparts A and C, in effect as of the date of the award of this Contract.

Addenda or Addendum - Revisions to any of the Contract Documents issued in writing by the Authority subsequent to the issuance of Request For Proposals R34211 and prior to the Award Date.

Adhesion, Coefficient of - During rolling contact, the ratio between the longitudinal tangential force at the wheel-rail interface and normal force.

Agent - Any employee of, or contractor to the Authority, or any subsidiary or affiliate agency of the Authority or of the MTA designated as such by the Authority.

Alerter - The device and control circuitry that accomplishes Alertness Control when operating in CBTC ATO mode.

Alertness Control - A function of controls that continuously monitors the activities of a Train Operator and takes pre-defined actions to forestall and/or protect against inattention or incapacitation of that Train Operator. (See also “Alerter”, “Deadman control”).

Allowable Stress - The maximum stress permitted in a structure under specified design conditions. The allowable stress is less than the stress causing damage because of various factors, including: (a) uncertainty as to conditions of service, *e.g.*, loads and forces imposed during the lifetime of the structure, (b) non-uniformity of material, and (c) inaccuracy of stress analyses.

Alteration - A change or substitution in the form, character, or detail of the work done or to be done within the original scope of the Contract.

Ambiguity Group Size - The number of components listed in a diagnostic test call-out during fault isolation/detection.

Anti-climber - A structural reinforcement at each car end to discourage adjacent (mating) cars in an end-to-end collision from overriding each other.

Approval - Review and acceptance, in writing, by NYCT. NYCT approval in no way relieves the Contractor of meeting all requirements of the Specification.

Approved or Approved Type - Design, type of material, procedure, or method given approval by NYCT.

Authority or the initials "TA", or "NYCT" or "NYCTA" - the New York City Transit Authority, a public benefit corporation existing by virtue of Article 5, Title 9 of the Public Authorities Law of the State of New York and any successor public benefit corporation or governmental agency.

Automatic Stop Arm - A mechanical device located on the wayside that when activated by the signal system places the passing car in emergency braking.

Automatic Train Control and Cab Signaling (ATC) – The operating mode under signal control on the Staten Island Railway, where a target speed is displayed to the Train Operator and penalty braking applied if that speed is exceeded.

Automatic Train Operation (ATO) – A CBTC operating mode in which any or all of the functions of speed regulation, programmed station stopping, door control, performance level regulation, and other functions normally assigned to the Train Operator are performed automatically.

Automatic Train Protection (ATP) - The vital component of an automatic train control system responsible for providing protection against collisions, derailments, excessive speed, and other hazardous conditions through a combination of train detection, train separation, and route interlocking.

Automatic Train Protection Manual (ATPM) Mode - The mode of mainline operation when the train operator controls the train within ATP limits prescribed by the CBTC system.

Auxiliary System - Any mechanism or structure, other than the car body and propulsion system which functions during car operation, *e.g.*, door operators, lighting, HVAC, communications, etc.

Auxiliary Wayside Protection (AWP) - Mode of operation for onboard train CBTC equipment used when the train is operating under AWS due to a communications or wayside failure. It is selected by the train operator by means of the Mode switch, located on the console.

Auxiliary Wayside System (AWS) - Traditional signal system for controlling interlockings and maintaining safe operation for non-CBTC trains.

AW0 - The assigned weight of an empty car, ready for revenue service, with neither crew nor passengers aboard.

AW1 - The assigned weight of a car ready for revenue service, with a full crew and all passenger seats occupied, with an average weight per passenger or crew member of 175 lb. (79.5 kg).

AW2 - The assigned weight of a car ready for revenue service with a full crew, all passenger seats occupied, and all available standee areas (defined as floor area available for standing, less a feet/knee allowance of 9 inches directly in front of each seat) occupied by passengers at 3 sq. ft (0.28 m²) per passenger, with an average weight per passenger or crew member of 175 lb. (79.5 kg).

AW3 - The assigned weight of a car ready for revenue service with a full crew, all passenger seats occupied, and all available standee areas occupied by passengers at 2 sq. ft (0.186 m²) per passenger, with an average weight per passenger or crew member of 175 lb. (79.5 kg).

Award Date - The date the Notice of Award is issued.

B Car - A Non-Cab Car located between A Cars.

Baseline Design - The design of the car or any of its components, apparatus, systems, subsystems, or materials which has received both drawing approval and first article approval by NYCT.

Bench Test Equipment (BTE) - A self-contained diagnostic test station utilized to test and diagnose the proper operation and/or failure modes of all systems, subsystems, LRUs and components.

Blending - In braking, a simultaneous dynamic and friction brake application, with the effort of each continuously proportioned to achieve the required total braking effort.

Braking, Dynamic - See "Braking, Electrical".

Braking, Electrical - Braking in which power generated by traction motors, when driven as generators, is either dissipated as heat by brake resistor grids or returned to the third rail as regenerative electrical energy.

Note: Although now generally considered synonymous with dynamic brake, electric brake is a more global term, as originally dynamic brake energy was only dissipated as heat.

Braking, Emergency - Braking that results in an irrevocable open-loop friction braking effort to a stop, at the maximum design brake rate.

Braking, Full Service - A non-emergency brake application which obtains the maximum brake rate consistent with the design of the primary brake system.

Buff Load - A horizontal compressive load applied to the car, usually along the car centerline at the couplers or anti-climbers.

Cab Car - See "A Car".

Calculations - Numerical computations performed to demonstrate compliance with the Specifications.

Car - A complete assembly of an A or B type R211 passenger car.

Carbuilder - See "Contractor".

Carline - Framing members that extend across the top of a car from one side to the other and support the roof and other loads.

CBTC - See "Communications-Based Train Control"

CBTC Bypass Mode - In this mode of operation, the CBTC equipment and the propulsion system speed limiter are bypassed to permit manual operation of the train up to full speed under AWS signal protection.

Change Order or Modification - An order executed by NYCT and issued to the Contractor amending the Contract Documents. The Change Order establishes the basis for payment and program adjustments, if any, of the Work affected by the changes. The Change Order becomes a part of the Contract when executed by the Contractor and NYCT.

Circuit, Vital - Any circuit that affects the safety of train operations.

City - The City of New York, according to its boundaries at the date of this Contract.

Coast - The mode of operation of a car or train in which propulsion (positive traction) and braking (negative traction) are inactive and the apparent braking effort results from the train's rolling resistance and aerodynamic drag.

Comment - Written critiques of the Contractor's submittals to NYCT.

Commercial Off-The-Shelf (COTS) - COTS items are generally sold in the commercial marketplace and usually refer to hardware or software products tailored for specific uses and available for general public or widespread industry use. A COTS product is designed to be readily available in the commercial marketplace and user friendly, not requiring customized processes and development before installation and application. For the purposes of this Contract, COTS products may also include those items defined per existing NYCT specifications available from multiple, qualified suppliers that have previously met all NYCT requirements for the supply of such an item.

COTS products used by the Contractor to produce the R211 Cars shall not require software or hardware changes to its mating component within a Line Replaceable Unit (LRU) or Lowest Level Replaceable Unit (LLRU) prior to usage by NYCT. Examples of COTS products include standard PC board and power supply configurations, air conditioning filters, fuses, low power electronic components (i.e. capacitors), and small motors.

Commercial Test - A test wherein the equipment is tested to determine that it has been manufactured in accordance with the Specification and within tolerances permitted; plus, that all normal safety and quality assurance procedures have been met. This test is done on every piece of equipment.

Communications-Based Train Control (CBTC) - An automatic train control system, comprised of wayside and on-board vital processors and a high capacity, bi-directional, radio-based train-to-wayside communications network, capable of providing Automatic Train Protection and Automatic Train Operation functions.

Component - Parts, devices, and structure(s) performing a distinctive function necessary to the operation of a subsystem or system.

Concept Drawings or Plans - An initial set of drawings showing the general car layout and arrangement provided by NYCT with the Specification in the contract Appendices.

Consumable Items - Those parts, components and materials of a particular system which, pursuant to the manufacturer's maintenance manual, are required to properly maintain such system for a one-year (or less) period based upon the Authority's expected usage of 60,000 miles per year per Car.

Contact Rail - A third rail located outside the running rails which supplies the external source of 600 VDC electrical power.

Contract, Contract Documents or Agreement - The ATTACHMENTS, CONTRACT TERMS AND CONDITIONS, CONTRACT TESTIMONIUM, TECHNICAL SPECIFICATION, TECHNICAL PROPOSAL, CONTRACT DRAWINGS (if any), all ADDENDA, if any, hereafter issued, the Notice of Award, and Change Orders, if any, executed by the Authority and the Contractor subsequent to award of the Contract. The Contract and Contract Documents are also deemed to include by reference those portions of the Schedule J, Responsibility Questionnaire, which contain additional conditions and obligations on the Contractor and rights in favor of the Authority.

Contractor or Carbuilder - That person or persons, firm, partnership, corporation, or combination thereof to whom this Contract is awarded, its successors and assignees. For convenience, the Contractor may hereinafter be referred to as if the Contractor were an individual. The word "he" shall, as the sense may require include "she", "it" and "they"; the word "him" shall include "her", "it" and "them"; and the word "his" shall include "her", "its" and "their".

Contract Amendment - See "Change Order".

Contract Data Requirements List (CDRL) - Item to be delivered by the Contractor to NYCT as defined in this Technical Specification.

Contract Drawings - Drawings provided by NYCT as part of the Contract Documents.

Contractor's Drawings - Items such as general arrangement drawings, detail drawings, graphs, diagrams, and sketches which are prepared by the Contractor to detail its work.

Converter - A general term for a solid state device that converts electrical energy from one form to another, such as 600 Vdc to provide an output such as 37.5 Vdc for use as a power source.

Crash Energy Management – Approach to mitigation of damage and injuries resulting from collisions whereby the train is treated as a whole entity and controlled deformation and/or energy absorption is used.

C/R - See "Train Conductor."

Critical Area - The region of a structure requiring higher than normal quality of material and manufacture because stresses are at or near the limits of allowable stresses specified by the Modified Goodman Diagram.

Critical System - Shall mean each of the following: Propulsion, Auxiliary Power, CBTC, Doors (side doors), Friction Brakes, HVAC, Trainline Control, and Trucks. For SIR this shall include the ATC/Cab Signaling system.

Cross Level - Relative transverse elevation of the two running rails on level or superelevated track.

Current Collector - A carborne device to conduct electrical power from the contact rail to the car.

Days - Unless otherwise designated, days as used in the Contract Documents means calendar days.

Days, Business - Those calendar days during which regular business is conducted, excluding Saturdays and Sundays and all NYCT-observed Federal, State, and municipal holidays.

Deadman Control - A mechanically initiated device to detect inattention or disability of the Train Operator.

Deliverable - All materials and equipment furnished by the Contractor to

NYCT under the terms of this Contract including but not limited to drawings, documents, samples, data, special tools or test equipment.

Design Review (Preliminary, In-Process, Critical) - process by which the Contractor presents designs for NYCT review and approval. The three main stages are Preliminary (review of design concepts), In-Process (review of designs as they progress), and Critical (review of final designs).

Diagnostic Test Equipment (DTE) - Any test equipment, whether portable or not.

Dispatching - The process of starting a train into revenue service from a terminal zone or transfer switch.

Display - An electronic device that visually presents textual and/or graphical information to a human operator in a computer-generated format; may also include provision for operator input.

DOT - See "United States Department of Transportation."

Drive - A system consisting of one or several motors, their direct control equipment (power circuits) and the associated mechanical devices required to produce a useful output.

Duty Cycle - The period or percentage of time associated with the activated state of operation, occurring during normal cyclic operations, in relation to the elapsed time of a full cycle.

Dwell Time - The total time from the instant that a train stops in a station until the instant it resumes moving.

Dynamic Outline - The largest dimensional cross sectional area generated by a moving train under worst-case conditions.

Endurance Limit - The maximum stress in a material that can be completely reversed an infinite number of times without causing fracture.

Engineer - See "Project Manager."

Engineering Test - A test wherein the equipment is operated to simulate actual operation either by itself or in a subsystem to determine that all functions specified are met and are within the tolerances permitted. The testing shall provide engineering information of all of the operating parameters of the equipment.

Equal or Approved Equal - In connection with make or quality of material or equipment in these Contract Documents, NYCT's decision that any material or equipment proposed by the Contractor is equal to that specified.

Ethernet - A system for connecting a number of on-board computer systems to form a local area network, with protocols to control the passing of information and to avoid simultaneous transmission by two or more systems.

Excusable Delay - A delay which satisfies the criteria set forth in Terms and Conditions Article 205, Extension of Time.

Factor of Safety - The ratio of the applied design load to the load necessary to meet the allowed material strength.

Fail-Safe - A characteristic of a system, component, or device which ensures that any malfunction affecting safety will cause the system to revert to a state that is known to be safe.

Failure Analysis Report – Report detailing the root causes and corrective actions associated with a failed component, system or condition.

Failure - An improper condition which requires unscheduled equipment maintenance or replacement to restore affected equipment to its normal operating condition.

Failure Rate - The frequency of failure, expressed as failures per hour or failures per mile. Failure rate is the mathematical reciprocal of MTBF or MDBF.

Fatigue - Failure of a structure by progressive fracture under large number of repetitions of stress considerably less than the yield stress.

Federal Government - The government of United States of America.

Field Jumper - see "Jumper."

Field Modification - Any change, alteration, adjustment, or modification to the equipment or any part not done at the original manufacturer's plant.

First Article - The first one of any production component of the car that is produced. The Specification provides that nothing be manufactured prior to approval, so the First Article shall have been made to approved drawings.

First Article Approval - The examination of and approval by NYCT of an initial production part, major assembly, subassembly, system, subsystem, apparatus, or material, manufactured or assembled by either the Contractor or subcontractors.

First Article Inspection (FAI) - An extraordinary inspection of a First Article which accomplishes two purposes:

- 1) First, it permits NYCT to see, in three dimensions, what could be seen only on two-dimensional drawings up to that point. If the First Article Inspection is of a component that the Contractor is purchasing, rather than making itself, the First Article Inspection discloses details that were not visible beforehand. The First Article Inspection is usually the first point at which maintainability of

the component can be evaluated, in as much as it is the first point at which relationships between elements can be appreciated. NYCT may approve the design that is revealed at the First Article Inspection, or may require changes in order that the component can meet the requirements of the Contract.

- 2) Second, it is used to establish the quality level of workmanship that will be maintained for the balance of the components. The level is established jointly by NYCT and the Inspector.

FRA - Federal Railroad Administration of the United States Department of Transportation.

Free Axle - An axle of the non-motorized truck that is not fitted with friction brake equipment, resulting in freewheeling of this axle at all times during train movement.

Freewheeling - The mode of operation of a car in which both propulsion and braking are inactive, that is, tractive effort is zero. See also "Coast."

Frog - Track structure at the intersection of two running rails to support wheels and provide passageways for their flanges as wheels on either rail pass through the intersection.

FTA - Federal Transit Administration of the United States Department of Transportation.

Furnishing - Furnishing, manufacturing, fabricating, and completely assembling all materials, plant, power, tools, pattern, supplies, appliances, cars and conveyances necessary or required for the completion of the Work.

Gauge, Track - Distance between the inside face of rails measured 0.625 inch (15.9 mm) below the top of the running rails at right angles thereto.

Guaranteed Emergency Brake Rate - Deceleration rate that can be guaranteed to occur under all reasonable failure and operation conditions, used for signal system design purposes.

Guard Rail - A rail or other structure laid parallel with the running rails to contain and control car movement following derailment by holding the wheels in correct alignment to prevent their flanges from striking either crossing frogs or the point of switches.

Headway - The time separation between two trains, both traveling in the same direction on the same track. It is measured from the time the head-end of the leading train passes a given reference point to the time the head-end of the train immediately following passes the same reference point.

Independent Failure - A failure which is not the result of another failure, either directly or indirectly.

Indicated - As used in these Contract Documents, "Indicated" shall be understood to mean, "as shown on the Concept Drawings", or "as described in the Contract Documents".

Inspector - Any representative of the Project Manager designated to act as an inspector for NYCT for the purposes of quality assurance.

Interchangeable - Two modules or components that, although possibly of different design, perform identical functions and have identical interface characteristics.

Interface - The points where two or more systems, subsystems or structures meet, transfer energy, or transfer information.

Inverter - A solid state device that converts direct current to alternating current.

Irretrievable - Condition where a brake application cannot be released until the train has come to a complete stop.

Jerk Rate - Time rate of change of acceleration and deceleration, equal to the second time derivative of velocity.

Jumper - A short piece of wire or cable with appropriate terminations on each end to permit connection to terminals within a terminal board or to an adjacent terminal strip.

Line Breaker - A contactor that can interrupt all normal currents to isolate power circuits from the 600Vdc. May also be called a Line Switch.

Line Replaceable Unit – see “Lowest Replaceable Unit.”

Line Switch - see “Line Breaker.”

Load Factor - Load factor is defined as a number by which the actual or specified load is multiplied in computing the calculated stress.

Load Weighing - A function incorporated in the traction system which measures changes of gross car weight. Its purpose is to permit control of tractive effort or braking effort in order to achieve a constant effort-to-weight ratio.

Lowest Replaceable Unit (LRU) - A unit/component or subsystem which is normally replaced at the Service and Inspection Facility (S&I). (Interchangeably called Line Replaceable Unit).

Low Voltage Distribution Network (LVDN) - A general reference to the wiring and protective devices that are involved in the distribution of low voltage power.

Low Voltage Power Supply (LVPS) - The solid-state power supply that converts a high voltage input to a 37.5 VDC output.

Lowest Level Replaceable Unit (LLRU) - The lowest level component or part which can be replaced, but cannot be repaired. An exception may be made for printed circuit boards which may be repairable with special equipment.

Main Knife Switch - A manual disconnect switch to disconnect the car from primary power.

Maintainability - A characteristic of design and installation, expressed as the probability that an item shall be restored to a specified condition within a given period of time when maintenance is performed in accordance with prescribed procedures and resources.

Maintenance, Corrective - Repair or replacement of components as a result of failure.

Maintenance, Scheduled - Inspection and repair or replacement of components at intervals measured by time or usage.

Major Supplier - A supplier of a System or of a Subsystem of a System. Refer to NYCT document MCD-11-01, “Suppliers of Major Subsystems for Passenger Subway Classes;”.

Manual Operation - An operating mode in which the train responds to the actions of its operator through manual control of the operator's master controller.

Manufacturer or Original Equipment Manufacturer (OEM) - The original builder or producer supplying materials, equipment, or apparatus for installation on the car.

Margin of Safety (MS) - Margin of Safety is defined as the Allowable Stress divided by the Calculated Stress, minus one (1). The calculated stress shall include the applicable load factors. MS shall be a positive number.

Maximum Wear - Condition in which a piece of equipment can be retained in service but beyond which it must be removed from service.

Mean Distance Between Failures (MDBF) - The mean distance (in miles) between "train delays" attributed to car equipment. (Reference Section 21.1.2)

Mean Distance Between Service Failures (MDBSF) - The mean distance (in miles) between “relevant service failures” which cause a train to be removed from service attributed to car equipment. (Reference Section 21.1.2)

Mean Distance Between System Component Failures (MDBSCF) - The MDBSCF of a system is the ratio of the total operating distance accumulated by the total population of cars in the class to the total number of relevant failures occurring for that population of components within each specified system of the cars in the class, during the time period, 't'. (Reference Section 21.1.2)

Mean Time Between Failures (MTBF) - The mean time (in hours) between component failures.

Mean Time To Repair (MTTR) - The arithmetic mean of all active repair time.

MDBF Measurement Period - a period of 12 continuous months calculated throughout the time period beginning on the first of the month after 4 million car-miles have been accrued, or 12 months of revenue service, whichever occurs later, and ending with the last full month during which at least four Units remain under warranty.

Mock-up - A full-scale model used to demonstrate Specification compliance.

Monitoring and Diagnostic System (MDS) - A system that collects, processes and displays operating and fault data for the car, Unit and train.

MTA - shall mean the Metropolitan Transportation Authority, and any other board, body, commission, official or officials to which or to whom the powers now belonging to the said authority in respect to the location, construction, equipment, maintenance and operation of transit facilities or the purchase of rapid transit cars under the provisions of Article 5, Title 11 of the Public Authorities Law of the State of New York shall, by virtue of any act or acts, hereafter passed or be held to appertain.

New York City Transit System (NYCTS) - or the letters "NYCTS" shall mean the rapid transit and surface transit facilities of the Authority including all rolling stock, appurtenances and equipment.

No. 1 End - In the case of the A Car, the end of the car where the cab is located. For B cars, the No. 1 end of the car shall be defined by the Contractor based on a unique design feature.

No. 2 End - The end of the car opposite to the No. 1 end.

No-Motion - A referenced state of Unit velocity of 1 mi/h (1.6 km/h) or less, unless otherwise specified.

Noise Level - As defined by the latest version of ANSI S1.4: The weighted sound pressure level measured by the use of a metering characteristic and weighting A, B, or C as specified in ANSI A1.4. The unit of noise level is the decibel (dB), and the reference pressure is 20 micropascals.

Non-Free Axle - An axle on the non-motorized truck that is outfitted with friction brake equipment.

Notice of Acceptance - Notice given by the Authority pursuant to Article 207 to the Contractor that the Unit or an individual Car, if applicable, has passed all required tests and is being accepted by the Authority.

Notice of Arrival - Notice given by the Authority that a shipment of Cars has been delivered to the designated point.

Notice of Award - A document that apprises the Contractor that this Contract has been awarded by NYCT to the Contractor and is in full force and effect.

Notice to Proceed - The date upon which the Work under this Contract shall commence as specified in the Notice of Award.

NYCT - See "Authority."

Open Architecture - A type of hardware or software architecture that is designed to make adding, upgrading and swapping components easy, without the use of proprietary information. Designs and interfaces are available in the public domain without restriction on use.

Open Gangway - An open gangway is an enclosed flexible walkway, semi-permanently connected to the ends of adjacent cars, to allow passengers to freely move between cars through openings in the ends of the cars, or to stand in the open gangway area, while protecting the passengers from the external environment.

Operating Unit or Unit – Four, Five or Six semi-permanently coupled cars in the configuration of A-Bx-A cars respectively (one A Car in each unit shall be an A1 Car and the other an A2 Car) (see Section 2.2.1.2).

Party, Parties - Entity(ies) entering into the Contract.

Permanent Deformation - A member shall be considered as having developed permanent deformation if one of the following conditions is met:

- a) The minimum yield strength as published by ASTM for the specified material and grade is exceeded.
- b) For materials or grades not covered by an ASTM specification, the minimum yield strength as guaranteed by a recognized industrial standard or by the manufacturer is exceeded.
- c) The material has buckled or deformed and will not return to its original shape or position after the load is released.
- d) For materials without a specific yield point, the 0.2 percent offset method shall be used to determine yield strength using data derived in accordance with ASTM E8.

Plans - See "Concept Drawings".

Plug and Play - A device with a specification that facilitates the discovery of a hardware component in a system without the need for physical device configuration or user intervention in resolving resource conflicts. In this application it means a system element or component that can be directly replaced with another from a different supplier or of a different internal hardware or software design, without the need to make any hardware or software modifications to the car or system to which it is installed. If a physical adapter is needed for full interchangeability, this shall become part of the new component. An example is a visual display panel, or a CCTV camera. See also "Open Architecture."

Portable Test Equipment (PTE) - Laptop PCs or approved equal devices and any required associated software and interconnecting cables, and any other portable testers, for testing all Systems and Subsystems,.

Profile Grade - A straight line along the centerline of track representing an established slope to the horizontal, usually expressed in percent, i.e., rise over run.

Project Manager or Engineer - Person designated by NYCT to be its liaison with the Contractor on all matters pertaining to the work. The Project Manager is empowered to act on behalf of the Authority in such matters as approval of Contractor's Drawings, test procedures, First Article approvals, and Car or Unit Acceptance, payments to Contractor and contractual issues.

Proof (used as a suffix) - Apparatus is designated as splashproof, dustproof, etc., when so constructed, protected, or treated that its successful operation is not interfered with when subjected to the specified material or condition.

Prototype Car - The first production car of each type to be delivered and accepted by NYCT.

Prototype Train - The first production Train of each type to be delivered and accepted by NYCT.

Purline or Purlin - A longitudinal roof frame member extending over the carlines, extending from one end of the car to the other, to which the roof sheets are fastened.

Qualification Test - A test performed on a production item to show that it is capable of achieving all of the performance requirements over the specified operating range and therefore, is expected to perform in accordance with the Contract requirements.

Rail Gap Detector - An electrical device able to sense the absence of third rail voltage.

Railroad - See "New York City Transit System."

Redundancy - The existence of more than one means of accomplishing a given function.

Regenerative Braking - Process of returning the braking energy of the Unit to the third rail power system through the conversion of kinetic energy to electrical energy.

Relevant Failure - An independent failure that results in a temporary or permanent loss of function of that item caused by either of the following:

- a) A fault in a component while operating within its design and environmental specification limits.
- b) Improper operation, maintenance or testing of a component as a result of Contractor-supplied documentation

Reliability - The probability of performing a specified function without failure and within design parameters for the period of time specified under actual operating conditions.

Request For Proposal - NYCT document RFP 34211 which requests Contractor proposals for the supply of the R211 cars.

Restricted Manual - In this mode of operation, the train will operate under wayside signal protection with the train speed limited by the propulsion system. Selection of Restricted Manual Mode by the Train Operator will be governed by operating procedures. This is the mode of operation following loss of CBTC train location detection, due to a failure of the carborne CBTC equipment.

Safe - The condition in which passengers, crew, or maintenance, and repair workers are secure from threat or danger, harm, or loss arising from improper design, manufacture, assembly, malfunction, or failure of the car or any of its components or systems.

Scheduled Maintenance System (SMS) - The heavy maintenance and overhaul program used by NYCT, currently with a 7-year interval for most systems (4 years for brake system).

Screen - A pre-defined set of information presented on a display, typically optimized in content and format for a particular task or situation.

Service, as in Service Use, Service Braking - The operation of the Units under normal conditions with passengers.

Service Failure - a failure which causes a train to be removed from service, including preventing a scheduled entry into service.

Shell - That part of a car body composed of roof, sides, end and underframe structure, floor and sheathing but devoid of any interior finish, windows, doors and exterior accessories.

Shop Drawings - Drawings or sketches prepared by the Contractor for use in its manufacturing facility, assembly facility, or shop, to fabricate, assemble, and/or install parts of the car, whether manufactured by it from raw materials or purchased from others in a ready-to-use condition.

Side, Left - The side of the car to the left of a person facing the No. 1 End of the car from inside the car.

Side, Right - The side of the car to the right of a person facing the No. 1 End of the car from inside the car.

Slide, Wheel - During braking, the condition existing when the rotational speed of the wheel is less than that for pure rolling contact between tread and rail.

Slip, Wheel - During acceleration, the condition existing when the rotational speed of the wheel is greater than that for pure rolling contact between tread and rail. Also termed Wheel Spin.

Software Supplier - An R211 car equipment supplier whose product incorporates software and whose product is not a commercial-off-the-shelf (COTS) product.

Speed, Balancing - The steady-state speed attained by a train when resisting forces exactly equal the maximum available tractive forces on level tangent track.

Speed, Base - The maximum speed at which the traction motors produce full tractive effort in motoring.

Speed, Schedule - The average speed of a train from terminal to terminal obtained by dividing the distance between these points by the time taken to make the trip, including time for intermediate station stops.

Spin, Wheel – see “Slip, Wheel.”

State (where identifying an entity) - The State of New York.

Step Signal - A signal having a constant value prior to the step and a different constant value immediately thereafter.

Stop, Emergency - The stopping of a train by an emergency brake application.

Stop, Service - The stopping of a train by application of service braking. Brake application can be released and reapplied.

Subcontractor - A person, firm, contractor, corporation or combination thereof who enters into a contract to furnish labor or services only or labor and materials or apparatus in connection with the Work directly or indirectly for or on behalf of the Contractor and whether or not in privity of Contract with the Contractor.

Subsystem - A combination of components, parts and/or subsystems, whether or not mechanical in nature, which, when performing together or taken as a whole constitutes or provides the discrete function of a system of a car. For purposes of this definition, a component, part or other subsystem comprising a given subsystem may also comprise a different subsystem.

Superelevation - The amount by which the outer rail within a curve is higher than the inner rail. Usually measured in inches.

Supplier - A person, firm, contractor, corporation or combination thereof who furnishes materials, equipment or supplies for the Work to the Contractor either directly or indirectly and whether or not in privity of Contract with the Contractor.

System - A combination of subsystems, components and/or parts whether or not mechanical in nature, which, when performing together or taken as a whole constitutes or provides a discrete operation, function or subdivision of a Car. For purposes of this definition, a subsystem, component, or part comprising a given system may also comprise a different system.

Tamperproof - Fasteners are designated as tamperproof when they are selected so that they cannot be easily loosened with common tools such as a flat blade screwdriver, Phillips screwdriver, or pliers. Covers may also be designated as “tamperproof” if access to internal components, such as solid state devices, is restricted to authorized personnel

Technical Proposal - All technical documents submitted by the Contractor as required by this Request for Proposal.

Technical Specifications, Specifications or specifications - That portion of the Contract Documents that describes the scope of the work to be performed and details the technical requirements for the supply of

rail Cars and associated equipment, including any changes or Addenda made subsequent to the award of the Contract.

The Principle of Least Privilege - Each system and system component must access only the information and resources that are necessary for its legitimate purpose.

Tight (used as a suffix) - Apparatus is designated as water-tight, dust-tight, etc., when so constructed that the enclosing case will exclude the specified material.

Time Constant - Time interval from the beginning of change of a controlled variable in response to a step-forcing function to the attainment of a stated value.

Time, Build-up - Time interval from the beginning of change of a controlled variable (defined as being at 10 percent of the new steady state value) in response to a step-forcing function to the attainment of 90 percent of the new steady state value of the controlled variable.

Time, Dead (see "Time, Response") - Time from the occurrence of a step change of the control signal to the beginning of a change of the controlled variable defined as being to the attainment of 10 percent of the new steady-state value of the controlled variable.

Time, Down - The elapsed time during which equipment is not capable of doing useful work because of maladjustment, malfunction, or maintenance in progress.

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 destabilized.

Time, Response - Time interval from the occurrence of a step change of control signal to the attainment of 90 percent of the new steady-state value of the controlled variable, equal to the sum of dead time and build-up time.

Time, Warmup - The elapsed time from application of power to an operable device until it is capable of performing all of its intended functions.

T/O - See "Train Operator."

Track Tests - Tests of Units or any subsystem which is run on NYCT's track or a track simulating, as much as practicable, the actual track conditions found on NYCT's system to verify performance parameters of the Specification.

Traction System - The system of wheels, motors, driving mechanisms, brakes, direct controls and appurtenances that propels or retards a Unit in response to control signals.

Tractive Effort - Accelerating and braking forces.

Train - A configuration of one or two Operating Unit(s) to be used in revenue service.

Train Conductor - The individual who normally occupies a cab in the middle of the train and is responsible for performing functions necessary for controlling and monitoring side doors.

Train Delay - An incident causing a revenue train to be: a) More than 5 minutes late at its destination terminal; b) Canceled (either at its original terminal or en-route); or c) Rerouted.

Train Operator - The individual who normally occupies the head end cab of a train and is responsible for performing functions necessary for train movement and monitoring.

Train Operator Display (TOD) - Touch-screen display(s) in the Train Operator's console.

Trainline - A wire, air pipe, or bus, for transmitting signals and data to all cars in a train, via a continuous circuit connected through appropriate coupling devices.

Tram - A condition of ideal truck geometry in which the axles are perfectly parallel and the wheels longitudinally in perfect alignment. The centers of the journal bearings represent the corners of a perfect

rectangle. Tram is checked by measuring the diagonal and longitudinal distances between reference points on the axle bearing housing.

Trip Cock - A mechanical device located on the train which when activated results in an emergency brake application.

Truck, No. 1 - The truck located nearest to the No. 1 End of a car.

Truck, No. 2 - The truck located farthest from the No. 1 End of a car.

United States Government - See "Federal Government."

U.S. Department of Transportation - a federal Cabinet department of the United States government governed by the United States Secretary of Transportation with the mission to serve the United States by ensuring a fast, safe, efficient, accessible, and convenient transportation system.

Ultimate Load Carrying Capacity - The ultimate load carrying capacity of a member is the maximum load at which point the member can no longer support additional loading before a constituent member separation (rupture) begins or completely fails as a column under the design condition being considered.

Ultimate Strength - The maximum load carrying capability of a structure, for a load applied at a specified location and direction.

Unit – A group of semi-permanently coupled cars, with an A car at each end. (Reference Section 2.2)

Unitlines - Network and discrete connections between CBTC equipment location in A cars, at each end of a consist; they do not pass through the coupler between units.

Vehicle - See "Car".

Vital Circuit - Any circuit and its elements, the function of which affects the safety of train operations.

Warp, Track - The vertical distance between the plane of any three of four rail head contact points (two on each rail) forming a plane and the remaining point.

Weight, Actual - The measured weight of a finished AW0 car, with all fluid levels topped off, ready for revenue service.

Wheel Loads-Maximum - That loading representing total car weight transferred to the running rails from each wheel at AW3.

Work or Project - All required obligations of the Contractor hereunder, including but not limited to, Car and Unit design and manufacture, delivery, including loading and unloading, testing, submission of deliverables, performance of warranty obligations, furnishing of all equipment, items, materials, parts, systems, data, design, services, and other matters and things necessary or the required labor and management to be done by the Contractor pursuant to this Contract, including all miscellaneous and incidental work.

Yield Stress - The stress at which a material exhibits a specified deformation, as specified by the ASTM or equivalent body.

1.7.2. Abbreviations

The following is a list of abbreviations used in the Specification. The list is not intended to be all inclusive:

°C	Degrees Centigrade
°F	Degrees Fahrenheit
°FDB	Degrees Fahrenheit Dry Bulb
°FWB	Degrees Fahrenheit Wet Bulb
AAR	Association of American Railroads

AATCC	American Association of Textile Chemists and Colorists
AC	Alternating Current
ADA	Americans with Disabilities Act of 1990
AFBMA	Anti-Friction Bearing Manufacturer's Association
AFI	Air Filter Institute
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AMCA	Air Movement and Control Association
Amp	Amperes
ANSI	American National Standards Institute
API	American Petroleum Institute
APS	Auxiliary Power Supply
APTA	American Public Transit Association
AREA	American Railway Engineering Association (merged into AREMA)
AREMA	American Railway Engineering and Maintenance of Way Association
ARI	Air Conditioning and Refrigeration Institute
ASC	Air Spring Cutout
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASIC	Application Specific Integrated Circuit
ASM	American Society for Metals
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association of America
ATE	Automatic Test Equipment
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATPM	Automatic Train Protection Manual
ATS	Automated Timekeeping System
AVI	Automatic Vehicle Identification
AWG	American Wire Gauge
AWS	American Welding Society, also Auxiliary Wayside System (CBTC signaling system)
BHP	Brake Horsepower
BTE	Bench Test Equipment

Btu	British thermal unit
C	Capacitance
C/R	Conductor (Train)
CABTE	Consolidated Automated Bench Test Equipment
CAD	Computer Aided Design
CBTC	Communications-Based Train Control
CBTE	Consolidated Bench Test Equipment
CCTV	Closed Circuit Television
CDA	Copper Development Association
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CEM	Crash Energy Management
CFC	Chlorofluorocarbon
CFM or cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
CGHAZ	Coarse Grain Heat Affected Zone
CIIS	Ceiling Interior Information Sign
CMMI	Capability Maturity Model Integration (for Software Engineering)
COTS	Commercial Off-The-Shelf
CPM	Critical Path Method
CRF	Critical Radiant Flux
CRI	Color Rendering Index
dB	Decibel
DB	Dry Bulb
dBA	Decibel, A Scale Reading
DC	Direct Current
DOT	United States Department of Transportation
D _s	Specific Optical Density
E	Modulus of Elasticity
ECR	Engineering Change Request
ECU	Electronic Control Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
EER	Energy Efficiency Ratio
EIA	Electronic Industries Association
EMC	Electromagnetic Compatibility

EMI	Electromagnetic Interference
EPA	U.S. Environmental Protection Agency
ES	AC Train EMC Standards Document
ETFE	Ethylenetetrafluoroethylene
ETP	Electrolytic Tough Pitch
FAA	Federal Aviation Administration
FAI	First Article Inspection
FAR	Failure Analysis Report
FCC	Federal Communications Commission
FE	Finite Element
FEA	Finite Element Analysis
FET	Field-Effect Transistor
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode and Effects Criticality Analysis
FMVSS	Federal Motor Vehicle Safety Standards
FPM or fpm	Feet Per Minute
FRA	Federal Railroad Administration
FRACAS	Failure Reporting and Corrective Action System
FRP	Fiberglass Reinforced Plastic
FTA	Federal Transit Administration
ft-lbs	Foot-Pounds
FVFF	Fixed Voltage Fixed Frequency
GEBR	Guaranteed Emergency Brake Rate
GP	General Purpose
HAZ	Heat Affected Zone
HP	Horsepower
HSCB	High Speed Circuit Breaker
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz
I/O	Input/ Output
IACS	International Annealed Copper Standard
IC	Integrated Circuit
ICC	Interstate Commerce Commission
ICEA	Insulated Cable Engineers Association
IEC	International Electro-technical Committee

IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IGBT	Insulated Gate Bi-Polar Transistor
IPC	Institute of Printed Circuits
IPDR	In-Process Design Review
IPS	Iron Pipe Size
I _s	Flame Spread Index
ISO	International Standards Organization
J	Joules
JEDEC	Joint Electronic Device Engineering Council
JIC	Joint Industrial Council
kHz	Kilohertz
km	Kilometer
km/h	Kilometers per hour
kN	kilo Newton
kPa	Kilopascal
LAHT	Low Alloy High Tensile Strength (Steel)
LAN	Local Area Network
lbf	Pounds force
lb	Pounds
LED	Light Emitting Diode
LLRU	Lowest Level Replaceable Unit
LRU	Lowest Replaceable Unit
LVDB	Low Voltage Distribution Bus
LVDN	Low Voltage Distribution Network
LVPS	Low Voltage DC Power Supply
m	Meters
MA	Motor Alternator
MC	Master Controller
MDBF	Mean Distance Between (Delay) Failures
MDBSCF	Mean Distance Between System Component Failures
MDBSF	Mean Distance Between Service Failures
MDC	Master Door Controller
MDS	Monitoring and Diagnostic System
MHz	Megahertz

MIL	Military Specification
MKS	Master Key Switch
mm	Millimeter
mphps	Miles per hour per second
mphpsps	Miles per hour per second per second
ms	Millisecond
MSDS	Material Safety Data Sheet
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MU	Multiple-Unit
N	Newton
NBS	National Bureau of Standards
NCA	Noise Criterion, Alternate
NEC	National Electrical Code
NEMA	National Electrical Manufacturers' Association
NFL	No Field Lubrication
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NTP	Notice to Proceed
NYCT	New York City Transit
NYCTA	New York City Transit Authority
OD	Outside Diameter
OFE	Oxygen Free Electronic
OH	Overhead
OMP	Obsolescence Management Plan
PA	Public Address
Pas	Pascals
PC	Personal Computer
PCB	Printed Circuit Board
PCU	Pneumatic Control Unit
PDR	Preliminary Design Review
PEHU	Passenger Emergency Handle Unit
PIV	Peak Inverse Voltage
pphm	Parts per hundred million
ppm	Parts per million

PS	Pressure Switch
PSD	Platform Screen Doors
psi	Pounds per square inch
psia	Pounds per square inch, absolute
psig	Pounds per square inch, gauge
PTE	Portable Test Equipment
PTFE	Polytetrafluoroethylene
PWM	Pulse Width Modulation
QA	Quality Assurance
R-407C	Refrigerant 407C
RAM	Random Access Memory
R-C	Resistive-Capacitive
RFI	Radio Frequency Interference
RFP	Request For Proposal
RH	Relative Humidity
rms	Root Mean Square
ROM	Read-Only Memory
rpm	Revolutions Per Minute
RTO	Rapid Transit Operations
s	Second
S&I	Service and Inspection Facility
S/N Ratio	Signal to Noise Ratio
SAE	Society of Automotive Engineers
SCFM	Standard Cubic Feet per Minute
SCMP	Software Configuration Management Plan
SCR	Silicon Controlled Rectifier
SDD	Software Design Description
SFD	System Functional Description
SHR	Sensible Heat Ratio
SI	International System of Units
SIR	Staten Island Railway
SMS	Scheduled Maintenance System
SNAP	Significant New Alternatives Policy
SPL	Sound Pressure Level
SQAP	Software Quality Assurance Plan

SRS	Software Requirement Specification
SRTM	Software Requirements Traceability Matrix
SSP	System Safety Program
STP	Software Test Plan
STPr	Software Test Procedure
SVVP	Software Verification and Validation Plan
SVVR	Software Verification and Validation Report
T/O	Train Operator
Ta	Ambient Temperature
TFE	Tetrafluoroethylene
Ti	Interior Temperature
TIR	Total Indicated Runout
TOD	Train Operator's Display
TOR	Top-of-Rail
TXV	Thermal Expansion Valve
UA-Factor	Car Body Heat Transmission Factor
UL	Underwriters Laboratories Inc.
UNC	Unified National Coarse
UNF	Unified National Fine
US, U.S.	United States
USASI	United States of America Standards Institute
USDOT	United States Department of Transportation
UV	Ultraviolet
Vac	Volts, alternating current
Vdc	Volts, direct current
VOM	Volt-Ohm Meter
VPI	Vacuum Pressure Impregnation
VSWR	Voltage Standing Wave Ratio
VVVF	Variable Voltage Variable Frequency
W	Watt
WB	Wet Bulb
WPS	Weld Procedure Specifications
μA	Micro Ampere.

1.8. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
1-1	1.5.1.3	Written evidence that each supplier of a major system, has received a complete copy of this Specification as part of the Contractor's contract with the supplier	CDR
1-2	1.5.1.11	System to provide traceability from specification requirements to design documents to test results	CDR

Section 2

Design and Performance Criteria

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2. Design and Performance Criteria

2.1. General Design Requirements

- 2.1.1. This section describes those requirements which apply to all R211 Units and cars, except as noted in Sections 25 and 26. It describes the configuration of the Units, the operating environment, dimensional and weight requirements, and performance requirements for acceleration, braking, crashworthiness, noise and vibration, dynamics and Electromagnetic Compatibility. It also provides specific requirements for overall Unit and car design and maintainability.
- 2.1.2. The requirements specified in this section provide general performance criteria of the Unit and the car equipment design. Additional requirements for each subsystem are defined in the corresponding specification section.
- 2.1.3. The R211A and R211T cars shall be designed and manufactured to operate within the NYCT B Division environment (refer to Appendix A). The R211S cars shall be designed and manufactured to operate within the SIR environment (refer to Section 25).
- 2.1.4. The cars shall be designed for the following service life, assuming compliance with the maintenance intervals specified in the Contractor's Maintenance Plan (Section 21.2.3), and assuming current (at the time of Contract Award) NYCT maintenance practices and normal industry-accepted operating procedures:
- a) A minimum service life of 40 years for the carbody and truck frame.
 - b) A minimum service life of 20 years for the systems and subsystems, unless otherwise specified.
- 2.1.5. Assumed annual average operating distance per car shall be 60,000 miles (96,560 km), at an average schedule speed of 15 mi/h (24 km/h).

2.2. Car and Unit Configuration

2.2.1. General Characteristics

- 2.2.1.1. Each operating Unit shall be comprised of four or five cars.
- 2.2.1.2. Operating Units shall be assembled using the following types of cars:
- a) One "A1 car" and one "A2 car" shall be at the outer ends of each Unit and shall feature an operating cab and automatic coupler on one end of the cars, and a semi-permanent coupling arrangement at the other.
 - b) A1 and A2 cars shall be equipped with CBTC equipment, as described in Section 14 - Train Control System. A1 cars shall have one unpowered truck, with one unbraked, or free, axle on that truck. Other differences between the A1 and A2 cars shall be limited as much as possible to the specific CBTC equipment carried by each.
 - c) "B cars" shall have no operating cab and a semi-permanent coupling arrangement at both ends.
- 2.2.1.3. The design of the five-car Unit shall permit removal or addition of one B car, to form a four or six-car Unit. All B cars shall be identical, unless specifically approved by NYCT.
- 2.2.1.4. The R211 cars shall be operable as trains comprised of one or two operating Units.
- 2.2.1.5. All cars shall be stainless steel, rigid-bodied with a contoured cross section.
- 2.2.1.6. All cars other than A1 cars shall have four powered axles, with two trucks. A1 cars shall have two powered axles on one truck and one truck shall be unpowered.
- 2.2.1.7. All cars shall have four passenger side door openings located on each car side. The door openings shall be in alignment side to side and not staggered.
- 2.2.1.8. Connections between cars within a Unit shall accommodate inter-car passenger movement in a safe manner via bi-parting end doors.

2.2.2. Seating Arrangement

- 2.2.2.1. The seating arrangement shall be as shown in Appendix E-1, with the number of seating positions maximized.
- 2.2.2.2. The number of seats on the R211T shall be the maximum that may be achieved in the A and B cars while accommodating the Open Gangway design. See Section 26 for further details.

2.2.3. Accessibility

Car design shall comply with all requirements for rapid rail cars of the Americans with Disabilities Act of 1990, as set forth in U.S. Department of Transportation regulations, published at 36 CFR 1192 and 49 CFR, Part 38, Subparts A and C.

2.2.4. Identification

- 2.2.4.1. An identification system for equipment and components on Units and cars shall be devised and submitted for NYCT approval. [CDRL] See Section 20.8 for additional details.
- 2.2.4.2. The identification system shall be based on the A and B car designations, No. 1 End and No. 2 End conventions, and "Left Side" and "Right Side" as defined in Section 1.7. For an example of equipment numbering refer to Appendix C-2, "Designation of Sides and Ends of Locomotives".
- 2.2.4.3. Component identification includes all permanent identification plates, serialization tags, safety/warning signage, connection information, mounting information, electrical rating information, etc.
- 2.2.4.4. All component identification plates shall be permanently attached using mechanical fasteners. Exceptions may be made for small components and circuit boards. Component identification may also be permanently engraved or stamped into the non-replaceable casing portion of the component.

2.3. Dimensions and Clearances

2.3.1. Car Dimensions

The overall dimensions shall be as listed below and in Figure 2.1 for a new car, AW0 loaded, ready for revenue service. The dimensions given are nominal unless otherwise indicated.

- | | |
|---|------------------------------|
| a) Lengths and door centerline positions | Per Figure 2-1 |
| b) Body width at side sills, maximum | 9 feet 7 inches (2.9 m) |
| c) Width over door thresholds, maximum | 10 feet 0 inches (3.15 m) |
| d) Width at side skins, maximum | 9 feet 9.5 inches (3.0 m) |
| e) Width at belt rail including door masks, maximum | 9 feet 10 inches (3.0 m) |
| f) Height, at bolster, top of rail to top of roof, new wheels | 12 feet 0.3 inches (3.665 m) |
| g) Height, top of rail to top of finished floor, new wheels | 3 feet 9.5 inches (1.2 m) |
| h) Height, top of rail to top of anti-climber, new wheels | 3 feet 8.3 inches (1.1 m) |
| i) Side and end door clear opening minimum height | 6 feet 3.0 inches (1.9 m) |
| j) Side door clear opening minimum width | 4 feet 10.0 inches (1.47 m) |
| k) Clear opening minimum width for all End Doors | 2 feet 6.0 inches (0.8 m) |

- l) Interior height, floor to normal ceiling, minimum 7 feet 0.5 inches (2.1 m)
- m) Interior height, floor to low ceiling if used, minimum 6 feet 7.5 inches (2.0 m)

Note: The Contractor may propose a continuous interior ceiling arrangement with a different ceiling height, subject to NYCT approval; however, in no case shall the minimum height be less than that specified in (m).

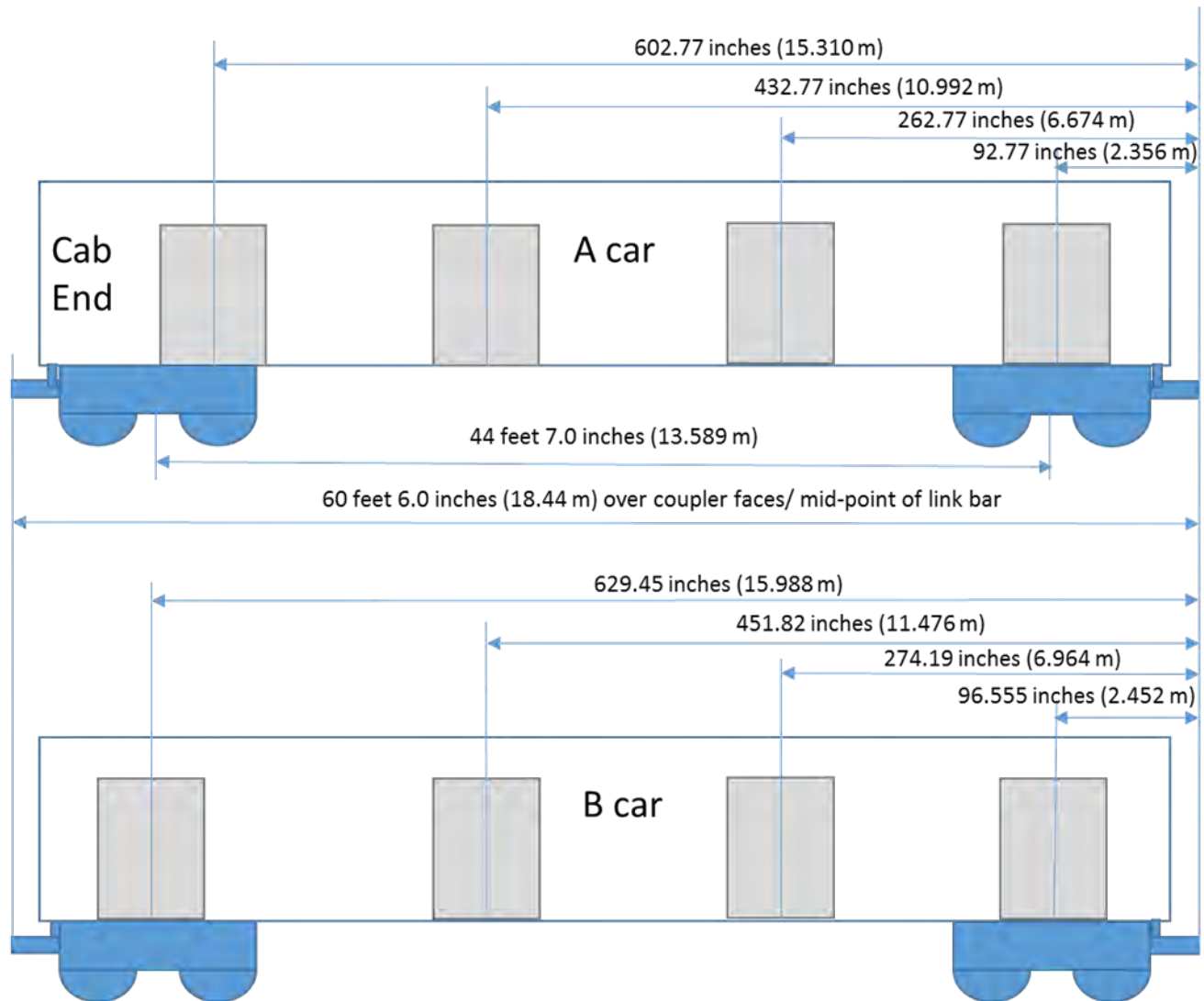


Figure 2-1: Car Dimensions – Side View

2.3.2. Clearance Requirements

- 2.3.2.1. The Contractor shall refer to and comply with the latest revision of NYCT document, “Memorandum of Understanding - Car and Line Equipment Clearances” (Appendix D-1), for details of platform heights and lateral distances and ADA compliance requirements for the NYCT system.
- 2.3.2.2. Carbody dimensions shall be such that the car complies with the Limiting Line of Car Clearance (LLCC) for the B Division, as described in the latest revision of NYCT document, “Memorandum of Understanding - Car and Line Equipment Clearances” (Appendix D-1).
- 2.3.2.3. Compliance with the LLCC shall be provided under all conditions of dynamic motion, wear of components, passenger loading, vertical and horizontal curves, suspension system deflection, and any single suspension system failure.

- 2.3.2.4. The car shall maintain the top of the side door threshold level with, or above, the station platform edge for all loading conditions and platform heights assuming no suspension system failures.
- 2.3.2.5. The car shall provide ADA compliant boarding at a minimum of one side door per car side when aligned with an "ADA zone" (as defined in NYCT document, "Memorandum of Understanding - Car and Line Equipment Clearances" (Appendix D-1) in a station platform.

2.4. Weight Requirements

2.4.1. Weight Limits

- 2.4.1.1. In a five-car Unit, the average car weight shall not exceed 82,000 lbs. (37,195 kg). This weight shall exclude customer furnished equipment (e.g. CBTC and flexible displays), but shall include all equipment supplied by the carbuilder to interface with such equipment.
- 2.4.1.2. Under all loading conditions, the average wheel load shall not exceed 15,485 lbs. (7,024 Kg) on any two wheels on the same side of a truck, with no single wheel exceeding 15,675 lbs. (7,110 kg).

2.4.2. Weight Balance

- 2.4.2.1. The cars shall be designed to achieve maximum weight uniformity on all axles.
- 2.4.2.2. The side-to-side imbalance of each completed car at AW0 condition shall not exceed 20,000 inch-pounds (2,260 Newton-meter), unless otherwise approved by NYCT.
- 2.4.2.3. The end-to-end truck pivot weight difference of each A car at AW3 condition shall not exceed 1,500 pounds (681 kg), unless otherwise approved by NYCT.
- 2.4.2.4. The end-to-end truck pivot weight difference of each B car at AW0 condition shall not exceed 500 pounds (227 kg), unless otherwise approved by NYCT.

2.5. Operating Environment

2.5.1. Operating Conditions

- 2.5.1.1. The car shall be capable of operational functionality and performance under the infrastructure and climate conditions specified in Appendix A, which provides a system description of the fixed facilities, including dimensions and track alignment and construction, and environmental conditions within NYCT's B Division.
- 2.5.1.2. All systems and subsystems shall be functional and shall provide full performance within the temperature range of minus 4 deg. F to 158 deg. F [-20°C to 70°C]. For interior passenger information displays, the operating temperature range shall be 32 deg. F to 122 deg. F [0 deg. C to 50 deg. C]. For CCTV cameras the operating temperature range shall be minus 4 deg. F to 140 deg. F [-20 deg. C to 60 deg. C]. Temperature ranges for HVAC system performance are defined in Section 7.2.1. The maximum ambient fresh air temperature is 120°F (49°C) as described in Appendix A.
- 2.5.1.3. No damage to any system or subsystem shall occur when stored or shipped within the temperature range of minus 22 deg. F to 185 deg. F [-30°C to 85°C]. For interior passenger information displays, the storage temperature range shall be minus 4 deg. F to plus 140 deg. F [- 20 deg C to 60 deg. C]. For CCTV cameras the maximum storage temperature range shall be minus 22 deg. F to plus 140 deg F [-30 deg. C to 60 deg. C].
- 2.5.1.4. A list of recommended cleaning agents shall be provided to NYCT for all materials exposed to normal cleaning operations [CDRL]. This information shall also be included in the maintenance documentation for the vehicle. Contractor recommended cleaning agents shall be from NYCT's list of approved cleaning agents (see Appendix C-3 – "Cleaners and Other Products Approved for Use on Railcars and Railcar Parts") unless otherwise approved by NYCT.

2.5.2. Supply Voltages and Voltage Tolerance

- 2.5.2.1. All equipment on the car shall function, without failure or degradation of service or in-service life, at any voltage between the maximum and minimum voltages defined for the system from which the equipment is supplied, for any duration. See also Section 2.5.4.2.
- 2.5.2.2. Equipment shall not be damaged by the continuous application of any voltage between zero and the maximum design voltage, at any polarity.
- 2.5.2.3. Unless otherwise specified, or due to the inherent physical characteristics of the system, rated performance shall be delivered at any voltage between nominal and maximum voltages.
- 2.5.2.4. Control components such as relays, solenoids or magnet valves shall be functional at any voltage between the minimum and the maximum, and shall be able to operate at the minimum voltage immediately following prolonged operation at the maximum voltage at high ambient temperature.
- 2.5.2.5. All equipment on the Unit shall be self-protected from damage and improper operation due to:
- a) High-voltage transients across the supply terminals of that equipment,
 - b) High-voltage transients applied between either supply terminal and the Unit body, and
 - c) Long-term over-voltage and under-voltage conditions resulting from other equipment failure modes.

2.5.3. Contact Line Voltage Range

- 2.5.3.1. Contact line voltages are as follows:
- Maximum Voltage 780 Vdc
 - Substation Light Load Voltage 675 Vdc
 - Nominal Voltage 600 Vdc
 - Minimum Voltage 450 Vdc.
- 2.5.3.2. At nominal third rail voltage and above, the tractive effort versus speed characteristic shall not vary as a function of third rail voltage.
- 2.5.3.3. Below nominal third rail voltage, the speed to which the full acceleration rate is maintained shall decrease in direct proportion to the reduction in third rail voltage.
- 2.5.3.4. The constant tractive effort level shall not be reduced under low voltage conditions down to 480 Vdc.
- 2.5.3.5. Below 480 Vdc line voltage, maximum tractive effort shall be reduced as approved by NYCT to minimize propulsion undervoltage shutdowns, while providing the best possible motoring performance under these conditions.

2.5.4. Low-Voltage Power System

- 2.5.4.1. The Units shall contain low voltage power supplies (LVPS) and secondary batteries to supply the control power for all car equipment.
- 2.5.4.2. The Low Voltage Distribution Network (LVDN) shall supply each piece of equipment with power conforming to IEEE Std. 1476-2000, "Standard for Passenger Train Auxiliary Power Systems Interfaces, Class 32", as follows:
- Maximum Voltage 42.5 Vdc
 - Nominal LVPS Voltage 37.5 Vdc
 - Minimum Voltage 23 Vdc.
- 2.5.4.3. All low voltage equipment that is fed from trainline to carbody potential shall be designed such that the voltage drop in the return rail over the maximum length of the train, including voltage drop due to traction current drawn by other trains on the same track, is taken into consideration when calculating pick-up and drop-out voltages.

2.5.4.4. All equipment attached to the LVDN shall operate reliably, within the voltage range and power quality specified above, with all train lengths defined in Section 2.2.1.

2.5.5. AC Power Supplies

2.5.5.1. All carborne rotating machines, with the exception of door operator motors and windshield wiper motors, shall be three phase ac powered, unless otherwise approved by NYCT.

2.5.5.2. An auxiliary power distribution network inverter shall supply the convenience outlets, specified in Section 9.4.20, with 120 Vac, 60 Hertz, 20 ampere power.

2.6. Pneumatic System Requirements

2.6.1. The Pneumatic system pressures shall be as follows:

	Normal Operating Range	Maximum
Main Reservoir and Brake Pipe pressures	130-150 psig* [900-1,030 kPa]	160 psig ** [1,110 kPa]

* Compressor Governor (“Cut-In”, “Cut-Out”) Settings

** Air Compressor Overpressure Relief Valve Settings

2.6.2. Equipment shall not sustain damage or fail prematurely when subjected to the maximum pressures above.

2.6.3. All pneumatically powered equipment shall function as required by the system design between the minimum and maximum pressures defined above.

2.6.4. Allowable air leakage for the total Unit shall not exceed 10 psig (70 kPa) in 8 minutes when charged to the maximum normal operating pressure. The required pneumatic system leakage test is specified in Section 24.9.5.

2.7. Performance Requirements

2.7.1. Propulsion and Braking Assumptions

2.7.1.1. All specified rates and tolerances are instantaneous, as measured with an inertial accelerometer.

2.7.1.2. All acceleration, braking, and jerk rate requirements shall be based on a five car Unit configuration operating on level tangent dry track, in still air, except as otherwise noted.

2.7.1.3. Braking system performance shall be met regardless of the third rail voltage, or its absence.

2.7.1.4. Equipment and analysis methods shall be equivalent to those currently employed by NYCT for all modes of braking and acceleration tests.

2.7.1.5. The propulsion and electric braking equipment shall compensate for train resistance, defined in 2.7.1.8.

2.7.1.6. The beneficial retarding effects of train resistance shall not be used when designing brake system capacities.

2.7.1.7. Train mass calculations shall include the effects of rotational inertia.

2.7.1.8. The Modified Davis Equation formula for train resistance, as shown below, shall be used.

Train Resistance (per Unit):

$$TR = 1.3W + 29n + 0.045WV + [0.0024 + 0.00034(Q-1)]AV^2 \text{ pounds force where:}$$

- TR = Total train resistance in pounds force
- W = Total train weight in tons
- V = Train speed in miles per hour
- A = Frontal area in square feet
- Q = Number of cars in the train

$n =$ Number of axles in the train

or $TR = 6.4M + 130n + 0.14MS + [0.046 + 0.0065(Q-1)]AmS^2$ Newtons where:

$TR =$ Total train resistance in Newtons
 $M =$ Total train mass in metric tonnes
 $S =$ Train speed in kilometers per hour
 $Am =$ Frontal area in square meters
 $Q =$ Number of cars in the train
 $n =$ Number of axles in the train

2.7.2. Acceleration Performance

- 2.7.2.1. Full acceleration rate shall be 2.50 mi/h/sec (1.117 m/s²) for Unit weights up to AW2 from zero to at least 15.0 mi/h (6.70 m/s), with the Master Controller handle in the **MAXIMUM POWER** position.
- 2.7.2.2. The acceleration rate with the Master Controller handle in the **MINIMUM POWER** position shall be in the range of 0.3 mi/h/sec (0.13 m/s²) to 0.7 mi/h/sec (0.313 m/s²) in all operating modes except ATO.
- 2.7.2.3. In the ATO operating mode, the **MINIMUM POWER** acceleration rate shall not be greater than 0.4 mi/h/sec (0.179 m/s²).
- 2.7.2.4. Between **MINIMUM POWER** and **MAXIMUM POWER**, acceleration rate shall vary linearly in proportion to Master Controller handle position.
- 2.7.2.5. The rate tolerance percentage for these acceleration rates shall be ± 7 percent.
- 2.7.2.6. It shall be possible to change dynamically between two performance modes, designated as High Performance and Low Performance. High Performance mode shall be enabled only by a signal from the CBTC system as described in Section 14 – Train Control System.
- 2.7.2.7. The performance curves for these two modes shall be adjustable through propulsion software configuration to any performance curve equal to or below the design maximum, subject to NYCT approval.
- 2.7.2.8. The High Performance mode nominal performance shall closely approximate, but not exceed, the “New Car Acceleration Performance, CBTC”, within NYCT Document Misc. # 97-01, including NYCT Drawing 253-9013 (see Appendix D-15).
- 2.7.2.9. The Low Performance mode nominal performance shall closely approximate, but not exceed, the “New Car Acceleration Performance, Trip Stop System”, within NYCT Document Misc. # 97-01, including NYCT Drawing 253-9013, (see Appendix D-16).

2.7.3. Speed Requirements

- 2.7.3.1. Propulsion and drive unit apparatus shall be designed to operate continuously at 55 mi/h (24.58 m/s) without damage, heating, or wear in excess of values used to calculate design life (e.g. bearing wear).
- 2.7.3.2. Maximum equipment safe design speed with fully worn wheels shall be 66 mi/h (29.5 m/s). Operation at the maximum safe design speed must be possible but does not represent normal operating conditions.
- 2.7.3.3. Tractive effort shall be removed at 55 mi/h (24.58 m/s).
- 2.7.3.4. The car propulsion systems shall use a jerk limited removal of tractive effort if the train speed exceeds the limit, specified in 2.7.3.3.

2.7.4. Service Braking Requirements

Performance

- 2.7.4.1. The full service deceleration rate capability shall be 3.0 mi/h/sec (1.34 m/s²) for all Unit weights up to AW3, over the entire speed range, for all wheel diameters, with the Master Controller handle in the **FULL SERVICE BRAKE** position.

- 2.7.4.2. The average deceleration rate with the Master Controller handle in the **MINIMUM BRAKE** position shall not be greater than 0.7 mi/h/sec (0.313 m/s²).
- 2.7.4.3. Braking rate shall vary linearly in proportion to Master Controller handle position, between **MINIMUM BRAKE** and **MAXIMUM BRAKE**.
- 2.7.4.4. Average brake rates shall be measured as follows: speed/time/distance data shall be digitally acquired using an approved method of data acquisition that is independent of the vehicle systems. Data shall be mathematically fit to a model that assumes a constant speed dead time, followed by a constant deceleration rate until stopped to generate the average deceleration rate in accordance with EN 13452.

Tolerances

- 2.7.4.5. The deceleration rate tolerance shall be as defined in Table 2-1.

	Friction Only Braking	Electric Braking	Blended Braking
Average Rate	±10 percent	±7 percent	Calculated according to the percentage of each type of brake applied
Instantaneous Rate	±20 percent	±7 percent	

Table 2-1: Braking Rate Tolerances

Electric Braking Requirements

- 2.7.4.6. The electric brake shall produce 100 percent of the brake effort from fade out speed up to the maximum speed possible, but in any case at least 35 mi/h (15.65 m/s), for an AW3 car weight.
- 2.7.4.7. Taper of the AW3 electric brake effort is permitted above 35 mi/h (15.65 m/s), with friction brakes blended to maintain the required brake rate.
- 2.7.4.8. The electric brake fade out speed shall be as low as practical, subject to NYCT approval with blended friction brake completing the stop.
- 2.7.4.9. The electric and friction braking systems shall be integrated to provide a smooth transition between electric and friction braking effort in accordance with the jerk limits defined in Section 2.7.8.1 and deceleration tolerance defined in Section 2.7.4.5.
- 2.7.4.10. In the event of electric brake failure at any speed, the friction brakes shall provide all of the required service braking effort.
- 2.7.4.11. The friction brake tractive effort and thermal dissipation capability shall be sufficient to replace a failed electric brake over the worst case combination of worst case segments of the entire B Division duty cycle.

2.7.5. Emergency Braking Requirements

- 2.7.5.1. The emergency braking system shall provide pneumatic-only controlled fail-safe braking which meets the performance requirements of Section 2.7.5.2 and 2.7.5.3. The emergency brake functions are defined in Section 12.3.3.
- 2.7.5.2. The emergency braking system shall produce a stopping distance that does not exceed the distance represented by the curve on NYCT Drawing No. 103-9002 (see Appendix D-3) for all Unit weights up to AW3, over the entire speed range with new wheels on level tangent track.
- 2.7.5.3. The variation of the instantaneous braking rate during emergency braking shall not exceed ±20 percent of the average brake rate after brake cylinder pressure has stabilized.
- 2.7.5.4. Minimum emergency brake rate for CBTC operation are defined in Section 14 – Train Control System, and for SIR operation in Section 25 - Staten Island Railway Cars.

2.7.6. Parking Brake Requirements

- 2.7.6.1. The parking brake system shall hold a Unit with all parking brakes applied and loaded to AW3 on a 5.6 percent grade indefinitely.

2.7.7. Wheel Spin/Slide Protection

- 2.7.7.1. The wheel spin/slide control system shall detect all spins and slides, whether they are random or synchronous, under all adhesion conditions at all speeds.
- 2.7.7.2. The wheel slide efficiency shall be defined as the ratio of the stopping distance attained in reduced coefficient of adhesion conditions of 0.06 to 0.08 to that attained in dry conditions and shall be calculated on a per-Unit basis.
- 2.7.7.3. Under reduced adhesion conditions, the wheel slide control system operating efficiency shall produce stopping distances no greater than 125% of the dry rail stopping distances. The efficiency of the wheel slip system shall be achieved over the speed range between maximum and approximately 5 mi/h (2.23 m/s).
- 2.7.7.4. The wheel spin efficiency shall be defined as the ratio of the actual accelerating rate to the adhesion limited theoretical maximum accelerating rate, from an initial speed to a higher speed. The theoretical rate is that which is obtained by continuously utilizing the available track adhesion. Efficiency shall be calculated over slip-affected portions of operation.
- 2.7.7.5. Under reduced adhesion conditions and with the Master Controller handle in the **MAXIMUM POWER** position, the wheel spin control system shall take no more than 125% of the dry rail time to accelerate the Unit between 5 mi/h (2.23 m/s) and 15 mi/h (6.7 m/s).
- 2.7.7.6. The wheel spin/slide control system shall deactivate slip control if the spin or slide has not been corrected within a specified period. Deactivation criteria and timing are subject to NYCT review and approval.
- 2.7.7.7. At a coefficient of adhesion of 0.05 or greater, the wheel slide control system shall prevent wheel lockups occurring for greater than 200 milliseconds at car speeds above 5 mi/h (2.23 m/s).
- 2.7.7.8. The wheel slide system shall not be enabled during emergency brake applications.

2.7.8. Jerk Limits

- 2.7.8.1. In response to a step input command signal, including brake blending, the average rate of change of actual instantaneous acceleration or deceleration, after the dead time, shall be 2.0 mi/h/sec² (0.894 m/s³) \pm 20 percent for car weights up to and including AW2, under all normal operating conditions.
- 2.7.8.2. Above car weights of AW2 in motoring, the maximum jerk rate may vary in direct proportion to the ratio of the AW2 car weight to the actual car weight.
- 2.7.8.3. The jerk limits specified shall apply to all normal power and service braking applications.
- 2.7.8.4. Reapplication of power after traversing non-bridging third rail gaps shall be jerk limited.
- 2.7.8.5. Emergency brake applications shall not be jerk limited, for either power removal or brake application.

2.7.9. Mode Change Dead Times

- 2.7.9.1. Single mode change dead times shall not exceed 300 milliseconds.
- 2.7.9.2. Dead times shall be measured from the time when the Master Controller is moved into the zone corresponding to the new command until the acceleration or deceleration begins to change at the specified jerk rate.
- 2.7.9.3. Multiple mode changes, such as propulsion to coast to brake, shall be measured consecutively, adding the jerk limited power or brake removal time (if it is to take place) to the two mode-transition time intervals, as appropriate.

2.7.10. Load Compensation

- 2.7.10.1. A passenger load compensation system shall adjust car motoring tractive effort to compensate for varying passenger load, with car weights between AW0 and AW2.
- 2.7.10.2. At loads greater than AW2, tractive effort shall be held at the AW2 level.
- 2.7.10.3. All specified braking requirements shall be met under all car loading conditions between AW0 and AW3.
- 2.7.10.4. The design shall conform to the requirements of Sections 10.3.5 and 12.3.5 in case of failure of the load compensation system.

2.7.11. Duty Cycle Rating

- 2.7.11.1. The Units shall be capable of operating under all conditions in the B Division service area, including those conditions listed below, and in Appendix A, without exceeding the continuous rating of any equipment.
- 2.7.11.2. The propulsion and braking systems' capacities shall enable a train, with 55 percent of the propulsion and braking capability inactive, to negotiate the B Division worst case route (C line), making all station stops and observing all speed restrictions, under the following conditions:
 - a) Ratings shall be based on AW3 passenger load from the worst case location to the next station stop, followed by AW0 passenger load for the duration of the trip.
 - b) Propulsion ratings shall be based on the use of electric braking with a non-receptive supply.
 - c) Friction brake ratings shall be based on full friction brake with no electric brake.
 - d) Analysis shall consider cases where load distribution and grade allow a "free-wheeling" acceleration rate of 0.25 mi/h/sec (0.11 m/s) or greater.
 - e) Nominal line voltage shall be assumed.
 - f) Acceleration and deceleration rates under these conditions will vary in proportion to the number of operable propulsion and braking systems in the train.
- 2.7.11.3. The propulsion and braking systems' capacities shall enable a train, with 33 percent loss of propulsion and braking capability, to operate continuously over the B Division worst case route, making all station stops and observing all speed restrictions, under the following conditions:
 - a) Analysis shall be based on the speed profiles anticipated under CBTC ATO operation (see Section 2.7.2.8).
 - b) Ratings shall be based on continuous operation with a car load of AW2.
 - c) Propulsion ratings shall be based on the use of electric braking with a non-receptive supply.
 - d) Friction brake ratings shall be based on full friction brake with no electric brake.
 - e) Analysis shall consider the case where the trains operate continuously in the Energy Conservation Mode described in Section 10.2.4.
 - f) Nominal line voltage shall be assumed.
 - g) Acceleration and deceleration rates under these conditions will vary in proportion to the number of operable propulsion and braking systems in the train.

2.8. Train Level Crashworthiness Performance

2.8.1. Crash Energy Management

- 2.8.1.1. The Contractor shall develop a Crash Energy Management (CEM) plan per the requirements in Section 3 – Carbody Structure, and shall design the overall train to minimize:
 - a) possibility of injury to occupants;

- b) loss of occupied volume;
- c) secondary collisions due to derailment and fouling of clearance envelope.

2.8.1.2. The CEM design shall provide for a controlled, progressive collapse of energy absorption zones of the carbody structure (see Section 3 – Carbody Structure).

2.8.1.3. The Contractor may incorporate other train elements, such as couplers and link bars (see Section 4 – Coupler Systems), or energy absorbing mechanisms in achieving the CEM performance requirements.

2.8.2. Collision Scenarios

2.8.2.1. Design Case A - R211 crashworthiness design shall be based upon a train of 10 coupled R211 cars at an initial speed of 15 mi/h (6.7 m/s), colliding with a stationary identical train, all cars with full-service brakes applied.

2.8.2.2. Design Case B - R211 train of 10 coupled R211 cars at an initial speed of 25 mi/h (11.18 m/s), colliding with a stationary identical train, all cars with full-service brakes applied.

2.8.2.3. Compatibility Case A - R211 train of 10 coupled R211 cars at an initial speed of 15 mi/h (6.7 m/s), colliding with a stationary train of 10 coupled R160 or R179 cars, all cars with full-service brakes applied. The requirements of Sections 2.8.3.4 to 2.8.3.6 do not apply to this specific analysis, and the following acceptance criteria shall be applied: (i) Sections 2.8.4.3 and 2.8.4.6 applied to all car types in this analysis; (ii) Sections 2.8.4.2, 2.8.4.7 and 2.8.4.8 applied to the R211 cars only in this analysis.

2.8.2.4. Compatibility Case B - The occupied volume of the R211 car shall resist the average crash force during CEM operation of R160 or R179 cars, applied quasi-statically through the crash load path. The R211 car shall be compressed quasi-statically between two rigid walls up to the reaction force equal to the average crash force during CEM operation of R160 or R179 cars. The acceptance criteria shall be as defined in Section 2.8.5.6.

2.8.3. Collision Conditions – All Cases

2.8.3.1. Force-displacement characteristics of the carbody structures of existing equipment to be used for the simulation scenarios described in Sections 2.8.2.3 and 2.8.2.4 will be supplied by NYCT following Notice to Proceed.

2.8.3.2. Force-displacement characteristics of couplers of existing equipment shall be those with the lowest elastic strength currently in use by NYCT.

2.8.3.3. Force-displacement characteristics of link-bars of existing equipment shall be those with the greatest elastic strength currently in use by NYCT.

2.8.3.4. All simulations defined in Section 2.8.2 shall also be conducted with combined maximum vertical and lateral offset conditions at the colliding interface for the R211 car.

2.8.3.5. Maximum vertical offset shall be based on the difference in floor height which could occur due to tolerances associated with wheel wear and suspension conditions, and where the total tolerance from all sources is combined using a root-sum-square, or 1.5 inches (38 mm), whichever is greater.

2.8.3.6. Maximum lateral offset shall consider the maximum lateral (parallel) distance due to carbody stops that limit carbody motion relative to its trucks, or 1.5 inches (38 mm), whichever is greater.

2.8.4. Acceptance Criteria - Design Case A, 15 mi/h (6.7 m/s) R211 Cars

2.8.4.1. Train to train interaction shall not exhibit overriding or telescoping responses.

2.8.4.2. Carbody structure shall exhibit progressive structural crush beginning at the ends of the individual carbodies.

2.8.4.3. Carbody acceleration shall not exceed 7.5g (73.6 m/s²) averaged over the duration of the collision. Acceleration data used to compute carbody acceleration shall be filtered in accordance with the SAE J211 collision class 60 low-pass frequency filter.

- 2.8.4.4. All cars in the trains shall remain upright and in line during and after the collision.
- 2.8.4.5. Trucks shall remain attached to their respective cars.
- 2.8.4.6. Stresses in the passenger compartment of the carbody shall not exceed the material yield strength. Localized plastic deformation may be considered on a case by case basis.
- 2.8.4.7. The operator's seat shall have a minimum of 12 inches (300 mm) of clear survival space (no intrusion of car elements) from the designed space around the seat, and a clear path from the seat to exit the cab.
- 2.8.4.8. The vertical (floor to ceiling) height of the cab shall not be reduced by more than 20% after the collision.
- 2.8.4.9. The tread of any wheel of the cars shall not rise more than 4 inches (100 mm) above top of rail.
- 2.8.4.10. The relative difference in elevation between the underframes of the colliding and connected railcars shall not change by more than 4 inches (100 mm).
- 2.8.4.11. Mounted equipment and fittings shall not interfere with performance of crash energy absorption structural elements.

2.8.5. Acceptance Criteria - Design Case B, 25 mi/h (11.18 m/s) R211 Cars

- 2.8.5.1. Train to train interaction shall not exhibit overriding or telescoping responses.
- 2.8.5.2. Carbody structure shall exhibit progressive structural crush beginning at the ends of the individual car-bodies.
- 2.8.5.3. Car acceleration shall not exceed 7.5g (73.6 m/s²) averaged over the duration of the collision. Acceleration data used to compute carbody acceleration shall be filtered in accordance with the SAE J211 collision class 60 low-pass frequency filter.
- 2.8.5.4. All cars in the train shall remain upright and in line during and after the collision.
- 2.8.5.5. Trucks shall remain attached to their respective cars.
- 2.8.5.6. Global car shortening shall be no more than 1% over any 4.6m (15ft) of the occupied volume (not including the crushable zone located at the car end). Highly localized plastic deformation of the occupied volume not affecting the ability of the structure to meet the requirements of this Specification shall be allowed. The 4.6m (15ft) of the occupied volume length located at the end of the car may reduce in length up to 2%.
- 2.8.5.7. A clear path for exit from the cab shall be maintained for the operator.
- 2.8.5.8. The vertical (floor to ceiling) height of the cab shall not be reduced by more than 20% after the collision.
- 2.8.5.9. The tread of any wheel of the cars shall not rise more than 4 inches (100 mm) above top of rail.
- 2.8.5.10. The relative difference in elevation between the underframes of the colliding and connected railcars shall not change by more than 4 inches (100 mm).
- 2.8.5.11. Mounted equipment and fittings shall not interfere with the performance of crash energy absorption structural elements.

2.9. Noise and Vibration Performance

2.9.1. General Noise Requirements

- 2.9.1.1. Maximum noise level requirements shall be as shown in New York City-Rapid Transit Noise Code, Chapter 736, see Appendix C-4.
- 2.9.1.2. Unless otherwise indicated, noise level (as defined by ANSI S1.4) is the weighted sound pressure level measured by the use of a metering characteristic and weighing A, B or C as specified in ANSI S1.4. The unit of noise level is decibels (dB), and the reference pressure is 20 micropascals.

- 2.9.1.3. Overall noise levels shall be measured in dB on the A scale (dBA) with slow meter response setting for stationary vehicle measurements, and fast meter response for moving vehicle measurements.
- 2.9.1.4. A Type 2 sound level meter, in accordance with the latest version of ANSI S1.4, shall be used.
- 2.9.1.5. For octave and one-third octave band measurements, filters in accordance with the latest version of ANSI S1.11 shall be used.
- 2.9.1.6. Under steady operating conditions, the measurement interval shall be 20 seconds.
- 2.9.1.7. Unless otherwise noted, the specified noise limits shall be for continuously-operating equipment and shall not apply to equipment that operates occasionally for brief periods only, such as a circuit breaker or pneumatic pressure relief device.

2.9.2. Interior Noise Levels

- 2.9.2.1. With the car stationary with windows and doors closed, with all auxiliary equipment operating simultaneously under normal operating conditions, the interior noise level shall not exceed 72 dBA when operating in a tunnel section.
- 2.9.2.2. With the car operating at 40 mi/h (64 km/h) in a tunnel section, and under any acceleration or deceleration condition, interior noise shall not exceed 80 dBA.
- 2.9.2.3. Noise measuring points, subject to NYCT approval, shall be as follows:
 - a) 3 ft. (914 mm) below the geometric center of each return air grille,
 - b) Not less than 1 ft. (305 mm) from the ceiling, end walls or side walls,
 - c) Not less than 10 measurements at the height of the average seated passenger's ears at representative locations throughout the car,
 - d) Not less than 10 measurements at the height of the average standing passenger's ears at representative locations throughout the car, and
 - e) One measurement at the ear height of the average Operator when seated in the cab seat.

2.9.3. Wayside Noise Levels

- 2.9.3.1. Average noise levels emanating from the car shall not exceed 65 dBA with the train stationary in lay-up mode, when measured at a distance of 15 ft. (4.6 m) from the centerline of the track, 5 ft. (1.5 m) above the ground.
- 2.9.3.2. Average noise levels emanating from the vehicle shall not exceed 75 dBA with all auxiliary equipment operating simultaneously, when measured at a distance of 15 ft. (4.6 m) from the centerline of the track, 5 ft. (1.5 m) above the ground.
- 2.9.3.3. With the car operating at 40 mi/h (64 km/h) in a tunnel section, and under any acceleration or deceleration condition, average noise levels emanating from the vehicle shall not exceed 80 dBA, when measured at a distance of 25 ft. (7.6 m) from the centerline of the track, 5 ft. (1.5 m) above the platform.
- 2.9.3.4. The car shall be assumed to have new wheels.

2.9.4. Equipment Noise Prior to Installation on Car

- 2.9.4.1. Noise levels produced by the operation of each truck's drive train shall not exceed 93 dBA at 15 feet (4.57 m) from the geometric center of each motor/gearbox, in any direction, under the following conditions:
 - a) Gears rotating in either direction
 - b) Any speed from zero to the equivalent of 50 mi/h (22.35 m/s) Unit speed
 - c) At all loads equivalent to maximum tractive effort (motoring and braking).

- d) At the Contractor's option, the motor and gear unit may be tested separately. The Contractor shall submit noise criteria for the motor, gear unit, and the remainder of the drive train. These optional criteria shall be submitted by the Contractor for NYCT approval prior to testing.

2.9.4.2. Noise produced by the individual operation of all equipment which operates continuously or frequently (except traction motors and gear units, above) shall not exceed 80 dBA at 15 ft. (4.6 m) from the center of the equipment while it is operating under any normal condition and load. This equipment includes motors, generators, blowers, brakes, compressors, valves and other noise generating components.

2.9.4.3. Equipment design shall mitigate the presence of any pure tones.

2.9.5. Vibration Generation

2.9.5.1. Equipment mounted anywhere on the car or trucks shall not cause vertical or horizontal vibrations anywhere on the floor, walls, ceiling, panels and seat frames in excess of the following:

- Below 1.4 Hz: Maximum deflection (zero to peak) of 0.10 inch (2.54 mm).
- 1.4 Hz to 20 Hz: Peak acceleration of 0.01 g (0.10 m/s²).
- Above 20 Hz: Peak velocity of 0.03 inches/sec (0.76 mm/s).

Except:

- i. HVAC Evaporator blower and/or Condenser fan rotation speed (frequency).
- ii. HVAC Compressor rotation speed (frequency).

2.9.6. Shock and Vibration Exposure

2.9.6.1. The Contractor shall determine the most severe shock and vibration values that result from the combination of the proposed equipment and operation on the B Division so that appropriate apparatus shall be provided.

2.9.6.2. The aforementioned shock and vibration requirements shall not be less than those of IEEE 1478, unless otherwise approved by NYCT.

2.10. Derailment Mitigation, Stability and Ride Quality Performance

2.10.1. Derailment Mitigation

2.10.1.1. Under any track alignment found on the B Division, with any track condition permissible under the standards defined in MW-1 Track Standards Manual (see Appendix C), the ratio of lateral force (L) to vertical force (V) on any wheel should not exceed the Nadal limit (with an assumed coefficient of friction of 0.5).

2.10.1.2. For a car stopped at a location with maximum track superelevation, as defined in MW-1 Track Standards Manual (see Appendix C-5), the minimum wheel load shall be no less than 60 percent of the normal static wheel load measured on level track.

2.10.1.3. Net Axle Lateral (NAL) force, as a check on track panel shift, shall be less than one-half the static vertical axle load for AW0 and AW3.

2.10.1.4. Under any combination of track conditions, speed, suspension condition or passenger loading, the wheel load shall not drop below 10 percent of the normal static wheel load measured on level track.

2.10.2. Stability

2.10.2.1. The car shall remain stable at all speeds up to 66 mi/h (29.5 m/s), considering any load condition, with either inflated or deflated air springs and the worst track conditions.

2.10.2.2. Stability shall mean the absence of hunting, defined as six or more consecutive oscillations where truck frame lateral accelerations exceed 0.8g peak-to-peak.

2.10.2.3. Truck and car stability shall satisfy safety limit requirements of 49 CFR 213.333 and 213.345.

2.10.3. Ride Quality

2.10.3.1. The ride quality shall be evaluated according to ISO 2631.

2.10.3.2. The RMS acceleration values shall not exceed the "4 hr., reduced comfort level (vertical)" and "2.5 hr., reduced comfort level (horizontal)" boundaries derived from Figure 2a (vertical) and Figure 3a (horizontal) of ISO 2631 over the range of 1 Hz to 80 Hz, for all load conditions AW0 to AW3 and all normal Unit acceleration, deceleration, and speed conditions.

2.10.3.3. The Unit shall be evaluated with new wheels on tie and ballast track with non-corrugated welded rail.

2.10.3.4. All equipment mounted in the car interior shall be free from resonance.

2.11. Electromagnetic Interference and Compatibility Requirements

2.11.1. General

2.11.1.1. The Unit shall be electromagnetically compatible within itself, with other Units provided by the Contractor, with all other trains in operation at NYCT, with the NYCT signal system, with NYCT communications systems, with other NYCT electronic equipment as specified elsewhere within this Specification, and with equipment owned by neighbors of NYCT along its right-of-way.

2.11.1.2. It shall be the responsibility of the Contractor to prevent any interference between any subsystem or signal and any other subsystem or signal on the vehicle or train.

2.11.1.3. All transmission signal frequency allocations shall be approved by NYCT.

2.11.1.4. Except where explicitly required otherwise, the Unit shall comply with all requirements of NYCT AC Train EMC Standards document (ES) that is included in Appendix C-6. The Contractor is not required to perform the Radio Emissions Susceptibility Qualification Test with the 1000W Microwave Oven that is detailed in Section 6.1, Table 6-1b of the NYCT AC Train EMC Standards.

2.11.1.5. The train electromagnetic emissions shall also comply with applicable portions of 47 CFR Communications.

2.11.1.6. The R211 cars shall not be capable of any operation which causes unsafe conditions to be induced in the NYCT signaling systems.

2.11.1.7. The Contractor shall ensure that each train configuration complies with the EMC requirements, in all possible operation modes, including all allowed modes of degraded performance and failure modes.

2.11.1.8. The Contractor shall work with NYCT and its suppliers to resolve any EMC problems, as they relate to the cars and their operation, discovered during execution of this Contract.

2.11.1.9. The Contractor may use an EMI detector compliant with ES Section 4.2, on a per-system basis, as part of the EMC control plan. The Contractor shall analyze and document the interaction and response to failure conditions of all installed EMI Detectors on the train ranging from failure on the car, to failure of the wayside equipment within the substation diodes, to failure of the EMI detector itself.

- a) The detection levels, response times, frequencies, and bandwidths shall be compatible with the EMI safety analysis and Failure Modes, Effects and Criticality Analysis (FMECA).
- b) The design of this detector shall ensure that no EMI hazard exists while maximizing car availability. False EMI detections shall not be permitted.
- c) Positive measures shall be taken to prevent the accidental or intentional tampering with the EMI Detector detection characteristics and response actions.

- d) The contractor must submit an EMI detector FMECA, Fault Tree Analysis , and System Hazard Analysis (SHA) to NYCT for review and approval. [CDRL]

2.11.2. Conducted Emissions Limits

- 2.11.2.1. The conducted emissions limits shall be as specified in the ES Section 3.2.3.

2.11.3. Inductive Emissions Limits

- 2.11.3.1. The train inductive emission limits shall be as specified in the ES Section 3.3.3.

2.11.4. Radiated Emissions Limits

- 2.11.4.1. The Radiated emissions shall not exceed the characteristic shown in Figure 2-2, measured 50 feet (15.24 m) from the center line of the rails.

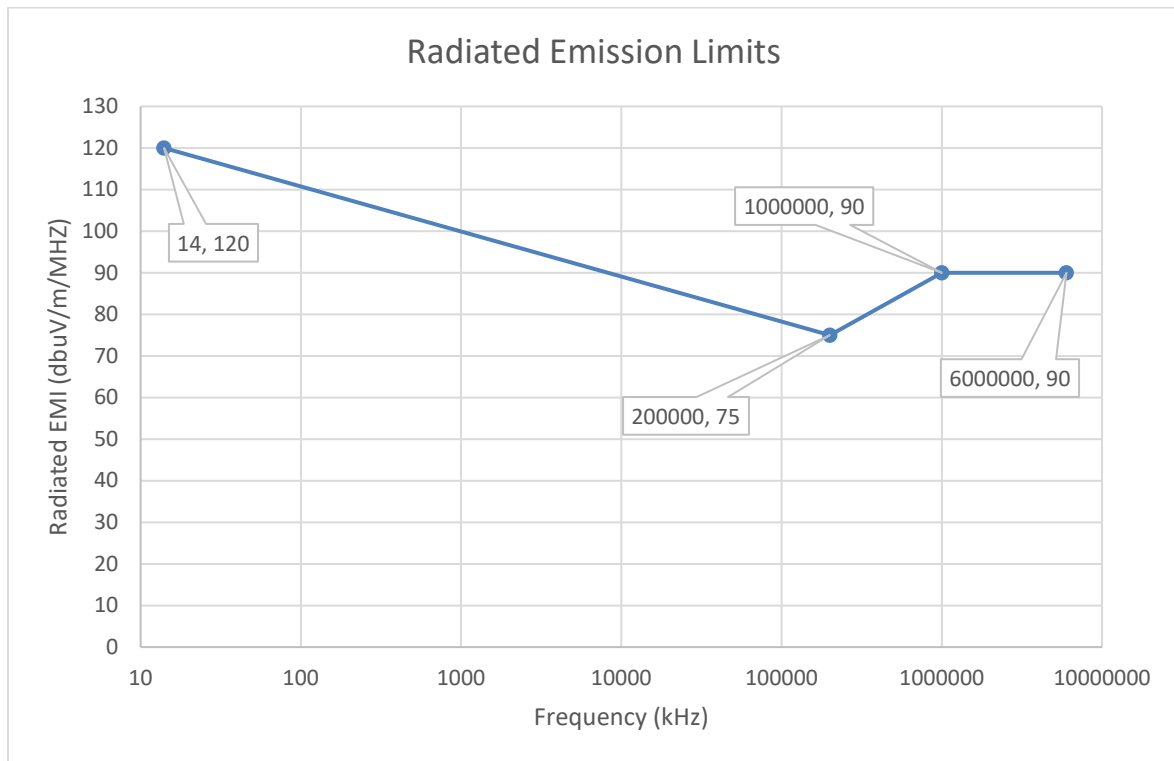


Figure 2-2: Radiated Emission Limit Characteristic

- 2.11.4.2. The Contractor shall cooperate in the satisfactory resolution of any complaints received by NYCT and attributed to the Units, including complaints of radio, television and telephone interference.

2.12. Safety Design Requirements

2.12.1. General Safety Design Requirements

- 2.12.1.1. The general safety design requirements of Paragraph 4.3 in MIL-STD 882, and the guidelines listed in this Section 2.12.1, shall be incorporated into the design of all vehicle systems affecting safety.
- 2.12.1.2. Only components with high reliability and which have been proven in conditions similar to the projected service for at least one year shall be utilized.
- 2.12.1.3. All devices not guaranteed to be fail-safe shall be assumed capable of failing in permissive modes (see Section 2.12.2.2).
- 2.12.1.4. Systems shall be based on closed-circuit principles in which energized circuits result in permissive conditions, while interrupted or de-energized circuits result in restrictive conditions (see Section 2.12.2.2). Exceptions are subject to NYCT approval.

- 2.12.1.5. All vital circuits not wholly within the system apparatus enclosure shall be double-wire, and double-break, with the exception of connections to non-vital circuits, which may be single-wire, and single-break.
- 2.12.1.6. Any component or wire becoming grounded shall not cause a permissive condition.
- 2.12.1.7. Safety critical circuits identified per the System Safety Program Plan (see Section 21.3.2) shall be kept free of any combination of grounds that will permit a flow of current equal to, or greater than, 75 percent of the release value of any safety device in the circuit.
- 2.12.1.8. The EMI safety analysis required by Section 2.15.2.5 shall demonstrate that circuit impedances, signal encoding, shielding, layout, and isolation control the effects of interference so that safety is maintained under all conditions.
- 2.12.1.9. Commands that result in permissive conditions shall be propagated by no less than two independent signals, both of which must be present before the permissive condition can occur. The lack of either signal shall be interpreted as a restrictive command.
- 2.12.1.10. Systems controlled by variable level signals shall be arranged such that zero signal level results in the most restrictive condition.
- 2.12.1.11. At least one enabling signal, however, independent from the variable control signal, shall be present before the control signal can modulate the system to a more permissive level.
- 2.12.1.12. Circuit breakers and fuses shall be guaranteed by the manufacturer to successfully interrupt rated currents.
- 2.12.1.13. Circuit breakers and fuses shall be applied such that the maximum circuit fault currents cannot exceed the manufacturer's guaranteed operating ranges.
- 2.12.1.14. Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures are not possible within the life of the vehicle under all possible conditions found in normal and emergency operation.
- 2.12.1.15. Systems subject to wear shall not wear to permissive states within a period less than three times the supplier recommended maintenance period under the worst-case combination of duty cycle, environment, and all other influences. Such devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.
- 2.12.1.16. Mechanical systems which apply force to achieve safe states shall not depend upon the application of fluid pressure or electrical energy, unless specifically approved by NYCT.
- 2.12.1.17. All locks, catches, and similar devices affecting safety shall be either self-engaging without application of power, or, if engaged by application of power, shall remain fully and safely engaged in the absence of power.
- 2.12.1.18. All locks, catches, and similar devices shall be submitted for NYCT approval.
- 2.12.1.19. All systems shall function safely under all combinations of supply voltages, fluid pressures, shock, vibration, dirt accumulation, and NYCT's environment.
- 2.12.1.20. All safety related systems, and devices within those systems, shall be clearly identified as SAFETY CRITICAL in all maintenance manuals, procedures, and training materials.

2.12.2. Failure Induced Hazards

- 2.12.2.1. Car equipment and systems shall be designed and constructed to revert to safe modes under failure conditions. The Contractor shall employ high quality components, proven systems, redundancy, checking devices, and other techniques to accomplish this goal.
- 2.12.2.2. Car systems whose failure could result in hazards of Category I or II severity (as defined in Section 21.3.3) shall conform to both of the following design principles, and safety shall be validated by analysis and Unit Qualification Testing as specified in Section 24 – Test Program:

- a) The failure of a single device shall not result in a permissive condition, and
- b) An undetected failure of any device shall not permit a subsequent device failure to result in a permissive condition.
- c) Other approved safety methods in which the result of hardware failure or the effect of software error prohibits the system from assuming or maintaining an unsafe state or causes the system to assume a state known to be safe.

Where:

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

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

The terms "restrictive" and "permissive" relate to potential system responses, which result in either a more-safe or less-safe condition, respectively, such as: stop vs. proceed, a lower speed vs. a higher speed, deceleration vs. acceleration, brakes applied vs. brakes released, actuation of alarm vs. no actuation of alarm.

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

- a) The utilization of fail-safe devices, that is, devices with known, guaranteed-by-the-manufacturer failure modes, such as signal-grade relays, and
- b) Independent channels, e.g. signals, commands, etc., with independent checking of each.

2.12.2.4. Where the independent channel method is used:

- a) All channels shall indicate a permissive state in order that the controlled system achieve a permissive state.
- b) Failure in any channel shall not affect any other channel, or force the system into a permissive state.
- c) Lack of correspondence between channels shall be alarmed and shall force a restrictive state on the system.

2.12.2.5. Failures in equipment which result in an indication and annunciation of danger, whether or not actual danger exists, shall be considered to have occurred in a safe manner.

2.12.2.6. Conversely, a failure which results in an indication of safety, when in fact a dangerous condition may exist, shall not be considered safe.

2.12.3. Fire and Life Safety Requirements

2.12.3.1. All aspects of the cars shall be designed for the prevention of fire, the protection of any personnel from injury due to fire, smoke, explosion, or panic due to fire, and the protection of system elements from damage by fire or explosion.

2.12.3.2. Designs shall provide for equipment to be located outside of the passenger compartment, whenever practical, in order to isolate potential ignition sources from combustible materials.

2.12.3.3. Car end-caps and the floor shall be designed to prevent the propagation of an underfloor fire to the car interior.

2.12.3.4. Fire-stops shall be provided at floor and roof penetrations.

2.12.3.5. Enclosures for control and other critical equipment shall protect against environmental contamination and mechanical damage.

2.12.4. Safety Under Normal Operating Conditions

- 2.12.4.1. The cars shall present a safe, hazard-free environment to passengers, and operating and maintenance personnel.
- 2.12.4.2. Passengers and operating and maintenance personnel shall not be exposed to tripping hazards, sharp points and edges, lethal or injurious voltages, toxic materials, abrupt or unexpected accelerations, excessive temperatures, or similar hazards.
- 2.12.4.3. Location, illumination levels, colors, graphics, and surface finishes shall be selected to maximize visibility of step edges, windscreens, devices, and other objects with which the passengers must interface.
- 2.12.4.4. Normal and emergency equipment and devices which the passenger may operate shall be clearly identified, and operating procedures shall be presented in both printed and graphic formats.
- 2.12.4.5. Exposure of maintenance personnel to lethal or injurious voltages shall be minimized through compartmentalization, interlocks, and similar measures.
- 2.12.4.6. All equipment shall be free from sharp points and edges.
- 2.12.4.7. All equipment enclosures containing hazardous materials, lethal or injurious voltages, or other risks shall be clearly labeled on both the outside and inside of the equipment enclosures.
- 2.12.4.8. Cabinets, panels, boards, and enclosures shall not have exposed hot surfaces with potential to cause injury.

2.12.5. Human Error and Other External Influences

- 2.12.5.1. All systems shall minimize unsafe conditions resulting from human error.
- 2.12.5.2. No sequence of operation of train controls, or the simultaneous activation of any controls, shall result in an unsafe condition being created.
- 2.12.5.3. Where conflicting commands, such as simultaneous power and brake, are requested, the more restrictive shall result.
- 2.12.5.4. The design of safety-related equipment shall be such that the effects of errors during maintenance are minimized.
- 2.12.5.5. Methods such as limitation of adjustment ranges, unalterable software, non-interchangeable parts, and visible wear indicators shall be employed.

2.13. Reliability Requirements

- 2.13.1. Design priority shall be given to maximizing both in-service reliability and mission completion probability for the complete Unit. Mission completion probability defines the probability that the system will not fail to complete the mission, considering all possible redundant modes of operations.
- 2.13.2. Reliability performance requirements are provided in Section 21.1.2.
- 2.13.3. The Contractor shall establish a database to monitor the reliability of the cars, measured as Mean Distance Between Failures (MDBF), and Mean Distance Between Service Failures (MDBSF).

2.14. Overall Design Requirements

2.14.1. Subsystem Interfaces

- 2.14.1.1. The Contractor shall be responsible for the system design of the entire Unit and its equipment, for the proper interrelation and interdependence of all car subsystems and their proper interfacing.
- 2.14.1.2. For each system/subsystem, the interface details shall be completely documented, such that future equipment purchases from alternate sources shall be possible.

- 2.14.1.3. The interface documentation shall be maintained and updated throughout the design, manufacturing, test, and until the design ceases to change, so that the document always reflects the best information regarding the interface.
- 2.14.1.4. The interface documentation shall include as a minimum the following items:
- a) Mechanical: outline, attachment, shock, vibration, mounting hardware;
 - b) Power: type (AC/DC) and quality, load (starting, in-rush and steady-state), power factor where applicable, protective devices;
 - c) Pneumatics: control definitions, measurement definitions, air consumption, air quality;
 - d) Electrical Control: local, trainlined, signal definition, pin assignments (electric portion, connector, etc.), response characteristics;
 - e) Software Interface: data definition, protocols, response characteristics;
 - f) Weather Environment: temperature, humidity;
 - g) Electromagnetic Compatibility: emissions, susceptibility;
 - h) Diagnostic Interface: data storage, data retrieval, test procedures; and
 - i) Networks: Car control and Diagnostics.
- 2.14.1.5. Interface characteristics appropriate to specific systems/subsystems shall be added to the above list as necessary to provide a full interface definition.

2.14.2. Illuminated Indicators

- 2.14.2.1. All illuminated indicators, other than those on the Train Operating Display (TOD), shall be LEDs except where otherwise approved by NYCT.
- 2.14.2.2. LED indicators shall be clusters of LEDs, (minimum of two LEDs with parallel circuit branches), depending on the requirements of the application, including brightness and safety.
- 2.14.2.3. Indicators shall be clearly visible and comfortable to the eye, in all light conditions (sunlight and darkness).
- 2.14.2.4. In order to identify LED failures, each LED or group of LEDs shall have a push-to-test switch located conveniently near the LED or group, unless otherwise approved by NYCT.
- a) For cab indicators, this function shall be provided as described.
 - b) For subsystems, as an alternate, when power is cycled to a subsystem, the related LEDs on that subsystem shall be all powered up momentarily in lieu of a push to test button.
- 2.14.2.5. Indicator colors shall be based on function as follows:
- a) Red shall be used to annunciate failures or inoperative conditions. Red shall also be used to indicate a restrictive condition or to annunciate a function that has been bypassed.
 - b) Yellow or amber shall be used for warnings. The illumination of a yellow or amber indicator does not necessarily indicate a failure; however, the condition may require close observation by a Train Operator or other personnel.
 - c) Green shall be used to indicate the normal state of a device or system. Whether illuminated or not, no failure shall be indicated by the green indicator.
 - d) Any new indicators or lamps shall have their color submitted to NYCT for review and approval.

2.14.3. General Control Circuits

Bypass and Cutout Circuits - Hardwired

- 2.14.3.1. Some control circuits will include bypass switches and cutout switches. These switches will allow the Operator, or other personnel, to override or disable certain functions. A bypass switch is used when equipment (a door interlock, for example) has failed. A cutout switch is used when equipment is to be disabled.
- 2.14.3.2. Unless specifically noted otherwise, all bypass and cutout circuits shall have the following features:
- An indicator shall be illuminated while the corresponding bypass function is engaged.
 - All bypass switches must include provisions for NYCT approved wire or plastic seals.
 - The following bypass functions shall be monitored on the car, and logged on the Event Recorder and Monitoring and Diagnostics System: Brake Release, CBTC, and Door Interlock.
 - Bypassed functions for Brake Release and Door Interlock shall reset on operator key-out or command. CBTC Bypass shall follow standard NYCT operating practices.
 - Cutout functions initiated by train crew shall be reset by crew command only.

Software and Touch Screen Bypass and Cutout Functions

- 2.14.3.3. Subject to NYCT approval, certain non-safety-related cutout and bypass functions may be implemented by means of the touch screen display(s) in the cab, utilizing the same principles as for hardwired circuits.

Automatic Fault Reset

- 2.14.3.4. Fault detection circuits and devices shall be configured to electrically reset using a manual switch, or automatic reset, or both, as specified for the application.
- 2.14.3.5. Automatic resets shall not be applied to safety-related functions.
- 2.14.3.6. All automatic resets shall be configured as follows:
- No reset shall be allowed while the fault is still detected.
 - There shall be an NYCT approved delay before an automatic reset.
 - The circuitry shall allow for an adjustable number of automatic resets, after which the system shall lock out all resets, requiring a manual reset action at the auto reset device.
 - Reset logic shall eliminate resets of progressively worse faults, thereby protecting equipment from increased damage.
 - The automatic reset device shall retain memory of the number of resets and memory of lockout status during control power interruptions.
 - Memory of the number of resets and memory of lockout status shall be retained until it is either reset or overwritten.
 - To prevent random, unrelated trips from causing a lockout, the automatic reset device shall have a count reset.
 - This count reset shall not function if the automatic reset device has reached the lockout stage.
 - The mechanism for causing a count reset shall be approved by NYCT on a case-by-case basis and in some cases will not be utilized.
 - The automatic reset device shall display the number of resets it has accumulated.

2.14.4. General Maintainability Design Requirements

- 2.14.4.1. Maintainability performance requirements are provided in Section 21.2.
- 2.14.4.2. Maintainability design shall make maximum use of Line Replaceable Units to effect repairs or maintenance, allowing unit exchange to minimize Unit downtime.

- 2.14.4.3. Human interfaces with all equipment shall be designed in accordance with the requirements of MIL-STD-1472, paragraphs 5.1 through 5.9.
- 2.14.4.4. Control equipment shall be mounted underfloor or with the equipment being controlled, unless approved by NYCT.
- 2.14.4.5. Equipment boxes shall be mounted to allow adequate space for maintenance and removal of the boxes from the car.
- 2.14.4.6. Access covers shall be provided where access to lights, switches, breakers, PTE ports, maintenance indicators, fluids, filters, or other devices requiring maintenance is required.
- 2.14.4.7. Wiring entrances for underfloor equipment boxes shall be no more than 8 inches (0.2 m) from the top of the box roof, except as otherwise approved.
- 2.14.4.8. Wiring entrances for interior boxes shall be at least 8 inches (0.2 m) above the floor.
- 2.14.4.9. All equipment shall be designed for removal by provision of handles, lifting eyes, lugs or pads, unless otherwise approved by NYCT.
- 2.14.4.10. Assemblies or components that are functionally interchangeable shall be physically interchangeable without additional adjustment, unless otherwise approved by NYCT.
- 2.14.4.11. Modules or plug-in assemblies that are not functionally interchangeable shall not be physically interchangeable and shall be shaped or keyed to prevent incorrect application.
- 2.14.4.12. Lowest Level Replaceable units (LLRUs) shall be arranged by function and grouped so as to simplify diagnostic procedures and facilitate replacement.
- 2.14.4.13. All enclosure and Lowest Replaceable Unit (LRU) mounting arrangements must meet the requirements of Section 15.15. Alternate means of mounting LRUs that allows removal and replacement with basic hand tools may be submitted for NYCT approval.
- 2.14.4.14. LLRUs at all levels of assemblies and subassemblies shall be mounted so that the mounting hardware is completely accessible with standard tools, unless otherwise approved by NYCT.
- 2.14.4.15. Wire harnesses, pipes, support brackets and other appurtenances shall not obstruct mounting hardware.
- 2.14.4.16. Replaceable components within a LRU shall not be "stacked" in such a way that one component must be removed to access another, without NYCT approval.
- 2.14.4.17. Terminal board hardware for terminals of the same size range shall be standardized throughout the Unit.
- 2.14.4.18. All panels, covers, light lenses etc. which are hinged and can swing free shall be equipped with NYCT approved safety chains which retain the cover from swinging free should the securing devices not be correctly engaged.

2.14.5. Adjustments

- 2.14.5.1. Electrical adjustments are permitted only with NYCT's approval.
- 2.14.5.2. Mechanical adjustments will be allowed only to compensate for a device's manufacturing tolerances and wear.
- 2.14.5.3. Once adjusted, like-assemblies shall be interchangeable without further adjustment. If not possible, the number of adjustments shall be minimized. When interchanged, all required safety and operational inspections shall remain as prescribed in Maintenance and Overhaul Manuals.
- 2.14.5.4. Mechanical adjustments shall occur in fixed, discrete steps using serrations, notches, pins or similar schemes to ensure positive adjustment retention.
- 2.14.5.5. Mechanical adjustments shall include positive locking devices.
- 2.14.5.6. Mechanical adjustments with threaded members and jam nuts are permitted only with NYCT approval.

2.14.5.7. Software adjustments shall comply with Section 18.6.

2.14.6. General Diagnostic Requirements

2.14.6.1. Each intelligent (microprocessor-based) subsystem shall incorporate its own diagnostic functionality and shall report a subset of the stored diagnostic data to the MDS, as approved by NYCT.

2.14.6.2. When a subsystem lockout occurs, it shall report the possible corrective measures and enough detail to the MDS to enable the maintainer to pinpoint the fault.

2.14.6.3. Intelligent subsystems shall incorporate internal self-testing, diagnostics and fault logging to support car commissioning, revenue operations and ongoing maintenance.

2.14.6.4. The following diagnostic data shall be stored in the resident memory of each intelligent subsystem for a minimum of 72 days between periodic maintenance without losing data to overwrites:

- a) Failure Indications: All failures during operation or self-test shall be recorded.
- b) Diagnostic Documentation: All parameters associated with failure indications and exception reporting shall be clearly documented. This includes the identification of the parameters, the relationship(s) among parameters, filtering, time delays, levels, counting and reset requirements.
- c) Historical Data Storage: All subsystem diagnostic data shall be stored in a non-volatile memory. Records shall include time stamp, condition and associated data.

2.14.6.5. An LED display on each system and LRU, as selected by NYCT, shall allow visual verification of the health of the system/LRU without the use of either the MDS or a PTE.

2.14.6.6. All nodes on the network shall collect summary statistics regarding current and historical error rates and make that information available through the Monitoring and Diagnostic System (MDS).

Snapshots

2.14.6.7. Each intelligent subsystem shall have the capability to record snapshots of relevant system parameters for an appropriate time period and at an appropriate sampling rate for selected faults. Parameters, time periods, and sampling rates shall be determined during Design Review for each subsystem.

2.14.6.8. Snapshots may also be triggered by configured events.

2.14.6.9. The snapshot data from any subsystem shall be retrievable using a PTE.

2.14.6.10. The Contractor shall provide software on the PTEs that shall allow the maintenance personnel to configure for each subsystem:

- a) The events or faults which trigger snapshots.
- b) The data which is captured.
- c) The amount of time which the snapshot covers.
- d) The sampling rate (within the limits of the system capability).

2.14.6.11. This same software shall also allow retrieval of the data and its display in a chart recorder mode.

2.14.6.12. The contractor shall submit the snapshot capabilities of each subsystem for NYCT's approval.

2.14.7. Design for Obsolescence Management

2.14.7.1. The design of the cars, and supporting documentation, provided by the Contractor shall enable NYCT to easily replace components which become obsolete during the life of the car with equivalent components

that meet design standards current at the time of replacement. Design shall follow the principals established in IEC 62402 – Obsolescence Management.

- 2.14.7.2. The Contractor shall identify, evaluate, and select components that are less likely to be affected by obsolescence and that are expected to have a long design life.
- 2.14.7.3. All interfaces between a piece of equipment and the car shall be clearly documented, as required by Section 2.14.1.
- 2.14.7.4. The car and Unit networks shall be of open source design, facilitating “plug and play” replacement of units which are connected to the network, as required by Section 16.
- 2.14.7.5. All software functions shall be fully documented, as required by Section 18.4.
- 2.14.7.6. The Contractor shall submit an Obsolescence Management Plan (OMP) which covers the entire car, with specific OMPs for each subsystem **[CDRL]**. As a minimum, the OMP shall contain:
 - a) Review of components used which could cause a negative impact to on-going NYCT operation if they were to become obsolete before the design life of the car or equipment in which they are located, and evaluation of their anticipated supply life.
 - b) Highlighting any components used which have a high risk of obsolescence during the life of the cars or equipment in which they are located.
 - c) Recommended mitigation strategy for high risk components (e.g. last time buy on a certain date, design for replacement with newer technology).
 - d) Monitoring plan for all components, and means to provide warning to NYCT of impending obsolescence.

2.15. Validation Requirements

2.15.1. Vehicle Dynamic Analysis

- 2.15.1.1. The Contractor shall prepare a three-dimensional dynamic simulation model that shall be used to analyze the performance of the vehicle for safety against derailment during low speed curving, and freedom from truck hunting at speeds up to 66 mi/h (29.5 m/s), in addition to compliance with the ride quality and clearance requirements of this Specification.
- 2.15.1.2. The Contractor shall perform static and dynamic tests on NYCT property or approved test tracks to validate the model.
- 2.15.1.3. Prior to performing the analysis, the Contractor shall submit a description of the dynamic simulator for NYCT approval. **[CDRL]**
- 2.15.1.4. The Contractor shall prepare a final report of the results of the dynamic simulation in accordance with this Section. **[CDRL]**
- 2.15.1.5. NYCT approval of the final report shall be required prior to approval of the truck drawings.
- 2.15.1.6. The fully configured model and the characteristics used to build the numerical model shall be delivered to NYCT no later than delivery of the first vehicle. **[CDRL]**
- 2.15.1.7. This analysis shall be used to satisfy the ride quality, stability, and low speed curving requirements found in Section 2.10.
- 2.15.1.8. Safety against derailment shall be demonstrated by an analysis that includes the evaluation of:
 - a) New and worn wheels, resulting in the maximum Effective Conicity.

- b) The worn wheel profile shall be any profile not condemnable by current NYCT practice.
- c) Variations in suspension stiffness that reflects the anticipated range that would be used in practice.
- d) Variations in damper characteristics that reflect the reduction in damping during the damper's life.

2.15.2. EMC Compliance and Safety Analysis

- 2.15.2.1. The Contractor shall develop an EMC Plan (EMCP) compliant with Section 2 of the ES.
- 2.15.2.2. The Contractor shall submit a draft EMCP for approval. [CDRL] Unless otherwise directed by NYCT, the approved EMCP shall serve as the final EMCP.
- 2.15.2.3. The Contractor shall provide an EMC Design Report compliant with Section 5 of the ES. [CDRL] The Design Report shall cover power, acoustic and radio frequencies, as appropriate.
- 2.15.2.4. Final approval of EMC compliance will be based on testing of full trains (2 Units), under worst case conditions on the actual NYCT right of way, as defined in Section 24 – Test Program.
- 2.15.2.5. The Contractor shall submit for approval an EMI safety analysis as specified in ES Section 4.1. [CDRL]
- 2.15.2.6. The safety analysis shall comply with all applicable requirements referenced in Section 21.3 of this Specification.
- 2.15.2.7. The safety analysis must also include any equipment used for self-testing in areas that affect EMI.
- 2.15.2.8. The Contractor shall submit a preliminary description of the EMI Detector, if used as part of the EMC plan, for approval. [CDRL]
- 2.15.2.9. The Contractor shall submit a document describing the detailed EMI Detector design, if used, as referenced in ES Section 4.2 for approval. [CDRL]
- 2.15.2.10. The EMCP shall document subsystem testing requirements for EMC compliance as provided in IEC 60571. For each subsystem, the emission and immunity aspects of EMC shall be consistent with IEC 62236-3-2.
- 2.15.2.11. The EMCP shall list test scope and applicable susceptibility criteria for each subsystem, including any clarifications and deviations from the test setting and procedures outlined in respective standards.

2.15.3. Subsystem Interfaces

- 2.15.3.1. A summary drawing defining the relationship between subsystems shall be presented for NYCT review.

2.15.4. Crash Energy Management Analysis

- 2.15.4.1. Crash Energy Management of the train set shall be validated by crashworthiness analysis and testing. An approved crashworthiness analysis shall be a prerequisite for approval of crashworthiness testing. [CDRL]
- 2.15.4.2. The crashworthiness analysis shall be performed using a nonlinear large deformation explicit finite element software program. The software program shall be LS-DYNA, ABAQUS or NYCT approved equal.
 - a) Lumped mass features may be used in the finite element model for the vehicle structure and mass located away from the crush zone(s) and the adjacent passenger area.
 - b) Other train elements such as the coupler and link bars may be rigidly modeled with the appropriate force-displacement characteristics.
 - c) The simulation(s) shall be initiated with sufficient time prior to impact to allow gravitational and braking loads to develop.
 - d) The coupler shall be configured in a typical service condition.
 - e) The simulation (collision) may be stopped when the velocities of all of the cars are the same when measured at or near the centers of gravity (i.e. no residual relative velocities).
- 2.15.4.3. All scenarios required in Section 2.8 shall be simulated.

- 2.15.4.4. Additional simulations for the test conditions described in Sections 3.6.18 and 3.6.19 shall also be performed.
- 2.15.4.5. The results of the train to train simulations shall demonstrate compliance with the performance requirements described in Section 2.8. Key results from the finite element simulations shall, at a minimum, include:
- Force versus displacement curves for all non-recoverable crash energy absorption structure and components.
 - Energy absorption versus time for all crash energy absorbing structure and components.
 - Deformation plots after the collision stops.
 - Animations or static displays of animation frames showing progressive crushing.
 - Velocity of each car versus time curves.
 - Acceleration of each car versus time curves.
 - Energy data shall be included to demonstrate conservation of momentum, conservation of energy balance and minimization of computational energy loss, such as might be caused by computational element deformation (hourglass energy).
 - Displacement versus time curves for key components and structure, as necessary, to demonstrate compliance with performance requirements described in Section 2.8.

2.16. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
2-1	2.2.4.1	Identification system for equipment and components on Units and cars	CDR
2-2	2.5.1.4	List of recommended cleaning agents	CDR
2-3	2.11.1.9	EMI detector FMECA, FTA, and HSA	CDR
2-4	2.14.7.6	Obsolescence Management Plan	CDR
2-5	2.15.1.3	Description of the dynamic simulator	Prior to analysis*
2-6	2.15.1.4	Final report of the results of the dynamic simulation	Prior to approval of the truck drawings
2-7	2.15.1.6	Fully configured dynamic simulation model and the characteristics used to build the numerical model	Delivery of the first vehicle*
2-8	2.15.2.2	Draft EMC plan	PDR
2-9	2.15.2.3	EMC Design Report	CDR
2-10	2.15.2.5	EMI safety analysis	CDR
2-11	2.15.2.8	Preliminary description of the EMI Detector, if used	PDR

2-12	2.15.2.9	Detailed EMI Detector design	CDR
2-13	Not used	Not used	Not used
2-14	2.15.4.1	Preliminary Crashworthiness plan	PDR
2-15	2.15.4.1	Preliminary Crashworthiness analysis	IPDR

* - Simulation may be waived if the design can be shown to be close to an existing design proven on the NYCT system.

Section 3

Carbody Structure

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3. Carbody Structure

3.1. Introduction and General Requirements

3.1.1. This section defines the requirements for the carbody structure for the cars. The requirements are categorized into Performance, Functional, Design, Maintainability, and Validation.

3.1.2. Refer to the following sections for car systems and components interfacing with the carbody structure:

- a) Design and Performance Criteria – Section 2.
- b) Cab and Cab Controls – Section 5.
- c) Side Door System – Section 6.
- d) Heating, Ventilation, and Air Conditioning (HVAC) – Section 7.
- e) Trucks and Suspension System – Section 11.
- f) Carbody Equipment and Interiors – Section 15.
- g) Materials, Processes, and Workmanship – Section 19.

3.2. Performance Requirements

3.2.1. General

- 3.2.1.1. The carbody structure shall meet all of the requirements of this section and all of the applicable system design and performance requirements defined in Section 2, Design and Performance Criteria.
- 3.2.1.2. The framing and sheathing of the carbody shall form an integrated (semi-monocoque) structure capable of withstanding the specified static, dynamic, and fatigue loads in this section without exceeding the specified margins of safety.
- 3.2.1.3. All equipment mountings shall meet the specific static, dynamic, and fatigue loads, without exceeding the specified margins of safety.
- 3.2.1.4. Whenever yielding or permanent deformation limits are specified, it shall be understood that stability considerations, such as column or plate buckling shall be considered. Elastic buckling is acceptable except for operating load cases and all vertical load cases.
- 3.2.1.5. Carbody deflection shall be limited to prevent loss of watertightness in structural sealing elements and equipment seals (glazing, HVAC sealing, end bonnets, end (storm) doors), and to maintain safe and proper side door operation and other system and sub-system functionality under all carbody design loads, excluding those specified for diagonal jacking.
- 3.2.1.6. The carbody and all attached equipment shall allow a minimum of 1.5 inches (38 mm) clearance from rigid truck components and 0.5-inch (13 mm) clearance for flexible components (except cases where stops are used for limiting truck movement or for truck lifting, and where the carbody is titled for disassembling a truck).
- 3.2.1.7. The carbody shall be designed using Crash Energy Management (CEM) principles to absorb the kinetic energy of the crash impact to minimize secondary passenger collisions due to car deceleration.
- 3.2.1.8. The carbody shall be designed for a controlled crush starting at the ends of the car under the collision scenarios defined in Section 2.8.2. The design of the CEM system shall ensure compatibility with the minimum specified (yield and buckling) values for design loads in this section.
- 3.2.1.9. Carbody structural assemblies shall fail by buckling or crushing of structural elements and not by shearing of structural elements, or by failure of connections between elements.

3.2.2. Fatigue Strength

- 3.2.2.1. The fatigue design shall be based on applied and allowable fatigue stress ranges at 10 million cycles for a constant amplitude design.
- 3.2.2.2. The applied fatigue loads and dynamic load factors shall be determined by the Contractor. Dynamic load factors shall not be less than $\pm 0.20 g$, $\pm 0.15 g$, and $\pm 0.20 g$ in the vertical, lateral, and longitudinal directions, respectively.
- 3.2.2.3. Longitudinal fatigue loading shall be applied through the coupler and drawbar mounting attachment points. Loads applied to the carbody based on traction and braking forces shall be considered in the fatigue loading.
- 3.2.2.4. The Contractor may propose a cumulative damage approach for fatigue design validation, based on 10 million cycles, including Contractor proposed load values and number of individual loading cycles. The cumulative damage analysis proposal shall be subject to NYCT review and approval.
- 3.2.2.5. The minimum margin of safety shall be positive for base metal and 0.15 for all connections.
- 3.2.2.6. The design fatigue stress range for vertical, lateral, and longitudinal loading shall be computed by multiplying the static stress at the AW3 load by the dynamic factor (fatigue load range). The computation of the design fatigue stress range shall be proposed by the Contractor and approved by NYCT.
- 3.2.2.7. The computed design fatigue stress range must be within the design fatigue stress range (fatigue limit) obtained either from AAR C-II, Section 7.2, or AWS D1.1. The applied fatigue stress range shall be approved by NYCT.
- 3.2.2.8. For arc-welded joint designs not covered by AAR C-II, Section 7.2 or AWS D1.1 the Contractor may propose alternative, industry proven standards for approval by NYCT on a case by case basis only. The Contractor shall demonstrate prior application of the proposed standard; the selected design life shall meet the requirements of this section.
- 3.2.2.9. The allowable fatigue values for spot welds and mechanically fastened joints shall be established by the Contractor via published data or fatigue tests, and shall be approved by NYCT.

3.2.3. Vertical Loading

- 3.2.3.1. The complete, ready-to-run carbody shall withstand, combined:
 - a) A load factor of 1.6 applied to its AW0 carbody weight (not including truck weight).
 - b) Uniformly distributed passenger load equal to the passenger portion of AW3 load.
 - c) An allowance for vertical impact of 30 percent of the total AW3 carbody including passenger weight, with the passenger load distributed uniformly.
- 3.2.3.2. Under this loading, the stresses in the carbody, including the carbody bolster, shall not exceed the lesser of 80 percent of the guaranteed minimum material yield strength or the buckling strength of any carbody element.

3.2.4. Compression Loading

- 3.2.4.1. With an AW0 vertical load and a compression load as required to satisfy the CEM performance requirements of Section 2.8, but in any case not less than 200,000 lb. (888 kN), applied at the horizontal and vertical center of the end sills and distributed over an area not greater than 12 inches (305 mm) wide, the carbody maximum stress in any member shall not exceed:
 - a) The yield stress, or the critical buckling stress outboard of the bolster, or
 - b) 90 percent of the yield, or critical buckling stress between the bolsters, or the proportional stress limits required to sustain loads from the CEM system without permanent deformation.

- 3.2.4.2. With an AW0 vertical load and a compression load of 120 percent of the coupler automatic overload release force or 300,000 lb. (1,334 kN), whichever is greater, applied longitudinally to the coupler pivot, the carbody maximum stress in any material shall not exceed the yield (tension or compression), the critical buckling stress, or the allowable shear stress.
- 3.2.4.3. Equipment loads shall be applied concurrently to the end sill and coupler compression loads based on the following loading factors applied to the weight of the equipment supported at the mounting points simultaneously:
- Vertical: 1.00 g.
 - Lateral: 0 g.
 - Longitudinal: ± 2.00 g.
- 3.2.4.4. For the purposes of preparing the required calculations associated with the validation cases specified in Sections 3.6.12 and 3.6.13, the Contractor may calculate the stresses due to equipment loads separately and superimpose the results as required.
- 3.2.4.5. The specified allowable stress limits shall not be exceeded in any structural members, sheathing, roof skins, or their fasteners when subject to the compression loadings specified above.
- 3.2.4.6. The vertical deflection of each side of the shell with respect to the body bolsters at the outer-bottom edge of the side sill shall not differ from the analytically determined value by more than ± 10 percent when subject to the compression loadings specified above. Reference Validation Sections 3.6.12 and 3.6.13.

3.2.5. Lateral Combined Loading

- 3.2.5.1. The carbody shall withstand lateral loads applied to the carbody resulting from operating on a non-super elevated curve at the minimum track radius contained within Appendix C-5 ("Track Standards and Reference Manual MW-1"), at a speed which applies the entire weight of the car, including trucks and AW3 passenger load to the four wheels on the outside rail.

The following loads shall be applied concurrently with the lateral load to generate a worst case loading condition.

- Dead load of a complete, ready-to-run AW0 carbody.
- A uniformly distributed passenger load varying from AW0 to AW3.
- A vertical impact equal to 30 percent of the sum of the carbody dead load per Section 3.2.5.1 a) and the passenger load per Section 3.2.5.1b).
- A longitudinal buff or draft of 50,000 lb. (222 kN) applied at the centerline of the coupler faces, or at the link bar pivot.

Under the specified loading the maximum allowable stresses in the carbody structural members, their attachments, and supporting structures shall not exceed 80 percent of the minimum material yield stress or the buckling stress.

3.2.6. Transverse Loading

- 3.2.6.1. The carbody structure shall resist inward transverse loads of 40,000 lb. (178 kN) applied independently over an area of 96 inches (2,438 mm) by 6 inches (152 mm) anywhere along the side sill, and 10,000 lb. (44 kN) applied anywhere along the belt rail (the horizontal rail member at the bottom of the window openings in the side frame).
- 3.2.6.2. The allowable stress shall be the lesser of yield or the critical buckling stress.
- 3.2.6.3. Local yielding of the side skin adjacent to the side sill and belt rail is permitted.

3.2.7. Camber

- 3.2.7.1. The camber shall remain positive with the car at AW3, and shall not exceed 0.625 inch (16 mm) at AW0.
- 3.2.7.2. The vertical deflection of a complete, ready-to-run car under AW3 passenger load shall be no more than 0.375 inch (9.5 mm) from the AW0 condition.
- 3.2.7.3. All car equipment shall be fully operational and shall not bind due to deflection caused by variations of load from AW0 to 105 percent of AW3.
- 3.2.7.4. The maximum difference between the camber of each side sill shall not exceed 0.125 inch (3.2 mm), measured at the location of maximum deflection.

3.2.8. Natural Frequency

- 3.2.8.1. The natural frequency of the carbody under a uniformly distributed AW3 passenger load, and on its bolster suspension points, when considered as a free-free beam, shall be greater than or equal to 2.5 times the natural frequency of the truck secondary suspension, or 4.5 Hz, whichever is greater.
- 3.2.8.2. The natural frequency of the carbody and secondary suspension system shall be adequately separated from the primary bounce frequency of the truck primary suspension to avoid excitation in the carbody and secondary suspension system under all modes of normal operation.

3.2.9. Anti-Climber

- 3.2.9.1. The anti-climber and its attachment design shall withstand a 75,000 lb. (333 kN) vertical load in either direction combined with a minimum longitudinal compression load equal to the end sill compression load applied at the carbody centerline, without permanent deformation of structural members or structural sheathing. Localized plastic deformation of the anti-climber is permitted.
- 3.2.9.2. One rib less than the total number of ribs on the anti-climber shall be used in computing and testing the vertical strength of the anti-climber. The direction of vertical offset, up or down, shall not result in different performance.

3.2.10. Collision Posts

Primary Center Collision Post

- 3.2.10.1. The load capacity of each primary center collision post, when loaded in a horizontal plane at a point 18 inches (457 mm) above the top of the underframe and within 15° of either side of the longitudinal axis of the car, shall be 33 percent of the end sill compression load or a minimum of 66,000 lb. (293 kN) without permanent deformation of any part of the carbody.
- 3.2.10.2. The ultimate horizontal shear strength of each primary center collision stub post shall be the greater of 200,000 lb. (890 kN), or the strength required to comply with the CEM requirements, when the load is applied in any direction within 15 degrees of the longitudinal axis of the car at a point even with the top of the underframe to which the posts are attached.
- 3.2.10.3. The shear strength for the collision posts shall be based on the area of the web, which is the depth of the member, in the direction parallel to the applied load, times the web thickness, times the ultimate shear strength of the material ($0.577 \times$ ultimate tensile strength). This shear strength shall extend to the bottom of the end underframe.

Primary Side Collision Post

- 3.2.10.4. Primary side collision posts shall withstand separately applied loads consisting of an inward horizontal load of not less than 42,000 lb. (187 kN) in the longitudinal direction and not less than 21,000 lb. (93 kN) in the transverse direction, both applied 18 inches (457 mm) above the top of the end underframe. Under these loads there shall be no permanent deformation of any carbody structure.

- 3.2.10.5. The ultimate horizontal shear strength of each primary side collision post, in the longitudinal direction at the level of the top of the end underframe, shall be not less than 75,000 lb. (334 kN) at the cab end and at least 50,000 lb. (222 kN) at the non-cab end. This strength shall be carried to the bottom of the end underframe.
- 3.2.10.6. The ultimate horizontal shear strength of each primary side collision post in the transverse direction shall be not less than 52,000 lb. (231 kN) for the cab end, and 35,000 lb. (156 kN) for non-cab end. This strength shall be carried to the bottom of the end underframe.
- 3.2.10.7. Not used.
- 3.2.10.8. Not used.
- 3.2.10.9. Not used.

General Requirements

- 3.2.10.10. Connections and supporting structure at the tops of the collision posts shall develop sufficient horizontal, vertical and bending strength so that if a one or more adjacent primary posts are overloaded in bending to ultimate strength, the post top connections and supporting structure, if stressed beyond their yield strengths by the resulting horizontal, vertical, and bending loadings, shall deform plastically by buckling and bending of the members to accommodate the post-plastic bending failure.
- 3.2.10.11. The top collision post connections shall not fail, even with severe plastic deformation of the collision posts and the supporting structural elements.
- 3.2.10.12. When one or more posts are overloaded, the initial failure shall begin as bending or buckling in the post(s) or in the end underframe.
- 3.2.10.13. Overload of collision post bottom connections shall result in buckling and crushing of the underframe structural members to which the collision posts and any collision post reinforcements are attached, and shall not result in shearing or fracturing of the posts.
- 3.2.10.14. The ultimate load carrying capacity of the post shall be defined as the condition where the post cannot support an increased load and the center of the post has deflected more than one-third its full depth. The deflection shall be measured at the middle of the post and referenced from a straight line between the top of end underframe at the post attachment and the bottom of the anti-telescoping plate at the upper post attachment. The deflected shape shall be measured without load applied. See Section 3.6.17 for performance validation requirements related to the center collision post elastic-plastic load case.
- 3.2.10.15. Ultimate failure shall occur in the post(s), and shall not be in the underframe or roof, nor in the connection to the roof or underframe; nor shall the failure be by shearing or fracturing of any structural member.
- 3.2.10.16. If the ultimate load carrying capacity of the post is greater than specified, the design of the supporting structure must be adjusted to balance this increased capacity.
- 3.2.10.17. Where required by the CEM analysis, the carbuilder may provide secondary posts that act to stabilize the underframe structure when participating in energy absorption. If used, these posts shall be connected from the floor to the roof structure that is sufficiently sized to sustain the transferred loads.

3.2.11. Structural Shelf

- 3.2.11.1. The structural shelf on the cab end shall support a longitudinal load of 15,000 lb. (67 kN) applied anywhere along the span between the primary center collision post and primary side collision post, without permanent deformation of any part of the car structure.
- 3.2.11.2. Non-cab end structural shelves shall consider potential horizontal loads generated in collisions.

3.2.12. Roof

- 3.2.12.1. All parts of the roof structure and sheets, equipment covers, roof walkway, screens, and other guards shall have sufficient strength to withstand, without permanent deformation, the load imposed by a mechanical car washer, consisting of a pressure of 60 pounds per square foot (2,873 kPa) over a 12-inch (305 mm) wide band extending transversely across the carbody.
- 3.2.12.2. All parts of the roof structure and sheets, equipment covers, roof walkway, screens and other guards, with the exception of the HVAC unit frame and cover and the screen over the condenser fan, shall have sufficient strength to withstand, without permanent deformation, the load imposed by maintenance personnel carrying tools and equipment while working on the roof, consisting of three concentrated loads of 250 lb. (1,112 N) with a footprint of 6 square inches (3871 mm²) spaced 30 inches (762 mm) apart.

3.2.13. Floor

- 3.2.13.1. Strength requirements of the carbody floor shall consider a car floor loaded to simulate a uniformly distributed AW3 passenger load in a complete, ready-to-run interior.
- 3.2.13.2. The floor beams shall not deflect by more than 0.4 percent of the span between supports, defined as the center of the connection fastening elements, measured at the point of maximum deflection.
- 3.2.13.3. The maximum stress in the floor beams shall be less than 50 percent of the critical buckling stress or 50 percent of the yield strength of the material, whichever is less.
- 3.2.13.4. The complete floor system shall allow the noise and vibration requirements of Section 2.9 to be met.
- 3.2.13.5. Fire endurance rating requirements of Sections 19.1.10.17 and 19.1.10.18 shall be met by the floor design. The floor design shall be confirmed to meet the fire endurance rating requirements prior to the Contractor's procurement of production material.
- 3.2.13.6. Subfloor pans shall remain attached for the duration of the floor fire test specified in Section 19.1.10.17.
- 3.2.13.7. Subfloor pans, if used as shear panels or stiffeners, shall withstand all static carbody loads, lifting loads, and diagonal jacking without permanent deformation such as buckling between attachment points or separation of attachment points.
- 3.2.13.8. The floor panels shall not deflect more than 0.4 percent of the shortest span between supports, up to a maximum of 0.094 inch (2.4 mm).
- 3.2.13.9. The floor panels shall not sustain any permanent deformation during the design life of the car, and shall be designed to withstand the specified loading without exceeding 50 percent of the yield stress of the flooring material.

3.2.14. Equipment Supports

Fatigue Design Loads

- 3.2.14.1. Under the loading specified, all carbody mounted equipment supports, regardless of mounting location, and any portion of the equipment carbody to which the equipment supports are attached shall not exceed their fatigue limit for the design life of the car. Fatigue life shall be demonstrated by analysis. The allowable stresses and margins of safety shall be per Section 3.2.2. Where multiple equipment is connected to the same structural member, the effects of the combined loading shall be considered in the analysis.
- 3.2.14.2. Fatigue design loads shall consider equipment loads generated from the shock and vibration environment denoted in Section 2.9.6 and loads due to equipment with rotating mass.

Static Design Loads

- 3.2.14.3. In no case shall the supports and the structure to which they are attached withstand equipment loads less than those considering the following load factors:

- a) 5 in the longitudinal direction, forward and aft.
 - b) 3 in the vertical direction, upwards and downwards.
 - c) 2 in the lateral direction, left and right.
- 3.2.14.4. Individual support loads shall be equal to the percentage of the weight of the component carried by the support multiplied by the appropriate load factor.
- 3.2.14.5. Specified tri-axial loadings shall be applied separately to the supports in their respective directions. For the vertical upward load, the weight of the equipment shall not be subtracted from the specified value. Under such loading, the strength of the member being investigated shall not exceed yield except in localized areas, and there shall be no ultimate failure or tear-out of the fasteners or failure of any electrical isolation materials within a joint, if used.
- 3.2.14.6. If any single support is removed from the analysis, the remaining supports shall withstand at least one-half of the value of the removed support loading without exceeding the ultimate strength of the remaining members.
- 3.2.14.7. The above requirements shall apply to the mounting brackets of all equipment boxes, equipment racks, or other structural members connecting equipment to the carbody. Where multiple equipment is connected to the same structural member, the effects of the combined loading shall be considered in the analysis and test.

Other Requirements

- 3.2.14.8. Structural connections in equipment supports shall be subject to the requirements of Sections 3.4.4 and 3.4.5.
- 3.2.14.9. Equipment support fastenings shall be designed so that the ultimate strength of the connection is not limited by the strength of the fasteners in any failure mode, by shearing or tear-out through the base metal, or by separation of the fastenings due to excessive deflection before reaching the ultimate strength of the load carrying members.
- 3.2.14.10. Equipment mounted to the underfloor, side, end, roof, in-roof, or interior portions of the carbody shall meet the shock and vibration requirements of Section 2.9.6.
- 3.2.14.11. Auxiliary stops utilized on resiliently mounted equipment, such as the air compressor, shall be capable of meeting service load conditions for a 72-day interval between maintenance inspections, while maintaining operational capability of the equipment.

3.2.15. Truck Retention

- 3.2.15.1. The strength of the truck to carbody retention shall be sufficient to resist an ultimate load of 150,000 lb. (667 kN) in any direction radial to the carbody center pin, applied at an elevation equal to the lowest point on the truck frame. All connections shall be subject to the requirements of Sections 3.4.3, 3.4.4 and 3.4.5. Retention strength shall be demonstrated by analysis.
- 3.2.15.2. Carbody to truck bolster and truck bolster to truck frame anchor rods shall not be used to provide any contribution to the strength of the truck connection in the analysis of ultimate truck retention load.
- 3.2.15.3. When the car is raised off the track, the carbody structure and the truck-to-carbody retention mechanism shall resist a load equal to two times the full weight of the truck without permanent deformation, regardless of truck rotation angle within the range of rotational stops.
- 3.2.15.4. The strength of carbody mounted bolster anchor brackets, if used, and the attachments to the carbody shall exceed that of the bolster anchor rods as described in Section 11.2.5.
- 3.2.15.5. Under overload conditions, the bolster anchor rods shall serve as a sacrificial element and fail without causing permanent deformation of the bolster anchor brackets, their attachment to the carbody, or of the carbody structure.

- 3.2.15.6. When a bolster anchor rod bracket installed on a car is loaded to failure from any horizontal direction anywhere in a zone from the lowest point on the bracket to one-half the distance from the lowest point to the centroid of the attaching fasteners, there shall be no permanent deformation of any part of the carbody structure.

3.2.16. Jacking and Lifting

- 3.2.16.1. Ready-to-run cars at AW0 shall be capable of being supported at one end by the jacking pads (without its truck attached), by the carbody drop table, while the other end is supported on its truck, without producing stresses greater than 75 percent of the yield point of the materials of the carbody structure.
- 3.2.16.2. Individual ends of assembled cars at AW0 may be jacked or hoisted at least 70 inches (1,778 mm) off the floor while the opposite end of the car remains on its truck. This action shall not produce stresses greater than 75 percent of the yield point of the materials of the carbody or jacking pad structure. Under this jacking condition, clearance shall be maintained between all surfaces of the car and the truck and all mounted components, including cabling and piping. Rotation of the truck that remains on the rail shall not be considered for this condition. Reference Section 3.4.19.5.
- 3.2.16.3. The carbody loaded to AW0, with trucks attached, shall be capable of being lifted at the corner jacking pads with two jacks at diagonally opposite corners of the shell without permanent deformation of the carbody or any part of the assembled car, or degradation of the water tightness of any glazing or other structural sealing elements. Structural performance shall be validated per Section 3.6.15 and watertightness shall be verified per the methodology of Section 24.9.2.
- 3.2.16.4. The assembled car at AW0, with trucks attached, shall be capable of being lifted with four jacks, one at each quadrant of the carbody under either the primary side collision post, bolsters, or inboard jacking pads, in any combination, without permanent deformation of the carbody or any part of the assembled car considering the load factors defined in Sections 3.2.16.5, 3.2.16.6 and 3.2.16.7.
- 3.2.16.5. Loads applied to jacking pads and their supporting structure shall consider a load factor of 2 based upon supporting AW0 car weight.
- 3.2.16.6. The vertical load on each jacking pad shall be combined with a horizontal load of 10 percent of the vertical load (including the load factor of two) applied in any horizontal direction.
- 3.2.16.7. The same load factors as above shall apply for lifting pads.
- 3.2.16.8. For any horizontal position of the coupler or link bar, the carbody shall withstand, without yielding, the loads imparted due to jacking of an AW0 car (for re-railing purposes) beneath the coupler or link bar. See Section 4.2.1.6.

3.3. Functional Requirements

3.3.1. End Underframe

- 3.3.1.1. The end underframe structure shall consist of the end sill, draft sill, body bolster, anti-climber, and collision post interface to the underframe sills and shall function to transfer loads generated from passenger loading, couplers, and equipment to the carbody and trucks. The end underframe shall contain all elements of the CEM system, configured as approved by NYCT.
- 3.3.1.2. The end sill shall transmit the required anti-climber loadings into the draft sill without exceeding the yield strength of the carbody structure.
- 3.3.1.3. The end sill shall transmit the loads from the primary center collision posts and primary side collision posts into the draft sill, including collision post shear loads, without separation, when the posts are loaded to their ultimate strength. If incorporated, the end sill shall transmit CEM loads without separation from all members attached under the CEM scenarios described in Section 2.8.2.

- 3.3.1.4. The draft sill shall extend longitudinally from the end sill to the body bolster and shall transmit the specified longitudinal loadings from the anti-climber and coupler into the body bolster. The draft sill shall transmit CEM loads without separation from all members attached under the CEM scenarios described in Section 2.8.2.
- 3.3.1.5. The body bolster shall transmit loads between the truck and the carbody, and between the draft sill and the body and side sills, including all induced, inertia, and secondary loading from the CEM scenarios described in Section 2.8.2.
- 3.3.1.6. Positive stops on the carbody and truck bolsters shall limit the vertical and transverse movement of suspended trucks when the carbody is lifted.

3.3.2. Anti-Climber

- 3.3.2.1. The anti-climber shall engage the anti-climber of an opposing car under the worst conditions of vertical and horizontal track curves with the same overlap as existing NYCT cars of the same length, and shall resist climbing forces between cars. Information on existing NYCT cars will be made available by NYCT upon request after Notice To Proceed (NTP).
- 3.3.2.2. The anti-climber shall be compatible with all existing NYCT B Division equipment and bumper blocks. Information on existing NYCT B Division equipment and bumper blocks will be made available by NYCT on request after NTP.

3.3.3. Side and Body Sills

- 3.3.3.1. The side sills shall function as a structurally continuous bottom chord for the side frame.
- 3.3.3.2. The side sills shall resist the combined vertical and longitudinal loads resulting from the specified static, transient, and dynamic design loads including those induced by the CEM scenarios in Section 2.8.2.
- 3.3.3.3. The side sills shall function as buffers to allow the car to withstand strikes due to lateral carbody movement against the station platform edge rubbing boards and their fasteners without structural damage to the car.
- 3.3.3.4. If used, center sills shall carry longitudinal loads through the underframe. Center sills shall consist of one piece and shall extend between body bolsters.
- 3.3.3.5. The side and center sills (if used) shall function as a component of CEM to ensure that energy absorption through buckling and crushing begins in the end sills and continues progressively inward. The side sill between the bolsters shall ensure passenger compartment integrity is maintained and shall not exhibit permanent deformation under CEM loads with the exception of highly localized deformation as allowed in Section 2.8.5.6.

3.3.4. Collision Posts

- 3.3.4.1. Collision posts shall function to prevent penetration into any passenger compartment in the event of a collision.

3.3.5. Structural Shelf

- 3.3.5.1. The structural shelf shall provide resistance to penetration of the cab or non-cab end frame in a collision.

3.3.6. Roof

- 3.3.6.1. Roof equipment arrangement design shall not permit accumulation of water or wayside debris (e.g., falling leaves). Drainage provisions shall be provided and shall be subject to NYCT approval.

3.3.7. Equipment Supports

3.3.7.1. Equipment or equipment supports shall not affect the controlled crushing of the structure under CEM collision scenarios in Section 2.8.2.

3.3.8. Truck Connection

3.3.8.1. Trucks shall be locked to the carbody in all directions. The engagement of truck locking elements, restraints, and lifting hooks shall not be dependent upon the rotational angle of the truck, regardless of rotational stops.

3.3.8.2. Center pins, if used to transmit traction and braking loads, shall transfer all shear and bending loads through direct bearing at its interface with the truck bolster, instead of attaching fasteners. The attachment of the center pin to the carbody structure shall be by lockbolts or as approved by NYCT.

3.3.9. Jacking and Lifting

3.3.9.1. The lifting and jacking pads shall allow the car to utilize the hoists, jacks, cranes with spanner rigging, and stands in use at any NYCT Maintenance Facility or wayside operation.

3.3.9.2. The jacking and lifting arrangement shall allow cars to be jacked or hoisted individually and as a Unit.

3.3.9.3. Trucks shall be retained with the body during jacking or hoisting unless intentionally disconnected as described in Section 11.5.1.5.

3.3.10. Gutters and Splash Guards

3.3.10.1. Gutters shall be applied to the car and shall function to collect and divert water from the roof edge.

3.3.10.2. Splash guards shall prevent rain water accumulated on the roof from flowing over the cab ends of cars, and between coupled cars.

3.3.10.3. If a corrugated roof is utilized, the splash guards shall function properly with water accumulation up to the maximum possible depth of the corrugation used.

3.4. Design Requirements

3.4.1. General

3.4.1.1. The carbody shall, at a minimum, consist of the roof, side frames, collision posts, underframe, and end frames.

3.4.1.2. The structural design shall be based on the specified loads and deflections. For structures not covered by this Specification, the design shall be based on the Contractor's experience, subject to successful stress analysis and testing.

3.4.1.3. The underframe, at a minimum, shall consist of two end underframes, two side sills, two body bolsters, and floor beams.

3.4.1.4. Center sills, if used, shall be continuous between body bolsters. There shall be collision posts at the ends of the carbody shell.

3.4.1.5. Two primary center collision posts shall be located on each end of each car and two primary side collision posts shall be located at each corner of the car.

3.4.1.6. Not used.

3.4.1.7. Secondary center posts may be provided for the purposes of stabilizing the end underframe structure under CEM loads. The spacing of these posts shall not prevent wheelchair passage (for emergency evacuation) and the finished door opening shall be in conformance with 49 CFR 38.53.

- 3.4.1.8. A structural shelf shall be provided on both sides of the cab end frame.
- 3.4.1.9. Portions of the roof, side frame, and underframe shall be designed to form a modified girder to carry the longitudinal and vertical shear, and bending loads resulting from the specified vertical loads.
- 3.4.1.10. The car ends shall be designed to permit access between adjacent cars from the track bed.
- 3.4.1.11. Jigs, fixtures, and templates shall be used to ensure that carbody components and subassemblies of the carbody, such as underframes, side frames, end frames, and roofs, are uniform throughout the fleet.
- 3.4.1.12. No elongated holes, slots, or shims shall be used in the carbody construction, unless specifically approved by NYCT.
- 3.4.1.13. Carbody envelope shall be sized for clearances considering worst case operating conditions contained in Appendix D-1 (NYCT Document MISC #00-01, "Memorandum of Understanding Car and Line Equipment Clearances") including concurrent worst case failure of the secondary suspension system at each end of the car.

Materials

- 3.4.1.14. The carbody structure, and all sheathing, except for the end underframe and primary center and primary side collision posts, shall be constructed of austenitic stainless steel with a carbon content of less than or equal to 0.03 percent. Use of alternate materials may be proposed for NYCT approval.
- 3.4.1.15. All stainless structures in public view shall have a brush finish, and shall be AISI 301LN (low carbon, with nitrogen) or SUS301L (low carbon, with nitrogen) or AISI 201L, 201LN, or SUS201. Reference Section 19.2.2 for finish requirements.
- 3.4.1.16. AISI 304 or 304 L stainless steel hidden from public view may be as permitted per Section 19.2.2.
- 3.4.1.17. Steels requiring pre- and/or post-fabrication heat treatment to develop acceptable strength or toughness are prohibited on the carbody primary structure.
- 3.4.1.18. Alternate materials for non-structural applications may be proposed, subject to NYCT review and approval.

3.4.2. Corrosion Protection and Drainage

- 3.4.2.1. Where dissimilar metals are joined, they shall be protected against electrolytic corrosion in accordance with Section 19.1.9.
- 3.4.2.2. A corrosion-resistant coating, as specified in Section 19.1.8, shall be applied to the entire underframe and the inside of side and end sheets. All areas accessible to spraying shall be coated.
- 3.4.2.3. A corrosion-resistant coating is not required on stainless steel members, but may be applied in accordance with Section 19.8.2 as a sound deadening measure to meet the noise requirements of Section 2.9.
- 3.4.2.4. Carbody structure members and all other carbody structure components shall be designed to prevent water entrapment.
- 3.4.2.5. In areas where water might be ingested, corrosion-resistant drain pans and drain lines shall be provided and shall divert the discharge clear of all equipment and structure.
- 3.4.2.6. Drain lines and drain holes shall be designed to prevent clogging.
- 3.4.2.7. Enclosed structural cavities that are not airtight shall be vented to prevent accumulation of condensate.
- 3.4.2.8. Any enclosed structural cavities of carbon steel members shall be treated with a rust-inhibiting coating as specified in Section 19.22.7. All areas accessible to spraying shall be coated.

3.4.3. Connections - General

- 3.4.3.1. All welded and mechanically fastened joints shall be designed in accordance with the requirements of Sections 19.21 and 19.18, respectively, and relevant clauses of this section.
- 3.4.3.2. The following components shall have structural connections designed and analyzed such that the load required to exceed the ultimate strength of the connection is greater than the load required to exceed the ultimate strength of any of the constituent components being joined:
- a) End sills.
 - b) Draft sills.
 - c) Coupler attachment structure.
 - d) All collision posts.
 - e) Truck-to-carbody connection, including the carbody center pin if used, and vertical attachments.
 - f) Truck-to-carbody bolster anchor brackets.
 - g) Connections where primary structure members resist the specified over-load conditions.
 - h) Equipment beams, if used, and their attachment to the carbody.
 - i) Equipment brackets.
 - j) Carbody roof corner covers.
- 3.4.3.3. All ultimate-load requirements shall be analyzed as specified and then re-analyzed with the load magnitude increased until calculations show structural member failure has commenced before connection failure.

3.4.4. Welded Connections

General

- 3.4.4.1. The carbody structure shall be assembled by welding.
- 3.4.4.2. Sheathing shall be attached to the framing by laser welding, unless otherwise approved by NYCT.

Laser Welding

- 3.4.4.3. Laser welding shall not cause visible surface indentation or protrusion (linear or otherwise), deformation, or discoloration. Laser welds shall not be applied to the exterior surfaces of side skins or end sheathing.
- 3.4.4.4. The use of laser welding shall be verified by analysis and testing and shall be supported with the appropriate Contractor design and process control documentation in accordance with AWS C7.2M. Application of laser welding shall be subject to approval by NYCT.
- 3.4.4.5. The static and fatigue strength of the laser welds shall not be less than that of the resistance welds for the service life of the car.
- 3.4.4.6. Laser welding shall be demonstrated to and approved by NYCT before being implemented in production.

Visible Resistance Welding - Sheathing

- 3.4.4.7. Visible resistance welds shall cause a minimum of surface indentation, shall not cause permanent discoloration, and shall be treated so as to minimize visibility at the completion of all manufacturing. Visible resistance welds shall be arranged in uniform patterns.
- 3.4.4.8. Spot weld spacing, selected to achieve the requirements of Sections 3.2 and 3.4.13, which is not in accordance with the requirements of Section 19.21.9 shall be specifically approved by NYCT. Weld spacing in

primary structural members made of composite sections shall ensure that the required strength in the entire member is achieved before weld failure.

Resistance and Fusion Welding

- 3.4.4.9. Fusion welding or resistance welding shall be used for the construction of all other components of the carbody structure. Fusion welding on exterior visible portions of the carbody shall be as permitted by NYCT.
- 3.4.4.10. Where welds are used to form a structural connection, the welds shall be designed to carry the entire load of the connection. Rivets, bolts, and other fasteners shall not be used in conjunction with welded connections to share loads within the connection welds.
- 3.4.4.11. Joints requiring a combination of tungsten inert gas (TIG) spot welds and arc welds such that both are needed to meet design load requirements shall be approved by NYCT.
- 3.4.4.12. The following welds shall not be used:
- a) Intermittent fillet welds on tension members.
 - b) Intermittent laser welds on tension members.
 - c) Plug or slot welds (Including slots with fillet weld attachment) on tension members.
 - d) Intermittent groove welds.
 - e) Spot welds in connections primarily loaded in tension.
 - f) Single sided partial penetration joint welds in tension members subject to transverse fatigue loading.
 - g) Welds in a configuration without readily associated fatigue criteria defined in any published industry standard or prior fatigue test data.
 - h) Use of TIG dressing and shot peening on welds to achieve fatigue design allowable strength.
- 3.4.4.13. If backing strips are used in one-sided full penetration arc welds in members subjected to tension fatigue, the backing strips shall be continuously welded and included in the fatigue analysis.
- 3.4.4.14. Stud welding to carbody structure shall not be used, except:
- a) In areas with low fatigue stress, as approved by NYCT.
 - b) On non-load carrying stiffeners and secondary structure.
- 3.4.4.15. No components shall be attached to the primary carbody structure by welding or drilling after the primary carbody structure has been manufactured, except for equipment hangers that are resistance spot welded to the web of a beam.
- 3.4.4.16. Welding on these equipment hangers shall be no closer than 0.8 inch (20 mm) from the primary carbody structure.
- 3.4.4.17. Weld procedures and supporting qualification records shall be submitted per Sections 19.21.1 and 19.21.3, respectively.

3.4.5. Mechanical Connections

- 3.4.5.1. Where carbody structure must be assembled with mechanical fasteners, the fasteners shall be high-strength lock bolts or structural rivets not smaller than 0.375 inch (9.5 mm); see Section 19.19.11. No visible fastener heads shall be permitted unless specifically approved by NYCT.
- 3.4.5.2. Mechanically fastened connections, including rivets, shall be designed using a factor of safety of 1.5 and the proof load for threaded fasteners to determine the allowable strength (stress) criteria. Clamping force friction shall be ignored in the static load design and analysis.
- 3.4.5.3. All holes for all mechanical fasteners shall be clean and free of burrs on both sides of the holes. See Section 19.19.14.

- 3.4.5.4. Self-tapping screws shall not be used for structural connections.
- 3.4.5.5. Tapped holes shall only be permitted for attachment of floor panels, interior panels, and trim.
- 3.4.5.6. If used, tapping plates shall conform to the following requirements:
 - a) Shall be attached to the car structure with mechanical fasteners. Welding may be used on a case-by-case basis, as approved by NYCT.
 - b) Shall be designed to the same strength as an equivalent nut for the bolt grade being used.
 - c) Shall incorporate a clearance hole in the material to which the tapping plate is attached.
- 3.4.5.7. Rivets, blind rivets, and Huck-bolts shall be installed with power tools, with the blind sides of blind rivet holes prepared and inspected to ensure burrs are removed on all faying surfaces.

3.4.6. End Underframe

- 3.4.6.1. The end underframe units shall consist of the end sill, draft sill, body bolster, anti-climber, collision post shear lugs, and stubs for connecting the collision posts to the underframe sills as required to meet the requirements of the Specification.
- 3.4.6.2. The end underframe and body bolster shall be constructed of Low Alloy High Tensile strength (LAHT) steel with improved corrosion resistances that is commercially available. Materials shall be as permitted by Section 19.3.1 and shall be approved by NYCT.
- 3.4.6.3. The end underframe shall be assembled and attached to the side sills by arc welding, in accordance with Section 19.21 using Complete-Joint Penetration (CJP) groove welded joints as defined by the AWS Structural Welding Code D1.1 wherever primary and fatigue loads are carried across the joint in tension or compression. Alternate weld configurations may be proposed for NYCT review and approval.
- 3.4.6.4. AWS partial joint penetration groove welded joints may be used where primary loads are carried in shear along the length of the weld, consistent with fatigue design requirements of this Specification.
- 3.4.6.5. Fillet welds may be used in joints that do not carry primary loads.
- 3.4.6.6. If heat treatment is required for stress relief, the assemblies shall be heat-treated after welding in accordance with AWS D1.1 Section 5.8.
- 3.4.6.7. The design of the end underframe shall provide for continuity of flanges and webs at all locations where load-bearing members intersect.
- 3.4.6.8. The design and construction of the body bolster shall consider the high fatigue environment in which it will be operating. A fatigue-resistant design shall be a prime requirement of the body bolster structure.

3.4.7. Anti-Climber

- 3.4.7.1. An anti-climber shall extend laterally over the full width of the car end frame at both ends, and shall be attached to the end sill or CEM equipment.
- 3.4.7.2. The anti-climber top surface shall have a diamond plate texture and shall be painted with a safety yellow anti-slip paint. Adhesive backed, non-skid tape or sheets are not permitted.
- 3.4.7.3. The distance from the edge of the anti-climber top surface to the vertical face of the end bonnet or end sheets shall not be less than 3.75 inches (95 mm) on both sides of the car at A car number 1 ends, and on the step of the non-cab ends of A and B cars.
- 3.4.7.4. A recess in the end bonnet or end sheet may be provided to allow for the necessary dimension described in 3.4.7.3.
- 3.4.7.5. If a recess is provided, it shall extend as far as possible to the side of the car without interfering with the structural integrity of the carbody or equipment located in the same region. The recess shall be pitched

slightly for drainage and shall allow sufficient clearance for a men's size 14 (European size 48.5) protective work boot.

3.4.8. Side and Body Sills

- 3.4.8.1. Side sills shall be provided to form the lower longitudinal members of the carbody structure.
- 3.4.8.2. The side sills shall be securely connected to floor beams, cross-bearers, carbody bolsters, end sills, and underframe shear panels.
- 3.4.8.3. If center sills are used, they shall be welded to transverse floor members and bolsters, and shall be braced by cross-bearers.

3.4.9. Camber

- 3.4.9.1. Carbody camber shall be proposed by the Contractor and approved by NYCT.
- 3.4.9.2. Carbody camber shall be measured from a datum line drawn between the intersections of the arc with the centerlines of the body bolsters to a line tangent to the arc midway between the bolsters.
- 3.4.9.3. The carbody shall be designed with positive camber such that the tangent point of the camber arc is above the datum line.

3.4.10. End Frames

- 3.4.10.1. The front end frame shall be designed to support the windshield assembly when tested in accordance with the requirements outlined in Section 15.6.6.5.
- 3.4.10.2. The end frames shall be designed to resist the specified vertical, transverse, longitudinal, and torsional loads.
- 3.4.10.3. Two primary center collision posts shall be located at each side of the end doors (cab and non-cab ends), spaced approximately 1/3 distance from each corner but less than 40 inches (1,016 mm) apart.
- 3.4.10.4. Two primary side collision posts, shall be located at the juncture of each front end and side frame (cab and non-cab ends).
- 3.4.10.5. A structural shelf shall be provided on both ends of the car that connects horizontally from primary side collision post to primary center collision post. On the cab end, the structural shelf shall be located below the operator's cab window.
- 3.4.10.6. Framing posts shall be provided as attachment points for outer sheathing, end bonnet, and interior panels.
- 3.4.10.7. Door posts and a header shall be provided and designed to mount the body end (storm) door while maintaining weather tightness.
- 3.4.10.8. The end frame outer sheathing, end bonnet, or combination thereof shall be connected to the structural framing members as necessary and shall be as required by Sections 3.4.1.14 to 3.4.1.18.
- 3.4.10.9. The cab-end bonnet shall be constructed from contoured fiberglass reinforced plastic panels with integral carbon or stainless steel reinforcements.
- 3.4.10.10. Fiberglass reinforced plastic used for end frame outer sheathing shall meet the requirements of Section 19.12, and shall not contribute to resistance of carbody structural loads.
- 3.4.10.11. Fiberglass reinforced plastic used for this purpose shall maintain a watertight seal with the car body, and shall not be damaged by any car body deflection including all deflections resulting from the structural tests of Section 3.6.11 through 3.6.15.
- 3.4.10.12. The end bonnet and its connection shall, without failure, sustain air pressure loading from tunnel / station entry and exit, windshield impacts, extension of safety springs, and safety appliances (if attached to bonnet).

- 3.4.10.13. Fiberglass shall be fastened to the car structure by one of the following methods unless otherwise approved by NYCT.
- a) Recessed flat head bolts through areas of fiberglass shell that have a reinforcement molded within the shell with an approved filler used to cover the bolt heads.
 - b) Cap screws with lock washers under the head from inside the car into tapping plates molded within the fiberglass.
- 3.4.10.14. All reinforcements, attachment clips, and tapping plates used in the installation of the end bonnet shall be free of corrosion for the life of the car.

3.4.11. Collision Posts

- 3.4.11.1. Collision posts shall be continuous closed sections from the bottom of the end sill to the roof.
- 3.4.11.2. If reinforcement is used to provide the specified shear strength at the floor, such reinforcement shall be designed to transmit the specified shear and other loads into the end underframe.
- 3.4.11.3. Such reinforcement shall have shear strength of at least the corresponding collision post shear load from the bottom of the end underframe to a point 18 inches (457 mm) above the top of the end underframe, and then tapering to a point at least 30 inches (762 mm) above the top of the end underframe.
- 3.4.11.4. All collision posts and shear reinforcements shall be arranged to penetrate the end underframe unit, and welded to the top and bottom plates of the end underframe unit, except as otherwise approved by NYCT.
- 3.4.11.5. Primary collision posts shall be fully welded to the shear reinforcement at the floor (if used), or to stub posts (if used), and to the roof.
- 3.4.11.6. The side collision posts shall be welded to the shear reinforcement at the floor (if used), to the intermediate side frame rails and sheathing, and to the roof.
- 3.4.11.7. The body end doors shall be mounted on the primary center collision posts.

3.4.12. Side Frames

- 3.4.12.1. Side frames shall consist of vertical and horizontal members as well as sheathing and internal skin stiffening members.
- 3.4.12.2. Side frame vertical components shall consist of members such as window posts, door posts, and appropriate stub posts.
- 3.4.12.3. Side frame longitudinal components shall consist of members such as roof rails, side sills, window top rails, and belt rails.
- 3.4.12.4. Structural posts shall be formed sections and shall be located at the sides of all door and window openings and elsewhere as required to meet deflection and fatigue stress design requirements.
- 3.4.12.5. Structural posts shall be continuous between the side sill and the roof rail.
- 3.4.12.6. Gussets, if used, shall be full height.
- 3.4.12.7. Where horizontal rails are interrupted by posts, full height gussets shall be used to reinforce connections to effectively make the rails continuous.
- 3.4.12.8. The belt rail and its supports shall be designed to resist the specified side load.
- 3.4.12.9. Side frame posts, or stub posts, extending between the side sills and the belt rails, shall be provided to transmit vertical load from the body bolster ends, cross-bearer ends, and jacking pads into the side frame sheathing.

3.4.13. Exterior Sheathing

- 3.4.13.1. All exterior surfaces of the carbody (except the cab bonnet) shall be unpainted stainless steel with a brush finish to be approved by NYCT.
- 3.4.13.2. All exterior stainless steel shall undergo a chemical passivation treatment to prevent rust or shall be shown to be free from iron contamination per Sections 19.2.2.5 and 19.2.2.6.
- 3.4.13.3. Exterior, non-corrugated surfaces shall not contain any ripples or buckling.
- 3.4.13.4. The surfaces of flanges and webs of all structural members shall be straight, flat, and free from ripples, buckling, dents, gashes, and other surface imperfections.
- 3.4.13.5. Variation from a straight line on all visible carbody exterior surfaces shall not exceed:
 - a) 0.094 inch (2.4 mm) peak to valley in 40 inches (1,016 mm) over 95 percent of the area.
 - b) 0.125 inch (3.2 mm) peak to valley in 40 inches (1,016 mm) over the remaining 5 percent of the area.
 - c) 0.188 inch (4.8 mm) from the side sheet contour within 8 inches (203 mm) of the side doors, sloping towards the door mask.
- 3.4.13.6. The slope of any variation shall not exceed 0.125 inch in 12 inches (3.2 mm in 305 mm).
- 3.4.13.7. Variation from a straight line on all carbody exterior surfaces hidden by covers or shrouds shall not exceed 0.313 inch (8 mm) peak to valley in 40 inches (1,016 mm) measured in any direction.
- 3.4.13.8. Dents, gashes, deep spot weld dimples, or other surface imperfections in the sidewall skins and visible portions of the roof corner shall not be permitted.
- 3.4.13.9. Exterior exposed welds, located in the unpainted surfaces of the stainless steel on the sides of the cars, shall be arranged in regularly spaced patterns.
- 3.4.13.10. Stiffeners, if used, shall be attached to the sheathing by welding.
- 3.4.13.11. Side sheathing shall be flat and welded to the outside of the side frame posts in the space between the side sill and the roof, unless otherwise approved by NYCT.
- 3.4.13.12. Side sheets may be stiffened by corrugations or similar sections and welded to the inside face of the side sheet.
- 3.4.13.13. Flat side sheathing shall be a minimum of 0.059 inch (1.5 mm) thick.
- 3.4.13.14. Sheets under the windows, if corrugated on the inside, shall be a minimum of 0.039 inch (1.0 mm) thickness, unless otherwise approved by NYCT.
- 3.4.13.15. Horizontal lap joints shall be permitted where the flat side sheets are connected to each other or to corrugated side sheets, provided the direction of the joint sheds water and the joint is either seam welded or spot welded and sealed at the faying surfaces with a weld through sealer or silicone foam gasket. Connections between the side wall skin and other primary structure also shall be sealed at the faying surfaces.

3.4.14. Roof

- 3.4.14.1. The roof assembly shall be constructed of flat or corrugated stainless steel sheathing and structure covering the entire roof area.
- 3.4.14.2. Corrugations, if used, shall have a depth of less than or equal to 0.5 inch (13 mm) and shall not trap moisture.
- 3.4.14.3. The roof sheathing and structure shall be designed to support the roof loads specified in Section 3.2.12.
- 3.4.14.4. Equipment mounted under the roof suspended from the roof structure shall be bolted to the framing members.

- a) The framing members shall be reinforced to accept the equipment load.
 - b) Roof mounted equipment weighing more than 25 lb. (111 N) shall meet the mounting provisions of Section 3.4.18 and the design loads in Section 3.2.14.
- 3.4.14.5. Both ends of the roof shall be designed to support the tops of all collision posts and distribute the specified collision post loads, including those from the primary center and primary side posts.
- 3.4.14.6. The roof shall be framed and reinforced around openings with watertight welded stainless steel. Mechanical fastening through the roof is not permitted.
- 3.4.14.7. If separate covers are provided at the side wall interface, they shall be permanently attached using welding or lock bolts (rivets). The attachments shall comply with Section 3.4.3.
- 3.4.14.8. Areas designated as walkways to service roof mounted equipment shall have an NYCT approved non-slip coating.

3.4.15. Subfloor

- 3.4.15.1. A stainless steel subfloor pan shall be provided throughout the length of the car.
- 3.4.15.2. The subfloor pan may be an integral part of the floor structure, or separately attached. The integrity of the subfloor pans shall not be compromised by the structural loads specified in Section 3.2.
- 3.4.15.3. The subfloor pan shall be securely fastened to the car structure. Attachment spacing shall not be less than that required to meet fire rating and structural loading requirements.
- 3.4.15.4. Separately attached subfloor pans, if used, shall have a weatherproofing sealant applied to the edges of the sheets immediately before installation. The fastening and sealing system shall prevent weather and debris entry into the subfloor area for the design life of the car.
- 3.4.15.5. If separately attached subfloor pans are utilized, corrosion-resistant brackets or clips may be provided on the underframe for subsequent attachment of the subfloor pans.
- 3.4.15.6. The subfloor pan shall contain the underfloor thermal and acoustical insulation. Refer to Section 15.2 for insulation requirements.
- 3.4.15.7. The subfloor pan shall be stiffened to prevent resonance and "oil canning" under any operating condition. Insulation and/or sound deadening materials shall not be considered as stiffeners.
- 3.4.15.8. The subfloor pan material shall not be less than 0.02 inch (0.5 mm) thick.
- 3.4.15.9. Alternate methods of subfloor construction may be proposed, subject to NYCT review and approval.

3.4.16. Floor Beams

- 3.4.16.1. Transverse floor beams shall be securely fastened to the side sills to form the framing for support of the floor panels and the underfloor equipment units if equipment beams are not used.
- 3.4.16.2. Floor beam flange and web structural connections shall be continuous with mating structural members.
- 3.4.16.3. If direct flange to flange or web to web connections are not possible, full height gussets may be provided to ensure load transfer.
- 3.4.16.4. Floor beams shall also be used as required for equipment support and to control floor deflection, if equipment beams are not used.

3.4.17. Floor Panels

Construction

- 3.4.17.1. The floor shall be constructed of composite panels that shall meet the strength requirements of Sections 19.10.2 or 19.10.6. Alternate floor construction methods may be proposed for NYCT review and approval.

- 3.4.17.2. Floor panels shall be faced with skins on the entire top and bottom surfaces.
- 3.4.17.3. The skins shall be permanently bonded to an approved core through an approved molding process, curing the skins directly against the core.
- 3.4.17.4. All exposed edges of the panels, interior holes, interior cutouts, and joints between panels shall have a machined composite or metal edge and shall be smooth and free of sharp edges and burrs.
- 3.4.17.5. The floor material shall be non-vermin supporting and shall not rot, corrode, or absorb moisture. Materials utilized to achieve performance shall be accompanied by Material Safety Data Sheets (MSDS) per Section 19.1.6.
- 3.4.17.6. The floor panels shall fit the car sidewalls and carbody structure without any gaps larger than required for thermal expansion and contraction of the panels.
- 3.4.17.7. Threaded corrosion resistant steel inserts, stainless steel tapping plates, and other assembly hardware shall be molded into the finished panels or otherwise attached as approved by NYCT. The area of the panel immediately above any tapping plates shall be reinforced.
- 3.4.17.8. Floor panels shall extend the full width of the car.

Joints

- 3.4.17.9. The number of joints used in the floor panel application shall be minimized, while meeting all requirements of this Specification, including diagonal jacking as specified in Section 3.6.15.
- 3.4.17.10. Joints between panels shall be fully supported ship-lap joints and shall only be located over transverse floor beams transmitting vertical floor loads to the side sills. There shall be no joints within a panel or in the top or bottom face skins of the panels. Alternate arrangements may be proposed for NYCT approval.
- 3.4.17.11. All panel edges, including at cutouts, shall be sealed to prevent water intrusion.
- 3.4.17.12. Installed panels shall have height variations at panel joints no greater than 0.031 inch (0.8 mm). Floor flatness shall be better than 0.125 inch (3.2 mm) over any 36 inch span.

Fastening

- 3.4.17.13. Panels shall be mechanically fastened to structural elements. The use of adhesives in place of mechanical fastening shall be subject to NYCT review and approval.
- 3.4.17.14. All attachment methods shall be designed to sustain the worst case structural loads and deflections from all operational cases and deflections from all jacking operations with a positive margin of safety, as well as fire resistance requirements of Section 19.1.10.
- 3.4.17.15. Applied adhesive fastening systems shall be qualified for the application by aging tests to validate long-term structural integrity. Failure criteria shall be established by the Contractor and submitted for NYCT approval. Reference Section 19.20.2 for adhesive application requirements.
- 3.4.17.16. Adhesive system application methods shall ensure bond gap size is controlled and consistent with the joint design, and that uniform bond gap is maintained on all seams.
- 3.4.17.17. Mechanically fastened panels shall be insulated from the metallic structure by elastomeric tape that prevents squeaking and meets the fire resistance requirements of Section 19.1.10.

3.4.18. Equipment Supports

- 3.4.18.1. Equipment mounting hangers and brackets shall be attached to the carbody structure by mechanical fasteners, resistance welding, or other welding techniques as approved by NYCT.
- 3.4.18.2. The carbody structure shall be reinforced at the locations of the equipment mounting hangers and brackets to provide continuous load transfer at web and flange connections if necessary.

- 3.4.18.3. The holes for attachments shall be in the webs of framing members and not in the flanges, unless specifically approved by NYCT. If attachment to a flange is approved, full height gussets shall be provided in the member at the location of the attachment to assist in transferring the load into the web if necessary.
- 3.4.18.4. All equipment mounting provisions, including equipment support beams, shall be analyzed to confirm compliance with Section 3.2.14.
- 3.4.18.5. Underfloor equipment weighing more than 200 lb. (91 kg) shall be supported directly by the side sills, body sills, floor cross beams, or longitudinal supports between transverse floor beams.
- 3.4.18.6. All equipment shall be mounted with at least four supports, unless otherwise approved by NYCT.
- 3.4.18.7. Equipment supported on resilient mounts shall be provided with an appropriately sized auxiliary stop device for support in case of mount failure.
- 3.4.18.8. Bolts shall be used to mount or support equipment and shall not be less than 3/8 inch (9.5 mm) diameter, regardless of bolt grade.
- 3.4.18.9. Equipment weighing more than 25 lb. (11kg) shall be safety hung in accordance with the requirements of Section 19.18.2. Equipment weighing more than 25 lb. (11kg) shall not be supported solely by threaded fasteners in tension or shear. Alternate mounting arrangements shall be approved by NYCT.
- 3.4.18.10. Equipment shall not be supported by bolts in holes tapped only into the base material of the car structure. Tapping plates may be used for bolted connections which do not utilize nuts in accordance with Section 3.4.5.6.
- 3.4.18.11. Reference Section 19.18.2 for additional equipment mounting requirements.

3.4.19. Jacking and Lifting Pads

- 3.4.19.1. Twelve jacking and lifting pads shall be integrated into the design of the side frames.
- 3.4.19.2. The jacking and lifting pads shall have a bearing area at least 6 inches (152 mm) long by 4 inches (102 mm) wide, with a 0.5 inch (13 mm) lip on either end, and project a minimum of 0.5 inch (13 mm) below the bottom of the side sill.
- 3.4.19.3. There shall be a minimum of 2 inches (51 mm) clearance to any obstruction around each jacking and lifting pad.
- 3.4.19.4. The bottom of all jacking and lifting pads shall have an NYCT-approved non-skid surface with raised elements to provide frictional resistance against incidental horizontal loading between the jacking pad and jack head.
- 3.4.19.5. Four jacking pads shall be located at the corner of the carbody, under each primary side collision post, designed for jacking of the car along the right-of-way with carbody supported on one truck at the non-lifted end and with truck attached at the lifted end.
- 3.4.19.6. Four jacking pads shall be located as near the centerline of bolsters as possible, to permit jacking the car with NYCT standard floor jacks so that the truck can be rolled from under the car without removing any equipment or structure.
- 3.4.19.7. Four lifting pads shall be located between bolsters, designed for lifting of car with both trucks attached with an overhead crane with lift hooks.
- 3.4.19.8. The Contractor shall specify the type of wooden spacers to be utilized, if required, during jacking procedures.

3.4.20. Gutters and Splash Guards

- 3.4.20.1. Rain gutters shall be located above the doors, cab windows, passenger windows, and destination signs at the edge of the roof.

- 3.4.20.2. Gutters shall be continuous along the side of the car. Drain slots shall be utilized in the rain gutters only in the area between the side passenger windows and doors.
- 3.4.20.3. Rain gutters may be separately formed and attached as approved by NYCT, or may be integral with the roof structure.
- 3.4.20.4. Splash guards shall be installed at the ends of the roof and rain gutters.

3.4.21. Automatic Vehicle Identification System

- 3.4.21.1. NYCT, through a separate contract, is procuring an Automatic Vehicle Identification System (AVI). This system will include "tags" to be mounted underfloor on the R211 cars. The "tag" is a self-contained device with approximate dimensions of 5 inches by 10 inches by 3 inches (127 mm by 254 mm by 76mm).
- 3.4.21.2. The Contractor shall provide provisions for a surface, in the approximate middle of each car, to which the "tag" may be attached.
- 3.4.21.3. Provisions shall consist of identified space for the "tag" and the design of a support bracket, as approved by NYCT. The Contractor shall provide the design drawings for the surface and the bracket that may secure the "tag." The bracket shall be compatible with the "tag" being procured for the ATS-A contract (Transcore Amtech AT5118).

3.5. Maintainability Requirements

3.5.1. Carbody

- 3.5.1.1. The carbody shall be able to be cleaned using methods and cleaners currently used by NYCT in addition to any methods and cleaners defined by the Contractor, subject to NYCT review and approval. Reference Section 2.5.1.4.
- 3.5.1.2. The carbody shall be designed to not trap dirt or debris.
- 3.5.1.3. The body bolster shall provide clearance for the truck in all positions, and accessibility for truck maintenance and de-trucking.
- 3.5.1.4. Routing of HVAC drain lines within enclosed portions of the carbody shall allow for access to the drain lines in the event of maintenance or repair requirements.

3.5.2. Equipment Supports

- 3.5.2.1. Equipment shall be supported so that both bolts and nuts are accessible to maintenance personnel, if the internal component requires removal and replacement for other than accident damage.
- 3.5.2.2. Underfloor equipment and its connecting hardware shall not require disassembly or removal for maintenance, or for removal and replacement of internal components.

3.6 Validation Requirements

3.6.1. Samples

- 3.6.1.1. Fusion welded samples shall be notch-toughness tested; refer to Section 19.21.10.
- 3.6.1.2. Three samples of all exterior finishes, including the finish on all welded joints, shall be submitted to NYCT for approval. [CDRL]
- 3.6.1.3. Samples shall have a minimum surface area of 6 by 12 inches (152 mm by 305 mm).
- 3.6.1.4. Samples of welding shall include a minimum of six welds. The number of welds per sample shall be proposed for NYCT approval.

3.6.1.5. The following samples shall be included as a minimum:

- a) 2B (annealed, bright cold rolled), TR (cold worked), and scratch finishes.
- b) Other mill finishes per ASTM A480.
- c) Exposed resistance welds illustrating each of the various metal-thickness configurations if used.
- d) Exposed side skin areas with laser welds and stiffeners attached if used.
- e) Each type of exposed butt joint and finished arc weld.
- f) Each proposed method of mechanical fastening on exposed carbody structure surfaces.

3.6.1.6. After approval of the exterior finish specimens, one set of samples will be returned to the Contractor. The second set will be used by NYCT inspectors at the carbody manufacturing site. The third set will be retained by NYCT as a permanent record.

3.6.2. Structural Sketch

3.6.2.1. A structural sketch shall be prepared and submitted for approval. [CDRL]

3.6.2.2. The preliminary structural sketch shall be included in the Stress Analysis Plan required by Section 3.6.3 and updated thereafter.

3.6.2.3. Approval of the structural sketch shall be a prerequisite for approval of the Finite Element Model (FEM) (Section 3.6.5.4).

3.6.2.4. As a minimum, the following views shall be included on the structural sketch, including cross sections of the structural members with shape, dimensions, material, and thickness:

- a) Side elevation.
- b) Top view of the roof and the underframe.
- c) Typical cross sections of the carbody at a window, side door, and full-height side-frame post.

3.6.3. Carbody Stress Analysis and Test Plans

3.6.3.1. The Carbody Stress Analysis Plan (CSAP) shall be submitted for NYCT review and approval, and discussed during the first design review meeting. The Carbody Structural Test Plan (CSTP) shall be submitted for NYCT review and approval. [CDRL]

3.6.3.2. The CSAP and CSTP shall be working documents that will be updated as the carbody design develops. Whenever the process for the analysis and testing of the carbody is revised, the Plan shall be updated and resubmitted, but not more than monthly. Each revision shall include revision level indications.

3.6.3.3. The CSAP and CSTP shall include an outline of the procedures the car builder will use to analyze and test the design of the carbody. It shall also include the following:

- a) Listing of load conditions to be used during analysis and test, with load magnitudes and points of application.
- b) Description of the analysis to be used for each load condition, or load envelopes if used.
- c) Structural sketch as required in Section 3.6.2.
- d) Diagrams of load applications.
- e) Table of material properties.

- f) Description of the assumptions concerning stress analysis.
- g) Description of how meshing accuracy is assessed, globally and at stress concentrations.
- h) Description of how analysis results will be correlated with test results, as required in Section 3.6.6.

3.6.3.4. The CSAP must be approved prior to approval of the Stress Analysis Report required by Section 3.6.7.

3.6.4. Stress Analysis

- 3.6.4.1. A stress analysis shall be generated for the carbody structure of the most highly stressed car type and all equipment supports for equipment weighing over 200 lb. (91 kg). Stress analysis for supports for items weighing less than 200 lb. (91 kg) may be requested for review at the discretion of NYCT. [CDRL]
- 3.6.4.2. The stress analysis shall be used to design the car structure to meet the performance requirements of this Specification. Structural tests shall be performed as required within this section to confirm the accuracy of the analysis.
- 3.6.4.3. The stress analysis shall show the calculated stresses, allowable stresses, and margins of safety for all structural elements for all specified loading conditions. The stress analysis shall include calculations of stresses in joints, fasteners, and members.
- 3.6.4.4. The approved stress analysis shall be a prerequisite for approval of the structural test procedures and structural drawings required by this Specification, and shall be used in determining strain gauge locations for use during the tests.
- 3.6.4.5. Any time changes in the design, manufacture, or other changes are made, the stress analysis shall be revised and submitted for review. The final submitted and approved stress analysis shall be for the car in the as-built configuration.
- 3.6.4.6. Parts of the design that cannot be analyzed with the required accuracy shall be prototyped and tested to demonstrate compliance with the requirements of the design and the Specification.
- 3.6.4.7. The elastic stability of plates, webs and flanges shall be calculated for members subject to compression and shear. The variation in the stainless steel compression modulus with stress shall be taken into account in calculating compressive stability of stainless steel members.
- 3.6.4.8. In computing the shear strength of a beam, only the portion of the beam that is in line with the force vector shall be considered as resisting the force. If the force is skew to the beam's web, the force vector shall be divided into components, one in line with the web and the other in line with the flange. The shear resistance shall then be computed separately for each component.
- 3.6.4.9. For any portion of the proposed design that is based on a NYCT service-proven car, the Contractor may provide data from previous tests, historical data from operations, or stress analyses as required to satisfy the corresponding portion of these requirements, subject to NYCT approval.
- 3.6.4.10. The buckling strength of structural members shall be calculated for any member in any of the analyses with a calculated compressive stress equal to or greater than 35 percent of its material's yield strength.

3.6.5. Finite Element Analysis

- 3.6.5.1. As part of the stress analysis, a Finite Element Analysis (FEA) of the complete carbody shall be performed for NYCT review and approval. [CDRL]
- 3.6.5.2. The FEA shall be performed using a computer program such as NASTRAN or ANSYS, or an NYCT-approved equal program that generates both model and solution files compatible with post-processing programs that allow for model visualization and solution data reporting.
- 3.6.5.3. The carbody FEA along with other analysis types shall show that the carbody design meets the requirements of the Specification.
- 3.6.5.4. The FEM shall be submitted and approved by NYCT prior to performing the FEA. [CDRL]

- 3.6.5.5. The element mesh, all assumptions, and a complete electronic copy of the input file, which includes input data, such as loads, boundary conditions, area properties and material properties, shall be included as part of the preliminary submittal and again as part of the complete analysis. A key to all symbols and colors shall be included. Boundary reaction forces of the carbody at AWO shall be included.
- 3.6.5.6. Each load condition submittal shall include diagrams of areas of mesh refinement, all assumptions, all input data, reaction forces, and a table to show static equilibrium.
- 3.6.5.7. Wherever required to be submitted, the input and output shall have each page numbered, and columns of data shall be clearly labeled on each page using terms, symbols, abbreviations, and units defined in the analysis report.
- 3.6.5.8. At the discretion of NYCT, FE models and results shall be reviewed during live interactive sessions 3 weeks after each submittal. At these sessions, NYCT shall have full access to the FE model input and output, and use of the software on the computer used for the analysis.
- 3.6.5.9. Color plots shall be prepared showing the following:
- Deflections in all three axes.
 - Von Mises, or other approved combination stresses.
 - Maximum and minimum principal stresses.
 - Direction of maximum and minimum principal stresses.
 - Assessment of the meshing accuracy.
- 3.6.5.10. All plots required in Section 3.6.5.9 shall show the maximum and minimum values, and all values greater than 83 percent of the maximum or minimum (maximum compression) value as derived from the FE model. Plots shall clearly indicate units for each value being shown on the appropriate axes.
- 3.6.5.11. Each drawing shall include a triad showing the direction of the global axes.
- 3.6.5.12. Plots at high magnification shall be keyed to a plot showing the structure to an extent sufficient to orient the high-magnification plots.
- 3.6.5.13. The FEA input and output data also shall be submitted on electronic media as approved by NYCT. Submittal of the input file is required with the model, and at any time the file is changed, but not more often than monthly. Criteria for final approval of the analysis shall include the Contractor's submittal of the fully configured input data files as required by this paragraph.
- 3.6.5.14. The FE model and analysis report shall be updated to represent the final configuration of the structure upon completion and acceptance of the final car design by NYCT.

3.6.6. Finite Element Analysis Validation

- 3.6.6.1. For each carbody validation test required, the carbody structural test results shall be compared with the corresponding stress analysis results. This information shall be tabulated and submitted with the carbody structural test reports for each test. [CDRL]
- 3.6.6.2. The tables shall compare empirical stresses from the test with analytical stresses from the FEA.
- 3.6.6.3. Comparison shall be made for at least half of the total number of strain gauges in the test, which shall be amongst the higher reading strain gauges in the test.
- 3.6.6.4. The tables shall include the test stress value, the analytical stress value, the percent difference between the two values, and a space for notes.
- 3.6.6.5. The percent difference included within the table shall be based on the strain gauge value (in the denominator).

- 3.6.6.6. The percentage difference for stress values (as defined in Sections 3.6.6.4 and 3.6.6.5) for at least 75 percent of the strain gauges selected for the correlation exercise (as specified in Section 3.6.6.3) shall be within ± 15 percent.
- 3.6.6.7. If the analysis does not correlate with the test results, the Contractor shall revise the analysis until 90 percent correlation is achieved. Results from faulty strain gauges may be removed from the regression analysis with NYCT approval.
- 3.6.6.8. The analysis results shall be updated to reflect the correlation analysis, taking into account correlation analysis trend and at least one standard error.
- 3.6.6.9. The revised analysis shall demonstrate compliance with the Specification.

3.6.7. Stress Analysis Report

- 3.6.7.1. The stress analysis report for the most highly stressed car type shall be submitted for NYCT review and approval. [CDRL]
- 3.6.7.2. The report shall show that all structural members satisfy the requirements of this Specification and standards of the rail transit industry. The report shall be organized and in sufficient detail so that the NYCT reviewer can readily follow the theory and its application to this car.
- 3.6.7.3. The Contractor shall certify that the analysis and calculations have been reviewed and checked before the report is submitted to NYCT.
- 3.6.7.4. Particular reference in the stress analysis shall be made to, but not limited to the following:
 - a) Side sill.
 - b) Center sill (if used).
 - c) End sill.
 - d) Anti-climber.
 - e) Draft sills.
 - f) Coupler supports.
 - g) Side frame rails.
 - h) Side frame posts.
 - i) Transverse and longitudinal sections at doorways.
 - j) Body bolster.
 - k) Floor and floor beams.
 - l) Primary center collision posts.
 - m) Primary side collision posts.
 - n) Not used.
 - o) Structural shelf.
 - p) Roof structure.
 - q) Equipment supports.
 - r) Connections between structural elements.
 - s) Other structural components in the design.

- 3.6.7.5. In addition to the body of the analysis, the stress analysis report shall include, at a minimum, all of the following:
- a) Table of Contents.
 - b) Algebraic statement of all formulas and equations before the related calculations are performed. All terms shall be defined, and the values and units to be applied to these terms shall be stated.
 - c) Units shall be given with all quantities.
 - d) References for all formulas, calculation procedures, buckling coefficients, material strengths, fatigue strengths, and other physical and mechanical properties shall be cited where these items appear in the stress analysis.
 - e) For all manually produced stress analyses, each page shall be numbered, dated, and initialed by the stress analyst and the checker. In the event of a revision, the revision letter shall be included with revision date and initials of the stress analyst and checker.
 - f) All computer stress analysis input and output data shall have cover sheets listing all work performed. Each section shall be signed and dated by the stress analyst performing the work and checked by a second stress analyst who shall also sign and date the appropriate cover sheets. In the event of a revision, the revision letter shall be included with revision date and initials of the analyst and checker.
 - g) Approved structural sketch.
 - h) Each load case including diagrams displaying loads applied externally to the carbody and points of support.
 - i) Analysis showing compliance with each design load and condition, as required by Section 3.6.4.
 - j) Detailed calculations of stresses with margins of safety (MS) in all structural framing members and sheathing, with a summary of the results.
 - k) Table showing locations where the MS is less than 0.20, along with the design or operating conditions (loads) that cause the stresses.
 - l) Tabulation or diagram of calculated deflections of the carbody under full vertical loading and under combined vertical and compression loads specified in Sections 3.2.4 and 3.2.5.
 - m) Analysis of all connections required in Section 3.4.3.2 showing that the joint is stronger than the weakest member being joined.
 - n) Analysis of the strength of the connection of the trucks to the carbody, including calculated vertical and horizontal connection capacities.
 - o) Analysis of the carbody structure under the torsional loading resulting from diagonal jacking described in Section 3.2.16, and under torsional loadings resulting from normal operation. Analyses shall not include contributions from floor panel and floor panel attachment strength.
 - p) Tabulation of the Contractor's selection of allowable fatigue stresses, with sources, and assumed applied fatigue stress ranges for structural members that are critical in fatigue.
 - q) Table showing the engineering properties of each grade and temper of each material used in the car structure. This table shall include: material designation, yield strength, ultimate strength, elongation, Young's Modulus for tension, compression, and shear elastic moduli. In each case, minimum-guaranteed values from the Specifications for the corresponding grade and heat treatment of the material shall be used. Materials, grades, and tempers not used in the carbody construction shall not be included in the tables.
 - r) Table showing geometric properties, such as area and section moduli.
 - s) Table(s) showing the minimum static and fatigue strengths of single and multiple spot welds and of laser welded joints (if used). Values shall be given and the source of the data shall be provided for

each material, temper, weld size, load orientation relative to the weld for laser welds, and thickness combination used in the carbody.

- t) If tests are conducted to provide the necessary data, the entire test report shall be submitted. This report shall show the test procedure, raw data as well as reduced data, and summary.

3.6.8. General Test Requirements

- 3.6.8.1. Testing shall be performed to validate the carbody structural design and other portions of the carbody design. Carbody structural tests shall include vertical load testing, compression at end sill, compression at coupler, primary collision post, anti-climber load, diagonal jacking, and equipment support.
- 3.6.8.2. The first carbody of the R211A or R211S variants that is structurally unique shall be tested by the Contractor to demonstrate compliance with the Specification. The Contractor may propose testing a single car if it can be demonstrated that the worst case load condition for all structural configurations, including equipment mountings and supports, are validated. The Contractor may propose a reduced test program for the R211T structure for NYCT review and approval.
- 3.6.8.3. The test carbody(ies) shall be structurally complete, consisting of all carbody structure, and sheathing, but excluding parts that would obscure any structural member from view, or that would interfere with the performance of the test. Equipment shall be simulated by equivalent weights applied at the equipment mounting points.
- 3.6.8.4. The tests shall be conducted after the carbody stress analysis and CEM analysis have been approved.
- 3.6.8.5. Strain gauge requirements described in each of the tests are the minimum to be used for that particular test. Some strain gauges may be used for more than one test if their location is appropriate.
- 3.6.8.6. Before commencing with the application of instrumentation, the Contractor and an NYCT representative shall inspect the test specimen. The Contractor shall document the configuration of the carbody and present any known deviation from the latest approved configuration to NYCT. Instrumentation may commence after the known deviations are reviewed and approved by NYCT.
- 3.6.8.7. The Contractor shall make provisions to conduct data analysis at the time of the test to compare the collected data against all pass fail criteria. Testing shall not proceed until agreed upon by NYCT. Areas failing to meet any criteria shall be investigated to determine the course of action needed to bring the area in question into compliance with the Specification.
- 3.6.8.8. If the specific pass/fail criteria of a test are not met, the carbody design shall be corrected and retested at the Contractor's expense. This process shall continue until all test pass/fail criteria are satisfied.
- 3.6.8.9. Any structural modifications made during the test or during construction and assembly may be subject to all tests. All cars constructed prior and subsequent to the structural tests shall incorporate these modifications. The tests, including related costs incurred by NYCT, and modifications shall be at the expense of the Contractor.
- 3.6.8.10. NYCT reserves the right to request to test additional cars of each type during the construction period. Should such test be ordered, it shall be at the expense of NYCT unless the ensuing test proves that the design is non-compliant to any structural requirements.
- 3.6.8.11. If the design is found to be non-compliant, the Contractor shall then be responsible for the test expenses and for all other related costs incurred by NYCT, including the cost of any modifications that might be required to take place in order to comply with the Specification. The Contractor shall perform, at its own expense, a complete set of structural tests in order to qualify the modified car.

3.6.9. Test Procedures

- 3.6.9.1. Test procedures for each individual test denoted within this section shall be submitted for NYCT review and approval.

- 3.6.9.2. Test procedures, the carbody stress analysis, and the CEM analysis, shall be approved prior to conducting any part of the tests.
- 3.6.9.3. Each procedure shall include the following:
- a) Description and purpose of the test.
 - b) Step-by-step instruction of how the specimen is to be loaded and loading increments (if applicable).
 - c) Step-by-step procedure describing all initialization steps and instrumentation nulling.
 - d) All inspections required and measurements to be taken.
 - e) All equations for strain / strain conversion, and factors such as strain gauge factors, temperature compensation, and any other calculations.
 - f) Loading equipment.
 - g) Listing, type, numbering, and location of strain gauges via drawings with locating dimensions and a cross reference list as to location.
 - h) Strain gauge (Stress) value predictions for each load case based on analysis including fatigue stress category (when appropriate).
 - i) The location of deflection and dial gauges
 - j) Deflection gauge prediction based on analysis.
 - k) Complete description with accuracy of all instruments.
 - l) Details of the data acquisition system and a log of any preloaded conversion or gauge factors (by channel number), if applicable.
 - m) Drawing and sketches to clarify the text.
 - n) Drawings showing the test fixture, the specimen installed in the fixture, and location of load application points.
 - o) Typical logging sheets, print-outs, plotting forms, and examples of any other data sheets that will be used during the test or in the final report.
 - p) Tables showing the maximum allowable gauge reading for each gauge and loading condition.
 - q) Predicted or required load cell readings at support points. For jacking load cases, values for each load increment during jacking shall be provided.
 - r) Tables showing allowable criteria for all test parameters.
 - s) Reference to the current certification for every instrument and gauge to be used during the test.
 - t) Description of when to record data.
 - u) Steps where authorization to proceed is to be obtained from NYCT.

3.6.10. Test Reports

- 3.6.10.1. The Contractor shall prepare and submit a final test report for NYCT review and approval following successful completion of the structural tests.
- 3.6.10.2. Approval of this test report shall constitute the acceptance of the carbody structural tests.
- 3.6.10.3. The calibration certifications shall be maintained on file and available for review by NYCT upon request.
- 3.6.10.4. Calibration certification for the equipment used to perform the test shall be included in the final test reports.
- 3.6.10.5. The Contractor shall prepare a color photographic record of the tests. This record shall include:
- a) Photographs of the carbody in the test fixtures.

- b) Repairs or modifications.
- c) Deviations from the drawings.
- d) Any areas that were found non-compliant.

3.6.10.6. The test report shall include:

- a) Table of contents.
- b) Complete test procedure.
- c) Narrative describing the conduct of the test, with dates and locations of test elements.
- d) Tables showing stresses and deflections which are 85 percent or more of the allowable.
- e) Description and explanation of any value that exceeded the test criteria.
- f) Appendices containing all data; i.e., output from each gauge for each load step. These data shall be identified with the date that they were recorded.
- g) Photographic record shall be mounted on pages the same size as the report pages.
- h) Video recording of the testing that includes audio narration.
- i) Stress (or strain) vs. load curves for the 10 greatest tension stresses and the 10 greatest compressive stresses for each test series.
- j) Correlation analysis between the predicted strain gauge data and actual strain gauge data.

3.6.11. Vertical Load Test

3.6.11.1. The carbody test specimen(s) supported on trucks (or equivalent) shall be subjected to a vertical load test with a test load equal to the static vertical operating load specified in Section 3.2.3.

Test Setup

- 3.6.11.2. The carbody structure shall have a minimum of 275 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical and shall include uniaxial and rosette gauges.
- 3.6.11.3. Vertical deflection shall be measured along the side sills during the test. At least 11 locations per side shall be measured. Deflection gauges measuring the diagonal deflection of critical carbody openings, such as doors, windows, and HVAC roof openings shall also be provided.
- 3.6.11.4. Deflection gauges shall be located at the end sills, at the bolster, and halfway between the bolsters. The remaining gauges shall be evenly spaced between the five locations.
- 3.6.11.5. The load shall be applied in five or more equal increments, for a minimum of six load readings from zero to full load. The loading shall be decreased in the same load step sequence from full load to zero. One of these load steps shall be equivalent ready-to-run body weight plus a passenger load of AW3. For one of the test increments, the carbody shall be loaded to the static equivalent stress range and strains (stress) shall be measured to verify the fatigue calculations for the vertical load case in Section 3.2.2.
- 3.6.11.6. The test load shall be distributed in proportion to the distribution of weight in the finished car.
- 3.6.11.7. Load cells shall be provided at support locations. Load cells shall be calibrated to 1 percent accuracy over 1.5 times the full load range that the load cell will be subjected to during the test.
- 3.6.11.8. Each load cell shall be within its calibration period for the duration of the testing.
- 3.6.11.9. The recording of strain gauge, deflection gauge and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Door Function Verification

- 3.6.11.10. One pair of side doors and door operators shall be installed in the opening with the highest shear deformations, as determined by analysis. The doors and door operators shall be in accordance with production drawings and procedures.
- 3.6.11.11. At each increment of test from AW0 to 105 percent of AW3, the doors shall be opened and closed with the opening and closing times measured and recorded.
- 3.6.11.12. Failure to operate within the prescribed speed specified in Section 6, Door System, shall require corrective action taken by the Contractor and the door validation portion of the vertical load test repeated in its entirety.

Pass/Fail Criteria

- 3.6.11.13. The carbody structure will be compliant with this Specification if all of the following are met:
- a) All measured stresses are in accordance with the requirements of Section 3.2.3.
 - b) Vertical deflection readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point that represents the measured deflection for maximum vertical load.
 - c) Strain readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point that represents the measured strain at maximum load.
 - d) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.
 - e) Recorded residual vertical deflection between bolsters following removal of the maximum vertical test loading does not exceed 0.04 inch (1.0 mm).
 - f) Recorded residual car transverse width and/or opening diagonal dimensions following removal of the maximum vertical test load do not exceed 0.04 inch (1.0 mm).
 - g) Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed ± 50 microstrain.
 - h) Carbody deflection, as measured during the vertical load tests under a load equal to the passenger load of AW3, is not more than the design camber in the side sill at any point between the carbody bolsters.
 - i) There are no permanent deformations, fractures, cracks, or separations in the car structure. Broken welds shall be jointly inspected by the Contractor and NYCT to determine if the failure is the result of weld quality or stress.
 - j) The flatness and straightness of structural members meet the requirements of Section 3.4.13 after unloading.
 - k) The side doors open and close at the specified speeds without binding at all test loads between AW0 and 105 percent of AW3.

3.6.12. End Sill Compression Load Test

- 3.6.12.1. The carbody test specimen shall be subjected to the end sill compression load specified in Section 3.2.4.1.

Test Setup

- 3.6.12.2. The carbody structure shall have a minimum of 275 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical and shall include uniaxial and rosette gauges.

- 3.6.12.3. Vertical deflection shall be measured along the side sills during the test. At least 11 locations per side shall be measured. Deflection gauges measuring the diagonal deflection of critical carbody openings, such as doors, windows, and HVAC roof openings shall also be provided.
- 3.6.12.4. Deflection gauges shall be located at the end sills, at the bolster, and halfway between the bolsters. The remaining gauges shall be evenly spaced between the five locations.
- 3.6.12.5. The carbody shall be supported on trucks, or approved equal, to allow longitudinal movement.
- 3.6.12.6. The carbody shall be loaded vertically to simulate AW0 loading. The loading shall be distributed in proportion to the distribution of weight in the finished car.
- 3.6.12.7. The test load shall be applied to the anti-climber over an area not to exceed the height of the anti-climber multiplied by a width of 12 inches.
- 3.6.12.8. The compression load shall be applied by means of a controlled hydraulic ram. The force of the ram shall be measured by means independent of that producing the force.
- 3.6.12.9. The hydraulic ram shall be supported at the car end and shall be free to move longitudinally with respect to the car.
- 3.6.12.10. The load shall be uniform in bearing. Cushioning methods, such as lead sheets, shall be used as necessary.
- 3.6.12.11. The compression force shall be applied horizontally on the car longitudinal centerline in increments of 25 percent, 50 percent, 75 percent, 87.5 percent, and 100 percent of full load, and then reduced from full load to zero in the same increments.
- 3.6.12.12. After each load increment is applied from 25 percent to full load, the load shall be reduced to not more than 2 percent of full load.
- 3.6.12.13. Strain gauge, deflection gauge, and load cell readings shall be taken at each load increment and each relaxation of load.
- 3.6.12.14. The recording of strain gauge, deflection gauge, and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Pass/Fail Criteria

- 3.6.12.15. The carbody structure will be compliant with this Specification if all of the following are met:
 - a) Stresses are in accordance with the requirements of Section 3.2.4.1.
 - b) Vertical deflection readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point that represents the measured deflection for maximum vertical load.
 - c) Strain readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point that represents the measured strain at maximum load.
 - d) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.
 - e) Recorded residual vertical deflection between bolsters following removal of the maximum vertical test loading does not exceed 0.04 inch (1.0 mm).
 - f) Recorded residual horizontal deflection between ends following removal of the maximum test load does not exceed 0.04 inch (1.0 mm).
 - g) Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed ± 50 microstrain.

- h) There are no permanent deformations, fractures, cracks, or separations in the car structure. Broken welds shall be jointly inspected by the Contractor and NYCT to determine if the failure is the result of weld quality or stress.
- i) The flatness and straightness of structural members meet the requirements of Section 3.4.13 after unloading.

3.6.13. Coupler Compression Load Test

3.6.13.1. The carbody test specimen shall be subjected to the coupler compression load specified in Section 3.2.4.2.

Test Setup

- 3.6.13.2. The carbody structure shall have a minimum of 275 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical and shall include uniaxial and rosette gauges.
- 3.6.13.3. Vertical deflection shall be measured along the side sills during the test. At least 11 locations per side shall be measured. Deflection gauges measuring the diagonal deflection of critical carbody openings, such as doors, windows, and HVAC roof openings shall also be provided.
- 3.6.13.4. Deflection gauges shall be located at the end sills, at the bolster, and halfway between the bolsters. The remaining gauges shall be evenly spaced between the five locations.
- 3.6.13.5. The carbody shall be supported on trucks, or approved equal, to allow longitudinal movement.
- 3.6.13.6. The carbody shall be loaded vertically to simulate AW0 loading. The loading shall be distributed in proportion to the distribution of weight in the finished car.
- 3.6.13.7. The test load shall be applied to the carbody-coupler interface.
- 3.6.13.8. The compression load shall be applied by means of a controlled hydraulic ram. The force of the ram shall be measured by means independent of that producing the force.
- 3.6.13.9. The hydraulic ram shall be supported at the car end and shall be free to move longitudinally with respect to the car.
- 3.6.13.10. The load shall be uniform in bearing. Cushioning means, such as lead sheets, shall be used as necessary.
- 3.6.13.11. The compression force shall be applied horizontally on the car longitudinal centerline in increments of 25 percent, 50 percent, 75 percent, 87.5 percent, and 100 percent of full load, and then reduced from full load to zero in the same increments.
- 3.6.13.12. After each load increment is applied from 25 percent to full load, the load shall be reduced to not more than 2 percent of full load.
- 3.6.13.13. Strain gauge, deflection gauge, and load cell readings shall be taken at each load increment and each relaxation of load.
- 3.6.13.14. The recording of strain gauge, deflection gauge, and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Pass/Fail Criteria

- 3.6.13.15. The carbody structure will be compliant with this Specification if all of the following are met:
 - a) Stresses are in accordance with the requirements of Section 3.2.4.2.
 - b) Vertical deflection readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point that represents the measured deflection for maximum vertical load.

- c) Strain readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point that represents the measured strain at maximum load.
- d) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.
- e) Recorded residual vertical deflection between bolsters following removal of the maximum vertical test loading does not exceed 0.04 inch (1.0 mm).
- f) Recorded residual horizontal deflection between ends following removal of the maximum test load does not exceed 0.04 inch (1.0 mm).
- g) Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed 50 microstrain.
- h) There are no permanent deformations, fractures, cracks, or separations in the car structure. Broken welds shall be jointly inspected by the Contractor and NYCT to determine if the failure is the result of weld quality or stress.
- i) The flatness and straightness of structural members meet the requirements of Section 3.4.13 after unloading.

3.6.14. Anti-Climber Compression Load Test

- 3.6.14.1. The anti-climber and carbody structure shall be tested under the loads of Specification Section 3.2.9. Three tests shall be performed: the first of the anti-climber and its attachment to the end sill and the second and third test to permit, by superposition and extrapolation, validation of the anti-climber combined load case analysis.

Test 1

- 3.6.14.2. The first test shall be performed on an actual production anti-climber and its attachment to the end sill. A special fixture that simulates the end sill may be used provided that the attachment matches the production configuration.
- 3.6.14.3. The anti-climber structure shall have a minimum of 50 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical.
- 3.6.14.4. The load shall be applied to the anti-climber.
- 3.6.14.5. The loads shall be applied in increments of 25 percent, 50 percent, 75 percent, 87.5 percent, and 100 percent, and decreased in the same increment after reaching full load, with strain gauge and load cell readings taken at each increasing and decreasing load increment.

Test 2

- 3.6.14.6. The second test shall be performed on a carbody structure loaded to AW3 and may be performed during the Vertical Load Test per Section 3.6.11 when sufficient loading is present to resist the anti-climber vertical loads in Section 3.2.9.
- 3.6.14.7. The anti-climber structure shall have a minimum of 50 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical. Drawings showing the location of each strain gauge shall be submitted to NYCT as part of the test procedure.
- 3.6.14.8. The load shall be applied by placing a jack under the cab end sill with an intervening load cell. The jack shall be raised in five increments from 0 until the full load of 80,000 lb. (356 kN) is supported by the anti-climber or until the carbody is lifted.

- 3.6.14.9. Strain gauge, load cell, and deflection readings shall be recorded relative to the normal vertical load condition.
- 3.6.14.10. The Contractor shall propose a test method for this purpose in detail in the test procedure, including procedures for data extrapolation and superposition.

Test 3

- 3.6.14.11. The same test as Test 2 shall be conducted except the vertical loading shall be applied in the downward direction. The Contractor shall propose a means of securing the carbody for this load case. The loading may be applied at a convenient time during the Vertical load test.

Pass/Fail Criteria

- 3.6.14.12. The Contractor shall demonstrate that the carbody structure is compliant with the load requirements of Section 3.2.9 through correlation of test results with the analysis.

3.6.15. Diagonal Jacking Load Test

- 3.6.15.1. The carbody structure test specimen shall be subjected to the diagonal support case per Section 3.2.16.3.

Test Setup

- 3.6.15.2. The carbody structure shall have a minimum of 275 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical and shall include uniaxial and rosette gauges.
- 3.6.15.3. Vertical deflection shall be measured along the side sills during the test. At least 11 locations per side shall be measured. Deflection gauges measuring the diagonal deflection of critical carbody openings, such as doors, windows, and HVAC roof openings shall also be provided.
- 3.6.15.4. Deflection gauges shall be located at the end sills, at the bolster, and halfway between the bolsters. The remaining gauges shall be evenly spaced between the five locations. Outermost deflection gauges shall be adjusted, if necessary, to measure displacements at the corner jacking pads.
- 3.6.15.5. The carbody shall be loaded vertically to simulate AW0 loading. The loading shall be distributed in proportion to the distribution of weight in the finished car.
- 3.6.15.6. The carbody shall be supported at the jacking pads at the four corners of the car with trucks (or equivalent weight) hanging from the body bolsters. The supporting jacks shall be on a level plane; shimming shall be conducted before test to achieve the predicted load distribution at level jacking.
- 3.6.15.7. One of the jacks, or two diagonal jacks, shall be lowered in five equal increments until the load on the (lowered) jack(s) is not greater than 10 percent of the original load. One of the load step increments shall simulate the maximum twist experienced on the carbody under the worst case track conditions contained in Appendix C-5 (Track Standards and Reference Manual MW-1).
- 3.6.15.8. The procedure shall be reversed until the load on the jack(s) is returned to the original load level and height.
- 3.6.15.9. Strain gauge, deflection gauge, and load cell readings shall be taken at each load increment.
- 3.6.15.10. The recording of strain gauge, deflection gauge, and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Pass/Fail Criteria

- 3.6.15.11. The carbody structure will be compliant with this Specification if all of the following are met:
- a) Stresses are in accordance with results of the stress analysis conducted per Section 3.6.4, incorporating the diagonal support case loading of Section 3.2.16.3.

- b) Strain readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point that represents the measured strain at maximum load.
- c) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.
- d) Indicated residual strains at strain gauges following return to original level do not exceed ± 50 microstrain.
- e) There are no permanent deformations, fractures, cracks, or separations in the car structure. Broken welds shall be jointly inspected by the Contractor and NYCT to determine if the failure is the result of weld quality or stress.
- f) The flatness and straightness of structural members meet the requirements of Section 3.4.13 after unloading.

3.6.16. Collision Post Elastic Load Test

- 3.6.16.1. The ability of the carbody structure to resist the collision post elastic loads specified in Section 3.2.10 shall be tested. Three separate tests shall be conducted. Elastic load cases shall include the loads applied to the following collision posts.
 - a) Primary center collision post in the longitudinal direction.
 - b) Primary side collision post in the longitudinal direction.
 - c) Primary side collision post in the transverse direction.

Test Setup

- 3.6.16.2. Each collision post to be tested shall have a minimum of 90 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical.
- 3.6.16.3. The carbody shall be supported on trucks or a simulation to allow free longitudinal movement. The load shall be resisted at the opposite end at the coupler interface.
- 3.6.16.4. The transverse load applied to the primary side collision post shall be resisted at the truck-to-carbody interface.
- 3.6.16.5. The car shell shall be loaded with sufficient dead weight to bring the total body weight (of test specimen) up to that of an AWO loaded carbody. This loading shall be distributed in proportion to the distribution of weight in the finished car.
- 3.6.16.6. The test load for each test shall be applied by a hydraulic ram with the force measured by a means independent of that producing the force.
- 3.6.16.7. The hydraulic ram shall be supported at the car end and shall be free to move longitudinally and transversely with respect to the car.
- 3.6.16.8. The load shall be uniform in bearing. Cushioning methods, such as lead sheets, shall be used. The load shall be distributed over the loaded surface over an area not to exceed the width of the collision post multiplied by a height of 6 inches.
- 3.6.16.9. The force shall be applied horizontally at 18 inches (457 mm) above the top of the underframe on the car in increments of 25 percent, 50 percent, 75 percent, 87.5 percent, and 100 percent of full load.
- 3.6.16.10. After each load increment is applied, the load shall be reduced to not more than 2 percent of full load.
- 3.6.16.11. Strain gauge, deflection gauge, and load cell readings shall be taken at each load increment and each relaxation of load.

3.6.16.12. The recording of strain gauge, deflection gauge, and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Pass/Fail Criteria

- 3.6.16.13. The carbody structure will be compliant with this Specification if all of the following are met:
- a) Deflection readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point that represents the measured deflection at maximum load.
 - b) Strain readings plotted against load do not vary by more than ± 5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point that represents the measured strain at maximum load.
 - c) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.
 - d) Indicated residual strains at strain gauges following return to original level do not exceed ± 50 microstrain.
 - e) There are no permanent deformations, fractures, cracks, or separations in the car structure. Broken welds shall be jointly inspected by the Contractor and NYCT to determine if the failure is the result of weld quality or stress.
 - f) The flatness and straightness of structural members meet the requirements of Section 3.4.13 after unloading.

3.6.17. Primary Center Collision Post Elastic-Plastic Load Test

3.6.17.1. The primary collision post structure shall be loaded to the ultimate load capacity in the longitudinal direction as specified in Section 3.2.10.

Test Setup

- 3.6.17.2. The test specimen shall be a full scale structural model of a cab end of a car. The structural model shall contain all structural elements required to support the primary center collision posts, including the end underframe and roof extending from the forward end of the end frame to the bolster.
- 3.6.17.3. All connections shall be the same as on production cars.
- 3.6.17.4. The bolster end of the model shall be attached to a rigid fixture so that the stresses in the post and its supporting structure will be the same as those in a car subjected to the same load.
- 3.6.17.5. Each collision post to be tested shall have a minimum of 90 bonded resistance (SR-4) or approved equal strain gauges applied. Strain gauges shall be placed where the stress may be critical. Drawings showing the location of each strain gauge shall be submitted to NYCT as part of the test procedure.
- 3.6.17.6. The test load for each test shall be applied by a hydraulic ram with the force measured by a means independent of that producing the force.
- 3.6.17.7. The hydraulic ram shall be supported at the car end and shall be free to move longitudinally with respect to the car.
- 3.6.17.8. The load shall be uniform in bearing. Cushioning means, such as lead sheets, shall be used. The load shall be distributed over the loaded surface over an area not to exceed the width of the collision post multiplied by a height of 6 inches.
- 3.6.17.9. The longitudinal test load shall be applied to the collision post at an elevation of 18 inches above the top of the underframe.
- 3.6.17.10. The initial load shall be applied in increments of the same magnitude as those used during the primary center collision post elastic load test, as in Section 3.6.16.

- 3.6.17.11. The force shall be applied in increments of 25 percent, 50 percent, 75 percent, 87.5 percent, and 100 percent of full load.
- 3.6.17.12. After each load increment is applied, the load shall be reduced to not more than 2 percent of full load.
- 3.6.17.13. Strain gauge, deflection gauge, and load cell readings shall be taken at each load increment and each relaxation of load.
- 3.6.17.14. The recording of strain gauge, deflection gauge, and load cell data shall be simultaneous and accomplished using the same data logging equipment.

Pass/Fail Criteria

- 3.6.17.15. The strain gauge readings and deflections measured during this test shall be within ± 10 and ± 5 percent respectively of the gauge readings for the same load and location measured during the primary center collision post elastic test, as in Section 3.6.16. Strain gauge correlation shall be based on gauges applied to low strain gradient locations as agreed between NYCT and the Contractor.
- 3.6.17.16. If allowed differences are exceeded between the two tests, the contractor shall propose to correct the fixture and/or the model and rerun the test until the specified percentage agreement between the two tests is obtained.
- 3.6.17.17. After agreement between the two tests is demonstrated, the collision post will continue to be loaded in increments of 25 percent of the full load specified in the primary center collision post longitudinal load test until the load carrying capacity of the collision post is obtained. After the start of plastic deformation, the loading will be controlled by displacement, which shall be increased at NYCT approved increments.
- 3.6.17.18. At each approved increment, all load cell(s), strain gauges, and deflection gauges shall be recorded. The load need not be relaxed at each step.
- 3.6.17.19. The ultimate load carrying capacity of the post is defined as the condition where the post cannot support an increased load and the center of the post has deflected more than one-third its full depth as measured deflection, as measured at the middle of the post from a line connected between the top and bottom of the post, with the load completely removed.
- 3.6.17.20. The collision post will be compliant with this Specification if all strain gauges and deflection gauges have the same readings within ± 10 and ± 5 percent respectively for the same loads at the same locations as the primary center collision post elastic load test for 0 to 100 percent of the loads specified in Section 3.2.10.
- 3.6.17.21. Under the ultimate load carrying capacity of the post, as defined above, the connections between the primary center collision post and all other structural members shall not be separated.

3.6.18. Elemental Crash Energy Management Tests

- 3.6.18.1. The energy absorption properties of structural elements shall be validated by performance of a series of crush tests using full size elements to be witnessed by a representative of NYCT.
- 3.6.18.2. The force required to compress (crush) a structural element a defined distance shall be measured to develop force-displacement curves for each member contributing to the total energy absorption of the car required by Section 3.2.1.7.
- 3.6.18.3. Members designed not to contribute to the total energy absorption shall also be tested to validate that these members do not interfere with the energy absorption elements.
- 3.6.18.4. Test specimens shall be:
 - a) Manufactured in the same manner as the part to be used on the car.
 - b) Marked over the specimen's entire surface with grid patterns appropriate to the specimen size.
 - c) Connected to a fixture in the same manner it is connected in the car assembly.
 - d) Mounted in a calibrated test machine with the test fixture.

- 3.6.18.5. Specimens shall be dynamically compressed (crushed), or tested by an equivalent method proposed by the Contractor and approved by NYCT.
- 3.6.18.6. The force and deflection shall be continuously recorded (plotted) during the test.
- 3.6.18.7. The test shall be recorded concurrently with the force and deflection data on two color video cameras situated to best show the crushing of the specimen. One of the cameras shall be set up to show the force-deflection plot and the specimen in the same frame.
- 3.6.18.8. Prior to testing, a test procedure shall be submitted and approved by NYCT.
- 3.6.18.9. The procedure shall include as a minimum the following:
- Description and purpose of the test.
 - Description of the test, test specimens, and test apparatus.
 - Location of video cameras.
 - Complete descriptions of all instruments, gauges and data acquisition system.
 - Drawing(s) showing the specimen with grid pattern, the fixtures, the attachment of the specimen to the fixture, and test apparatus.
 - Step-by-step instructions describing how the loads are applied, and how they are recorded.
 - Detailed steps, calculations, and tables for the correlation of analysis results with test results.
- 3.6.18.10. A test report shall be submitted for approval by NYCT.
- 3.6.18.11. The report shall include:
- Raw test data as well as reduced data.
 - Force-deflection curves and photographs of the specimens before, during, and after the tests.
 - Copy of all the videos on digital storage media with the original report.
 - Correlation of test and analysis data.
- 3.6.18.12. Approval of the CEM analysis per Section 2.15.4 will depend on the approval of the CEM element test report.

3.6.19. Carbody Crash Energy Management Test

- 3.6.19.1. Full-scale crash testing of a car end shall be performed to validate the CEM analysis model per Section 2.15.4.
- 3.6.19.2. The purpose of the test is to show that the carbody meets the requirements of Section 3.2.1.7 and 3.2.1.8, and to verify the results of the CEM analyses specified in Section 2.15.4.
- 3.6.19.3. The CEM test shall be dynamic to simulate the maximum calculated crash energy absorption of the car end as determined from the train to train crash simulations.
- 3.6.19.4. The test specimen shall be:
- Manufactured in the same manner as the end assembly used on the production car and shall incorporate all elements contributing to CEM performance.
 - Marked over the specimen's entire surface with grid patterns appropriate to the specimen size.
- 3.6.19.5. The CEM test shall be recorded by a minimum of four high speed color video cameras with a minimum frame rate of 1,000 frames per second, and two standard frame rate color cameras. The location of the cameras shall be situated to best show the performance of the structure.
- 3.6.19.6. Key test parameters such as impact velocity, rebound velocity, and maximum dynamic deflection shall be recorded by at least two means.

- 3.6.19.7. Prior to testing, a test procedure shall be submitted for approval by NYCT.
- 3.6.19.8. The procedure shall include as a minimum the following:
- a) Description and purpose of the test.
 - b) Step-by-step procedures for execution of the testing.
 - c) Description of the test, test specimens, and test apparatus.
 - d) Location of all video cameras.
 - e) Complete descriptions of all instruments, gauges, and data acquisition system.
 - f) Drawing(s) showing the specimen with grid pattern, test fixtures, test apparatus, and location of instrumentation.
 - g) Step-by-step instructions describing how the dynamic load is applied, and how it is recorded.
 - h) Typical logging sheets, print-outs, plotting forms, and examples of any other data sheets that will be used during the test or in the final report.
 - i) Tables showing the maximum allowable gauge reading for each gauge and loading condition.
 - j) Tables showing allowable criteria for all test.
 - k) Detailed steps, calculations and tables for the correlation of analysis results with test results.
- 3.6.19.9. The Contractor shall prepare and submit a final test report after successful completion of the carbody crash energy test.
- 3.6.19.10. Approval of the CEM analysis per Section 2.15.4 will depend on the approval of the CEM carbody test report.
- 3.6.19.11. The test report shall include:
- a) Table of contents.
 - b) Complete test procedure.
 - c) Narrative describing the conduct of the test, with dates and locations of test elements, and any deviations from the test procedure.
 - d) Description and explanation of any value that exceeded the test criteria.
 - e) Comparison between the test data and the (test) simulation of the test showing:
 - 1) Force versus displacement curves for all (non-recoverable) crash energy absorption structure and components.
 - 2) Energy absorption versus time for all crash energy absorbing structure.
 - 3) Deformation plots after the test stops.
 - 4) Animations or static displays of animation frames showing progressive crushing.
 - 5) Velocity versus time curves.
 - 6) Acceleration versus time curves.
 - 7) Displacement versus time curves.
 - 8) Appendices containing all data. These data shall be identified with the date that they were recorded.
 - 9) Color photographic images mounted on pages the same size as the report pages.
 - 10) Video recording of the testing on digital storage media including audio narration with the original report.
 - 11) Calibration certification for the equipment used to perform the test.

3.6.19.12. If the Contractor can establish the accuracy of its carbody CEM analysis from prior programs where a test was performed and the results were in substantial agreement with the analysis, waiver of this test may be considered. It must be shown that the analysis model used previously and the model to be used for the R211 program are substantially the same.

3.6.20. Equipment Support Tests

- 3.6.20.1. The strength of equipment supports subject to stress analysis as required by Section 3.6.4 shall be tested. The three heaviest items of equipment, and a fourth selected by NYCT shall be subjected to the required tests.
- 3.6.20.2. Each item of equipment required to be tested shall be subjected to loading in both senses on all three principal axes in accordance with the requirements of Section 3.2.14.5 with all supports active. The tests shall then be repeated with one less than the total number of supports in accordance with the requirements of Section 3.2.14.6.
- 3.6.20.3. Prior to testing, a test procedure shall be submitted and approved by NYCT. See Section 3.6.9 for test procedure requirements.
- 3.6.20.4. The Contractor shall prepare and submit a final test report after successful completion of the equipment support tests. See Section 3.6.10 for test report requirements.
- 3.6.20.5. The test shall be considered as having been successfully passed if the failure criterion of Sections 3.2.14.5 and 3.2.14.6 are met.

3.6.21. Passivation Test

- 3.6.21.1. The carbody external sheathing shall be tested for free iron presence in accordance with the water-wetting and drying test per ASTM A380 section 7.2.5.1. Testing shall be applied to selected locations of a carbody skin.

3.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

<u>CDRL</u>	<u>Ref</u>	<u>Deliverable</u>	<u>Timing</u>
3-1	3.6.1.2	Three samples of all exterior finishes	IPDR
3-2	3.6.2.1	Structural sketch	PDR
3-3	3.6.3.1	Carbody Stress Analysis Plan (CSAP)	30 days after NTP
		Carbody Structural Test Plan (CSTP)	CDR
3-4	3.6.4.1	Carbody Stress Analysis	IPDR
3-5	3.6.5.1	Finite Element Analysis	With carbody stress analysis
3-6	3.6.5.4	Finite Element Model	PDR

CDRL	Ref	Deliverable	Timing
3-7	3.6.6.1	Finite Element Analysis Validation	With final structural test report
3-8	3.6.7.1	Carbody Stress Analysis Report	60 days before commencing carbody manufacture

Section 4

Coupler Systems

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4. Coupler Systems

4.1. Introduction and General Requirements

4.1.1. This section defines the requirements for the automatic couplers, link bars, and electrical and pneumatic devices used to connect the cars and Units to one another. The requirements are divided into Performance, Functional, Design, Maintainability, and Validation categories.

4.1.2. Reference the following sections for car systems and components interfacing with the Coupler Systems and overall requirements:

- a) Design and Performance Criteria – Section 2.
- b) Carbody Structure – Section 3.
- c) Cab and Cab Controls – Section 5.
- d) Friction Brake and Air Supply Systems – Section 12.
- e) Materials, Processes, and Workmanship – Section 19.
- f) Reliability, Maintainability, and System Assurance - Section 21.
- g) System Support - Section 22.
- h) Testing Program – Section 24.

4.1.3. Automatic Couplers

4.1.3.1. A fully automatic coupler shall be provided at the No. 1 end of each A Car to provide complete mechanical, electrical and pneumatic connection between Units, to form a train.

4.1.3.2. The brake pipe pneumatic connection shall be trainlined and form an integral part of the mechanical coupler.

4.1.3.3. Electrical connections (not including the high capacity grounding connection applied between cars within a Unit) shall be through an electrical coupler head mounted beneath the mechanical coupler.

4.1.3.4. Complete mechanical (including the avoidance of damage to electric coupler heads when coupled through mechanical compatibility) and pneumatic compatibility shall be maintained with the Tomlinson style flat face hook type couplers on existing R143, R160, and R179 cars.

4.1.3.5. Mechanical compatibility shall be maintained with older cars using NYCT's H-2-C type couplers, through the use of the coupler adapter specified in Section 4.4.4.

4.1.3.6. After manual retraction of the electric coupler pins (See Section 4.3.4.7), mechanical coupling to a car type other than an R211 shall not result in the interconnection of any electrical circuits between car types.

4.1.4. Connections within a Unit

4.1.4.1. A link bar shall be provided at each end of each B car and at the No. 2 end of each A Car to provide a semi-permanent mechanical connection between cars within a Unit.

4.1.4.2. Electrical connections between cars within a Unit shall be through jumper cables terminated with quick disconnect type connections, in accordance with Section 19.25.5.

4.1.4.3. Pneumatic connections between cars within a Unit shall include lines for main reservoir and brake pipe air.

- 4.1.4.4. All connections between cars within a Unit shall be capable of being made or disconnected manually, using commercially available hand tools.

4.1.5. Automatic Coupler Control

Controls

- 4.1.5.1. The electric and pneumatic control systems shall permit automatic coupling and uncoupling of Units from within an adjacent cab.
- 4.1.5.2. It shall be possible to manually command local electric and pneumatic coupling and uncoupling from track level at the front of the car.

Coupling

- 4.1.5.3. The coupling shall occur fully automatically when the couplers come into full contact if the displacement of the couplers is within the gathering range specified in Section 4.2.1.11.

Uncoupling

- 4.1.5.4. Coupler control shall be arranged so that the complete automatic uncoupling operation can be performed as commanded in Section 4.1.5.9, only from a cab with an active Master Controller.
- 4.1.5.5. Uncoupling shall be manually initiated, and protected by a key-switch. See Section 5.3.3.1.
- 4.1.5.6. The uncoupling control shall provide reliable, fail safe operation, requiring completion of an uncoupling cycle before train operation is possible.
- 4.1.5.7. Single-point failures in the uncoupling control circuits shall not produce uncoupling.
- 4.1.5.8. The trainline isolation function shall be available in any cab, regardless of active status.
- 4.1.5.9. During commanded uncoupling, the emergency brakes shall apply on the Unit being parked. The controlling Unit shall not have emergency brakes applied and shall not result in brake pipe pressure loss. Unintentional uncoupling or train separation shall cause emergency brakes to be applied to both Units.
- 4.1.5.10. Tail lights shall illuminate on each Unit end following uncoupling, except where headlights are activated.

4.2. Performance Requirements

4.2.1. Mechanical Coupler and Link Bar

Strength Requirements

- 4.2.1.1. The coupler and link bar systems shall absorb shock in both buff and draft, and shall withstand, without permanent deformation or maintenance intervention, the forces encountered during all modes of operation, including repetitive loading. The Contractor shall be responsible for determining the applied draft gear loadings.
- 4.2.1.2. The coupler and link bar systems shall withstand, without permanent deformation or maintenance intervention (e.g., replacement of broken shear pins), the loads occurring during recovery operation (defined as one AW3 loaded 10-car train towing another AW3 loaded 10-car train that is unpowered) over the Manhattan Bridge, including forces that may occur when attempting to start with the unpowered train being fully braked.

- 4.2.1.3. The coupler and link bar systems shall also absorb, without any permanent damage or maintenance intervention (e.g., replacement of broken shear pins or replacement of Crash Energy Management (CEM) elements), the forces that occur during a 3 mi/h (4.8 km/h) hard coupling of an AWO loaded 5 car Unit with another AWO loaded 5 car Unit that has its brakes applied.
- 4.2.1.4. The coupler and link bar systems, exclusive of energy absorption elements, shall withstand a static load, in buff or draw, sufficient to avoid yielding or buckling under the conditions stated in Sections 4.2.1.1 to 4.2.1.3, with a safety factor of at least 2.
- 4.2.1.5. Under extreme loading (beyond the conditions stated in Sections 4.2.1.1 to 4.2.1.3) the design of the coupler and link bar systems shall be such that the coupler and drawbar, or link bar, assembly fails before the anchor assembly or attachment to the carbody.
- 4.2.1.6. For any horizontal position of the coupler or link bar, the coupler and link bar systems shall withstand, without yielding, the loads imparted due to the jacking of the car (for re-railing purposes) beneath the coupler or link bar. Blocking materials or devices may be used between the coupler or link bar and carbody in this case.

Energy Absorption Requirements

- 4.2.1.7. The coupler and link bar systems may have an energy absorption feature that is integrated with the overall crashworthiness and CEM design of the train, as described in Section 2.8.
- 4.2.1.8. The coupler and link bar systems shall absorb energy as may be encountered during normal operation, including low speed collisions (as defined in Section 4.2.1.3) and bucking forces between cars.
- 4.2.1.9. The coupler and link bar systems shall be provided with an automatic release mechanism to provide emergency release in the event of severe end impacts, permitting the transfer of excess buff loads to the car's underframe. The release mechanism force value shall be determined in coordination with the CEM performance requirements of Section 2.8.

Geometrical Requirements

- 4.2.1.10. The coupler and link bar systems shall be designed and constructed to permit coupled cars to negotiate all horizontal and vertical curves specified in Appendix A (Fixed Facilities Description) and Appendix C-5 (Track Standards and Reference Manual MW-1), including operation with maximum mismatch between cars due to truck suspension deflections, wheel wear and track irregularities.
- 4.2.1.11. The automatic coupler shall permit automatic coupling with misalignment between couplers involving any combination of the following:
 - a) Vertical distance between the center lines of coupler of up to 3 inches (76 mm).
 - b) Horizontal distance between the center lines of the couplers of up to 3.375 inches (86 mm).
 - c) Coupler heads rotated up to a maximum of 5 degrees to each side of the vertical center line, varying a total of a maximum of 10 degrees from each other.

Other Performance Requirements

- 4.2.1.12. When uncoupled and without air pressure, the automatic coupler assemblies shall pivot laterally when a force of not more than 75 lb. (334 N) is applied to the face of the coupler head.
- 4.2.1.13. See Sections 4.6 and 24.8.8 for qualification testing and production acceptance tests, respectively.

4.2.2. Electrical Coupling

- 4.2.2.1. Low voltage (37.5 Vdc) coupler contacts shall be designed to transmit not less than 40 amperes for 1 hour and 30 amperes continuously (this requirement does not apply to data circuits).
- 4.2.2.2. The individual parts and the assembled electric coupler head shall be sufficiently rugged to withstand the coupling impacts and repeated stresses to which they will be subjected in service.
- 4.2.2.3. The electric coupler heads shall maintain positive contact under the forces and impacts to which the car couplers will be subjected in service.

4.3. Functional Requirements

4.3.1. Automatic Coupler Control

- 4.3.1.1. Auxiliary equipment shall be supplied as part of the coupler equipment to energize in both cars the activating relays and magnet valves performing the following functions:
 - a) Sense the uncoupled state and open the drum switch or an NYCT approved alternate. Close the looping circuits and open all other switched trainline circuits; close the air trainlines and open the coupler hook.
 - b) Sense the coupled state and close the drum switch or NYCT-approved alternate. Open the looping circuits, restore continuity of trainlines and open the air trainlines.
 - c) Manual means must also be provided by which specified air and electric trainlines can be opened or closed.
- 4.3.1.2. Sensing shall be done by positive means of Trainline control.

4.3.2. Mechanical Coupling

Automatic Coupler

- 4.3.2.1. The automatic coupler head assembly shall be a Tomlinson style, flat faced, hook-type coupler, fully compatible with the mechanical couplers on existing R143, R160, and R179 cars (NYCT commodity number 16-42-2032).
- 4.3.2.2. The automatic coupler design shall permit complete mechanical coupling by bringing cars at AWO loading together at speeds up to 3 mi/h without damage to any components.
- 4.3.2.3. Operation of the coupler uncoupling valve shall cause a complete uncoupling, with no further manual effort required.
- 4.3.2.4. Mechanical coupling with cars equipped with H-2-C couplers shall be possible through the use of an adapter. See Section 4.4.4.
- 4.3.2.5. An NYCT-approved device shall be provided within the mechanical automatic coupler to lock the couplers in close mating contact during a rescue operation.
- 4.3.2.6. If an external device is required for locking, it shall be stored in a similar manner and location as shown in Appendix C-7 (bulletin # 359.04 rev. A titled "Installation of Coupler Locking Bolt in Train Operator Cab on the R44 and R46 Car Classes"). See Section 4.4.4 for coupler adapter requirements.
- 4.3.2.7. Means shall be provided in the automatic coupler system to permit manual uncoupling from track level at the end of the A Car in the event of loss of air pressure.
- 4.3.2.8. Each coupler shall be supported in its nominal aligned position, in such a way as to permit the horizontal and vertical movement needed for proper operation.

- 4.3.2.9. Automatic couplers shall be equipped with a lateral centering device, or NYCT approved equal, that holds the coupler on the center line of the car, when uncoupled, to permit automatic coupling within the gathering range described in Section 4.2.1.11.
- 4.3.2.10. The centering device shall permit manual overriding movement of the coupler head to provide proper coupling alignment on curves.

Link Bars

- 4.3.2.11. Manual uncoupling at the non-cab ends of A Cars and both ends of the B Cars shall be accomplished by separating the link bar.
- 4.3.2.12. Special tools shall not be required for link bar separation.
- 4.3.2.13. The link bar shall not require additional support to be coupled, or after uncoupling.

4.3.3. Electrical Coupling

Automatic Coupler

- 4.3.3.1. The electric head shall be capable of automatically making the required number of electrical connections between Units.
- 4.3.3.2. Electric connectors shall maintain effective continuity under all car operating and storage conditions.
- 4.3.3.3. The electrical coupler sub-assemblies shall be heated by thermostatically controlled heaters of adequate capacity to prevent freeze-ups of these sub-assemblies in inclement weather.
- 4.3.3.4. Automatic electric coupler contacts and trainlines shall be symmetrically arranged about the vertical centerline so that they may be reversed with respect to any other R211 car variant, and the specified functions will not be affected.
- 4.3.3.5. Multiple sets of contacts shall be provided to meet the impedance, shielding, and balance requirements of the various data busses required elsewhere in this Specification.
- 4.3.3.6. The automatic coupler pins shall have sufficient diameter and travel to exceed the requirements under worst case conditions for condemning limits of the mechanical coupler.
- 4.3.3.7. The uncoupling control circuits shall preclude un-commanded uncouplings and shall be considered a safety critical function within the hazard analysis according to Section 21.3.4.
- 4.3.3.8. To prevent automatic coupler front contacts from arcing during uncoupling, a separate set of switching functions shall be included for the automatic disconnect of all circuits that might cause arcing damage, prior to separation of the current carrying contacts.

Connections within a Unit

- 4.3.3.9. Inter-car electrical connections shall utilize jumper cables with connectors at each end, connected to car-mounted junction boxes.
- 4.3.3.10. Semi-permanent jumper cables or an alternate connector arrangement may be submitted for NYCT approval.
- 4.3.3.11. The approved alternate arrangement must include provision for protecting loose ends of cables when cars are uncoupled.
- 4.3.3.12. A means shall be provided to remove power from all circuits capable of carrying more than 50 volts, and/or currents in excess of 10 amperes, prior to disconnection of inter-car cables.

4.3.4. Electrical Isolation

- 4.3.4.1. Provision shall be made to automatically isolate the electrical circuits as needed through an electro-pneumatically operated switch.
- 4.3.4.2. The isolation switch shall be capable of manual operation from either the front or side of the car from track level if either the electrical or pneumatic system malfunctions.
- 4.3.4.3. High current contacts shall be included in the isolation switch to allow electrical interruptions, with no paralleling of contacts permitted.
- 4.3.4.4. Loop circuits shall be made through the isolation switch.
- 4.3.4.5. All vital door control and indication circuit wiring shall be isolated from 37.5 Vdc B(+) and other circuits by approved terminal separation, wire arrangement, and wire dressing.
- 4.3.4.6. It shall also be possible to isolate all trainline circuits by manually retracting the electric coupler head, or by retracting the pins within the contact block.
- 4.3.4.7. A handle shall be provided on the coupler to manually retract or advance the coupler head or electric coupler pins.
- 4.3.4.8. The head/pin advance handle shall incorporate a locking device to prevent inadvertent retraction or advancing.

4.3.5. Pneumatic Coupling

- 4.3.5.1. Unit-to-Unit brake pipe connections shall be made automatically when couplers are fully engaged mechanically and locked.
- 4.3.5.2. Connections shall be provided in the coupler for brake pipe and any other connections necessary for the automatic coupling and uncoupling of the Units.
- 4.3.5.3. Trainline cutout valves specified within Section 12.4.5 shall be installed upstream of any flexible hoses. Refer to Figure 4-1.

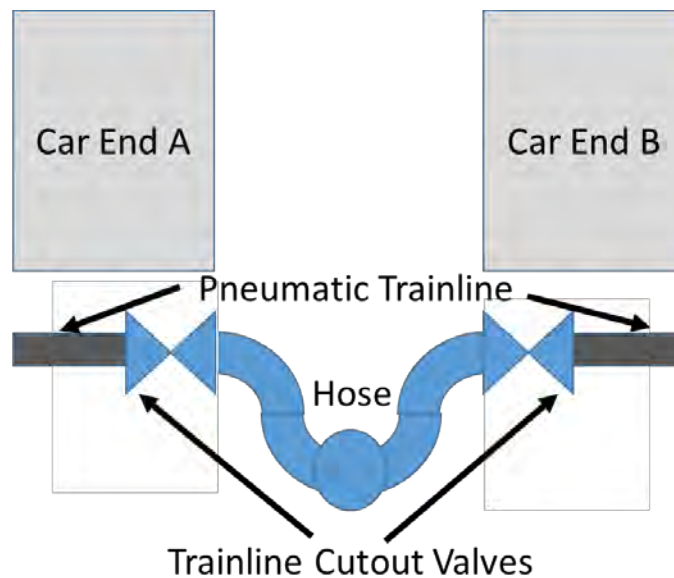


Figure 4-1: Location of Cutout Valves

- 4.3.5.4. A readily replaceable, self-closing valve shall be provided, which shall automatically close off the brake pipe when Units are uncoupled and which shall remain open between coupled Units.

- 4.3.5.5. Pipe union connectors shall be provided for the main reservoir and brake pipe trainlines where link bars are provided.

4.4. Design Requirements

4.4.1. General

- 4.4.1.1. All materials and manufacturing processes shall be in compliance with the requirements of Section 19, Materials, Processes, and Workmanship.
- 4.4.1.2. Water (rain, carwash, melting snow) shall not be able to collect anywhere on the coupler system.
- 4.4.1.3. All wearing surfaces shall have readily replaceable wear plates with sufficient area and hardness to perform the functions required in this specification for a minimum of two SMS cycles (14 years).
- 4.4.1.4. All surfaces mating to carbody attachments shall be machined.

4.4.2. Mechanical Couplers and Link Bars

- 4.4.2.1. The weight of the drawbar and mechanical and electrical (Cab Car No. 1 End) couplers shall be supported at their normal height by an NYCT approved support design.
- 4.4.2.2. Supports used for automatic couplers shall contain adjustment for correct coupler height, achievable using standard tools, and without removing the coupler.
- 4.4.2.3. The design of automatic coupler supports shall be such that the coupler can be removed and replaced without removing the supports.
- 4.4.2.4. Drawbar pins shall be top-mounted, and removable without the need to remove or lift the car relative to the adjacent truck.
- 4.4.2.5. An access plate shall be provided in the car floor for access to the drawbar pin.
- 4.4.2.6. Drawbar connections shall permit uncoupling between the drawbar and the coupler head or the anchor with the use of hand tools.

Emergency Release

- 4.4.2.7. Positive visual indication shall be provided for inspection purposes to determine the position of the emergency release mechanism and whether a full or partial release has taken place.
- 4.4.2.8. Restoring the emergency release feature shall require no special tools and a minimum of hand labor to restore the mechanical coupler to a normal operating condition.
- 4.4.2.9. It shall not be necessary to remove or disassemble the yoke or drawbar housing to replace the emergency release feature.
- 4.4.2.10. The emergency release assembly shall be designed to facilitate removal in the event of partial release.

Stops and Safety Support

- 4.4.2.11. Under no conditions shall any part of the coupler system contact or interfere with truck parts, wheels, cables, or other equipment due to excessive movement.
- 4.4.2.12. Mechanical drawbar stops to prevent such contact shall have elastomeric stop cushions with integral wear plates at the point of contact with the other member. Alternative arrangements may be proposed for NYCT approval.

- 4.4.2.13. Safety straps or other means of secondary retention, as approved by NYCT, shall be provided to retain couplers and link bars, and prevent them falling to the track or penetrating the car floor in case of primary support failure if a coupler carrier is not provided.

Coupler Carrier Requirements (If Provided)

- 4.4.2.14. The carrier shall be designed to allow for the required range of movements in the vertical and transverse directions under all track and vehicle operational conditions. See Section 4.2.1.10.
- 4.4.2.15. The drawbar carrier shall be machined from forged, fabricated, or cast steel material in accordance with the requirements of Section 19.3 and 19.4.
- 4.4.2.16. The carrier or drawbar jaws shall have replaceable wear plates of "Nylatron" or NYCT approved equal. See Section 4.4.1.3 for wear requirements.
- 4.4.2.17. Coupler carrier fasteners shall conform to the requirements of Sections 3.4.5 and 19.19.

4.4.3. Electrical Coupling

General Requirements

- 4.4.3.1. The automatic electric coupler head shall be mounted under the mechanical coupler in such a way as to provide for easy removal and replacement of the entire assembly, without the removal of any other adjacent equipment.
- 4.4.3.2. Registration (alignment) pins shall be provided for electric head alignment.
- 4.4.3.3. The automatic electric coupler head shall contain multi-pin contacts to provide electrical connection for critical trainline signals between Units.
- 4.4.3.4. A multi-pin arrangement in a fixed pin block shall be used.
- 4.4.3.5. Grounding connections between cars within a Unit shall have readily accessible terminations using bolted attachments.

Automatic Coupler Contact Pins

- 4.4.3.6. All contact pins shall be of the conventional type, spring-loaded, butt-type, of an approved material, the heads of which shall be completely silvered with coined tips 0.030 inch (0.76 mm) thick.
- 4.4.3.7. The contact pins shall have ample surface capacity, suitable shape and positive action to prevent fouling in coupling.
- 4.4.3.8. Contact pins shall not stick or bind under any environmental condition.
- 4.4.3.9. Contact pins shall not freeze under any condition including snow, ice, rain, and other environmental factors. See Section 4.3.3.3.
- 4.4.3.10. Creepage distance between adjacent contact pins shall be adequate for the applied voltages including surges.
- 4.4.3.11. The Contractor shall coordinate the quantity and configuration of spare contact pins and carbody wiring for discrete, network, and CBTC trainline signals. Contact pin quantity shall allow for addition of and/or changes to signals based on car development and validation changes as well as future upgrades. Spare quantity and configuration shall be approved by NYCT.
- 4.4.3.12. Contact pin tips shall be replaceable from the front of the coupler without disassembly of the coupler or its internal wiring harness.
- 4.4.3.13. All contact pins shall be permanently and clearly marked with their actual circuit designation on the contact block directly beneath the contacts.

- 4.4.3.14. Spare contact pins shall be identified with decals only, designated by the word "Spare" and its corresponding contact pin number.
- 4.4.3.15. The contact pin holder block shall be removable from the front.
- 4.4.3.16. The contact pin springs shall be made of beryllium copper or stainless steel, must not be subject to a permanent set due to compression in service, and shall provide the design pre load force at the contact pin faces.
- 4.4.3.17. A bonded, braided shunt shall carry all current away from the spring if there is no direct tip-to-wire connection.
- 4.4.3.18. Network contacts shall provide connectivity for the networks, data, and trainlines as required by Section 16, Trainline and Car Control Architecture, and shall be designed in conjunction with the network supplier. See Section 16.1.1.3.
- 4.4.3.19. Network connections that do not utilize butt-type contacts shall be subject to approval by NYCT.
- 4.4.3.20. Network connections shall be made and broken through the coupler upon commanded electrical coupling or uncoupling without any requirement for manual configuration and without loss of data such as fault logs or subsystem configuration.

Automatic Electric Coupler Housing

- 4.4.3.21. Each electric coupler head shall be provided with not more than four receptacles to interface with car wiring cables.
- 4.4.3.22. The electric coupler head design shall minimize the entry of water and debris of any kind into the electrical housing, when in the coupled or uncoupled position. A drain hole shall be included in the design of the electric coupler housing.
- 4.4.3.23. Electric coupler head materials shall not absorb water and shall neither embrittle nor soften in extreme heat or cold.
- 4.4.3.24. Connections to the back of the electric coupler contacts shall be robust and shall be accessible for maintenance.
- 4.4.3.25. Connections from electric couplers to the trainline junction box shall be by means of multiple-conductor cables wired to NYCT-approved connectors. See Section 19.25.5 for connector requirements.
- 4.4.3.26. The maximum diameter for any multiple conductor cable shall be 1.50 inches (38 mm).
- 4.4.3.27. Air gaps and creepage distances within the electric coupler housing, including the cover, shall be maintained or mitigated with insulating materials.
- 4.4.3.28. A removable plate shall be provided on the bottom of the housing of sufficient size to make connections and to inspect the terminals, cross connections, and other internal parts of the coupler.
- 4.4.3.29. All parts within the electric coupler housing shall be made of non-corroding materials.

Automatic Electric Coupler Covers

- 4.4.3.30. A cover shall be provided to protect the electric coupler contact pin and contact blocks from dirt, dust, water, and ice when it is closed in the uncoupled position.
- 4.4.3.31. The cover shall be spring-closed and shall automatically open as the cars are buffed together during coupling, and automatically close as the cars are uncoupled.
- 4.4.3.32. The electric coupler cover shall be provided with an NYCT-approved hold-open feature for maintenance purposes.

- 4.4.3.33. The cover shall be easily replaced.
- 4.4.3.34. The cover shall not be damaged when used by personnel to move the coupler assembly.

Isolation Switches

- 4.4.3.35. Switch contacts for loop circuits shall be provided in the isolation switch described in Section 4.3.4.
- 4.4.3.36. The isolation switch shall provide a minimum of four annunciating circuits: one to the Train Operator's indication signal light, one to the taillights, one to the end door locks, and one spare.
- 4.4.3.37. These circuits shall be opened when the switch is in the coupled position and shall be closed when the switch is in the uncoupled position.

High Voltage Ground Connections

- 4.4.3.38. High voltage ground connections at the automatic coupler shall be made using a braided copper wire with bolted connections to the mechanical coupler head and carbody.
- 4.4.3.39. High voltage ground connections at the link bar shall be made using a braided copper wire with bolted connections to the link bar and carbody.

4.4.4. Coupler Adapters

- 4.4.4.1. One lightweight (portable) coupler adapter per Unit shall be furnished to permit coupling of the specified hook type coupler to cars equipped with NYCT's H-2-C type coupler.
- 4.4.4.2. The adapter shall have sufficient strength to pull or push (in the event of an emergency) a failed train under the conditions defined in Section 4.2.1.2.
- 4.4.4.3. The adapter shall be NYCT Standard Commodity No. 16-42-2100, or NYCT-approved equal.
- 4.4.4.4. The adapter shall be provided with an NYCT-approved carrier, to be mounted inside the car at an NYCT-approved location near the cab. Provisions for a locking bolt shall be provided with each coupler adapter.
- 4.4.4.5. An NYCT-approved graphic shall be provided to identify the location of the coupler adapter within the Unit.

4.5. Maintainability Requirements

- 4.5.1.1. The overhaul interval of the coupler systems, including all elastomers and energy absorption and release devices, shall be a minimum of one SMS cycles (7 years), under the normal operating conditions defined in this section.
- 4.5.1.2. It shall not be necessary to remove the drawbar to replace the coupler head.
- 4.5.1.3. Lubrication shall not be necessary on coupler head pivots. Lubrication of the coupler carrier support (if provided) may be proposed for NYCT approval to meet the requirements of Section 4.2.1.12.
- 4.5.1.4. The Contractor shall supply the required quantity of "GO/NO GO" gauges, together with associated drawings and calibration procedures, to allow checking of every critical surface of the coupler for proper dimension to assure continued proper operation. See Section 22.7 for Special Tools and Test Equipment requirements and quantities.

Trainline Portable Test Equipment

- 4.5.1.5. Portable Test Equipment (PTE) shall be provided that checks the integrity of the trainline wiring from the contact pins in the coupler electric heads at one end of the Unit to the contacts in the coupler electric head at the other end.

- 4.5.1.6. PTE shall be designed for use by one person, shall be microprocessor-based, and shall not require an external power supply.
- 4.5.1.7. PTE shall identify problems without the use of a code and subsequent need to refer to a table.
- 4.5.1.8. PTE shall be accompanied by all documentation needed for operation, maintenance, and troubleshooting of both the trainlines and the trainline PTE.
- 4.5.1.9. General requirements and quantities for the trainline PTE are provided in Section 22.8.

4.6. Validation Requirements

4.6.1. Draft Gear Analysis

- 4.6.1.1. The Contractor shall conduct an impact analysis of the coupler system to verify the performance of the coupler system in relation to energy absorption and/or force displacement. Results shall be utilized for consideration in the train level CEM analysis per Section 2.8. The analysis shall be submitted for NYCT review and approval. [CDRL]
- 4.6.1.2. An analysis showing the loads applied to each coupler element, together with an explanation of how they were derived, shall be submitted for NYCT review and approval. [CDRL]
- 4.6.1.3. A Finite Element Analysis (FEA) shall be conducted for applicable coupler and link bar elements utilizing the loads derived in Section 4.6.1.1. The analysis shall be submitted for NYCT review and approval prior to manufacture of coupler and link bar components. [CDRL]

4.6.2. General Test Requirements

- 4.6.2.1. The Contractor shall perform, or under its direction, a series of design qualification tests on the first complete production units of Coupler, Draft Gear, and Link Bar, to demonstrate conformance to the requirements of this Specification.
- 4.6.2.2. Coupler, Draft Gear, and Link Bar design qualification tests shall include tests to validate the performance and capacities of the following:
 - a) Coupler draft and buff loading.
 - b) Link bar draft and buff loading.
 - c) Draft gear deflection and emergency release.
 - d) Coupler anchor static loading.
 - e) Link bar anchor static loading.
 - f) Gathering range, and automatic mechanical coupling and uncoupling.
 - g) Electrical automatic coupling and uncoupling.
 - h) Pneumatic automatic coupling and uncoupling.
 - i) Centering.
 - j) Vertical strength capability.
 - k) Energy absorption.

4.6.3. Draft Gear Strength Validation

- 4.6.3.1. Draft gear buff and draft loading validation shall apply to the coupler and the link bar complete assemblies. The draft gear shall have Contractor-calculated maximum draft and buff loads applied. See Section 4.6.1.1. No damage or permanent deformations shall result.

- 4.6.3.2. Draft gear anchor validation shall apply to the coupler and link bar anchors (bearing brackets) that interface to the carbody. The anchors shall be tested to an ultimate test load of 1.5 times the design static load in draft and buff, without damage or permanent deformation.
- 4.6.3.3. For each fabricated weldment, the supplier shall perform a design qualification test on the first production component. Qualification shall consist of static load applications with an additional load factor of 1.5 above maximum calculated loads to be supported by the weldment. No damage or permanent deformations shall result.
- 4.6.3.4. The coupler shall be loaded with a static vertical load equivalent to the loads imparted due to jacking of the car (for re-railing purposes) beneath the coupler or link bar in both directions. Vertical strength validation shall be conducted in positions representing the normal and extreme horizontal positions of the coupler. No damage or permanent deformation of the coupler shall be observed.

4.6.4. Draft Gear Functional Validation

- 4.6.4.1. Draft gear deflection validation shall consist of verification of deflection limits of the coupler and link bar systems.
- 4.6.4.2. The ability of the coupler to automatically couple under the worst case misalignment shall be validated. Coupler gathering range validation shall consider the worst case combination of lateral, vertical, and angular misalignments.
- 4.6.4.3. The ability of the coupler to center after a lateral deflection shall be validated. Coupler centering validation shall consider both intermediate and maximum deflections of the coupler. Centering validation shall confirm the coupler returns to a position that is within the gathering range of the coupler system. Manual centering forces shall be validated to confirm coupler movement with the force specified in Section 4.2.1.12.
- 4.6.4.4. The ability of the coupler to automatically couple and uncouple mechanically, electrically, and pneumatically shall be validated. Integrity of the connections (mechanical, electrical, pneumatic) shall be confirmed as part of the automatic coupling and uncoupling validation.
- 4.6.4.5. The emergency release function and the forces necessary to engage the emergency release shall be validated. Full and partial release shall be conducted to validate the ability to reset the emergency release in a partial release situation. Emergency release validation shall include verification of the restoring procedure to reset the emergency release to a normal operating condition.
- 4.6.4.6. Energy absorption testing shall validate the energy absorption performance of the coupler and link bar systems. Testing shall be conducted for any reversible and non-reversible energy absorption systems integrated into the couplers and link bars. Results of the testing shall be compared to the energy absorption and/or force displacement values considered in the CEM analysis per Section 2.15.4.

4.6.5. Other Testing Requirements

- 4.6.5.1. Refer to Section 24, Testing Program, for production acceptance (routine) testing requirements.

4.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

<u>CDRL</u>	<u>Ref</u>	<u>Deliverable</u>	<u>Timing</u>
4-1	4.6.1.1	Coupler system impact analysis	CDR
4-2	4.6.1.2	Coupler load derivation analysis	CDR
4-3	4.6.1.3	Coupler and Link Bar FEA	CDR

Section 5

Cab and Cab Controls

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5. Cab and Cab Controls

5.1. Introduction

5.1.1. This section defines the requirements for the cab and cab controls. Requirements common to the cab and carbody interior are covered in Section 15 – Carbody Equipment and Interiors. Refer to the following sections for car systems and components interfacing with the cab and cab controls and other applicable requirements:

- a) Design and Performance Criteria – Section 2.
- b) Coupler Systems – Section 4.
- c) Doors – Section 6.
- d) Heating, Ventilation and Air Conditioning – Section 7.
- e) Auxiliary Electrical Equipment and Distribution– Section 9.
- f) Propulsion System – Section 10.
- g) Friction Braking and Air Supply Systems – Section 12.
- h) Carbody Equipment and Interiors – Section 15.
- i) Trainline and Car Control Architecture – Section 16.
- j) Monitoring and Diagnostics – Section 17.
- k) Materials, Processes, and Workmanship – Section 19.

5.1.2. General Cab Requirements

5.1.2.1. A full width cab shall be provided at the No. 1 End of each A Car.

5.1.2.2. Each cab shall contain, as a minimum, all appurtenances necessary for operation of the train and for the safety and comfort of the train crew as described in this Section.

5.1.2.3. The initial cab design shall be similar to the R160 or the R179 Car, and shall be guided by the conceptual renderings in Figures 5-1 through 5-5.

5.1.2.4. The size of the cab shall be no smaller than the NYCT R160 or R179 cab. See the general dimensions provided in NYCT reference drawings R160-5001 and R160-5002 (see Appendix D-25).

5.1.2.5. The cab shall be arranged to permit train operation by a Train Operator seated or standing in front of the console. The arrangement shall allow the Train Operator to stand up comfortably and move, without interference, to the side window on either side of the cab to observe and operate the side doors.

5.1.2.6. The cab layout and controls shall allow for train operation in the following modes:

- a) Two person train operation with a Train Operator in the lead A Car and a Conductor in another A Car in the middle of the train with the Conductor moving side to side in the cab to observe and operate the side doors.
- b) Restricted One Person Train Operation (OPTO) with a Train Operator in the lead A Car moving side to side to observe and operate the side doors.
- c) One Person Train Operation with a Train Operator in the lead A Car operating the side doors from the seated position.
- d) Any of a) through c) with the train under the control of the Communications Based Train Control (CBTC) system specified in Section 14, Train Control System.

- 5.1.2.7. The cab layout shall maximize the use of available space and shall employ sound human engineering factors as outlined in Military Standard MIL-STD-1472: "Design Criteria Standard: Human Engineering", and shall follow accepted industrial design principles in its development.
- 5.1.2.8. The Train Operator's space and equipment shall be properly designed to ensure safe and optimal Train Operator performance and shall provide a maximum field of view for Train Operators in the range of the 5th percentile female to the 95th percentile male in the general population.
- 5.1.2.9. The Train Operator's field of view shall be no less than that of the R160 or R179 cars.
- 5.1.2.10. The Contractor shall submit detailed layouts of the cab for approval by NYCT. Upon approval, the design shall be incorporated in the cab mock-up for final approval (see Section 20.6).
[CDRL]
- 5.1.2.11. The cab layout shall be designed to incorporate onboard CCTV monitoring by a Train Operator and/or authorized NYCT personnel seated or standing in front of the console as well as provisions for Platform Edge Closed Circuit TV (Platform Edge CCTV). See Sections 5.4.5, 13.9, and 13.10.
- 5.1.2.12. The cab shall be fully enclosed and secured to prevent unauthorized access.
- 5.1.2.13. Each cab shall be capable of taking control of the train regardless of its position in the train. Mid-cab operation may be accomplished by using bypass switches for trainline interlock functions.
- 5.1.2.14. Automatic Train Operation (ATO) shall only be available in an active, lead cab.

5.2. Cab Construction

5.2.1. General Design Requirements

- 5.2.1.1. Materials used in the cab shall minimize reflections and glare.
- 5.2.1.2. Materials used in the cab shall maximize durability and cleaning ability and there shall be no areas where liquids or debris can accumulate.
- 5.2.1.3. The Contractor shall design the cab to include lockers and enclosures to house required onboard equipment.
- 5.2.1.4. All equipment access areas within the cab shall be made vandal and tamper-resistant, either by lock and key, or by similar methods approved by NYCT.
- 5.2.1.5. All hardware shall be secured with tamperproof machine screws as approved by NYCT.
- 5.2.1.6. The cab shall be free of safety hazards including sharp edges, protruding objects, and floor obstructions.
- 5.2.1.7. Panels and components such as the and communications panels, duplex air gauge, and CBTC Bypass Switch Panel shall be designed such that they will be flush with, or recessed into, the adjacent walls.
- 5.2.1.8. Wall-mounted panels and equipment enclosures shall match the surrounding wall color scheme.
- 5.2.1.9. The console and all other panels not in a vertical position shall be designed so that liquid spilled on the surface will not damage or interfere with the operation of controls, indicators, or wiring.

5.2.2. Cab Partition

- 5.2.2.1. The cab shall be separated from the passenger area by a full-height, full-width transverse partition wall, as required by Section 15.9.6.

5.2.3. Cab Door

5.2.3.1. The cab door requirements are contained in Section 15.4.6.

5.2.4. Cab Flooring

5.2.4.1. The cab flooring shall be the same as provided in the passenger section, as required by Section 15.3.

5.2.5. Cab Side and End Linings

5.2.5.1. The cab side and end lining requirements are contained in Section 15.9.

5.2.6. Cab Ceiling

5.2.6.1. The cab ceiling shall be arranged to facilitate maintenance access to equipment located above the ceiling.

5.2.6.2. Equipment requiring scheduled attention more often than every two years shall be readily accessible through hinged access panels sized and located for convenient opening.

5.2.6.3. Equipment requiring less frequent attention shall be accessible through larger access panels arranged for complete removal using only hand tools.

5.2.6.4. All access panels shall conform to the general maintainability design requirements of Section 2.14.4.

5.2.6.5. Cab ceiling panels shall be adequately supported to prevent sagging and drumming.

5.2.6.6. Ceiling requirements are contained in Section 15.9.8.

5.2.7. Cab Side Window

5.2.7.1. The cab shall be equipped with vertically sliding windows on both sides of the cab to allow the Train Operator or Conductor to monitor the loading and unloading of passengers.

5.2.7.2. The cab side window requirements are contained in Section 15.6.4.

5.2.7.3. A permanently mounted fixed or movable step, as approved by NYCT, shall be provided inside the cab, beneath the cab side windows, to give an additional lift to the operating personnel looking out of the side windows. The step shall allow for the front portion of the Train Operator's boot to fit underneath it.

5.2.8. Equipment Enclosures

5.2.8.1. All equipment within the cab, except for items for safety or regular train operation, shall be housed in equipment enclosures.

5.2.8.2. Enclosures shall be arranged such that the train crew has a clear, comfortable working area and has full access to side windows, electrical switches, and all other controls within the cab.

5.2.8.3. The equipment enclosure requirements are contained in Section 15.15.5.

5.2.9. Instrumentation Through-Floor Access Port

5.2.9.1. A through-the-floor access port shall be provided within each cab.

5.2.9.2. The access port shall consist of two, one-inch diameter conduits located in the cab wall or cab partition to be used by NYCT for running of instrumentation wiring.

5.2.9.3. The conduits shall have removable caps on both ends.

5.2.9.4. The through-floor access ports, and all material used in the through-floor access ports, shall meet the flammability and smoke emission requirements of Section 19.1.10.

5.3. Cab Controls

5.3.1. General

- 5.3.1.1. The design of controls, indicators, and displays in the cab shall be coordinated to support operation under Train Operator and Conductor control, OPTO control, or CBTC control. The design shall provide Platform Edge and onboard CCTV viewing.
- 5.3.1.2. The cab controls shall be laid out in a logical and ergonomic manner such that they are within easy and convenient reach of the Train Operator as outlined in Military Standard MIL-STD-1472.
- 5.3.1.3. Controls shall be located such that they are conveniently reached based on their importance or frequency of use.
- 5.3.1.4. Each control or indicator that is associated with a particular side of the train, such as the MDC zone controls, shall be positioned on the corresponding side of its panel.
- 5.3.1.5. The assignment of controls and indicators shall be determined as part of the design development process. The assignments shall reflect the policies and practices of NYCT and shall be approved by NYCT. R211 Cab Concept Drawings are contained in Figures 5-1 to 5-5.
- 5.3.1.6. All controls and indicators shall mount to panels fastened to the panel cabinet or enclosure.
- 5.3.1.7. The Train Operator Displays (TODs) and other distinct, functionally integrated subassemblies shall be installed as modules to facilitate their rapid removal and replacement.
- 5.3.1.8. All control and indication devices shall be heavy-duty construction and comply with the requirements of Section 19, Materials, Processes, and Workmanship.
- 5.3.1.9. All control and indication devices shall be:
 - a) Arranged to prevent entrance of dirt or dust.
 - b) Designed to prevent inadvertent actuation.
 - c) Tamper resistant.
- 5.3.1.10. Control and indication devices, including lenses, shall not be removable from the front of the panels.
- 5.3.1.11. Indicators shall be capable of being replaced from the rear of the panel.
- 5.3.1.12. Pushbuttons, unless otherwise approved, shall be flush with the top of the bezel when not depressed.
- 5.3.1.13. Clearance between each pushbutton and its housing shall be as tight as practicable to prevent unauthorized insertion of foreign objects. If necessary, guards may be applied where approved by NYCT.
- 5.3.1.14. The design of all control devices shall include protection from damage due to rough handling and shall be approved by NYCT. An example is a clutch to prevent over-torquing of rotary devices.
- 5.3.1.15. Indicators shall be powered from the Low Voltage Power Supply (LVPS) and shall comply with the requirements of Section 2.14.2.
- 5.3.1.16. The allocation of controls and indicators to the three TODs (i.e. CCTV TOD, CBTC TOD, and MDS TOD) shall be arranged for normal operation with all three TODs functioning.
- 5.3.1.17. The assignment of controls and indicators to the TODs shall be such that normal train operation may continue indefinitely with loss of one of the TODs.
- 5.3.1.18. All controls and indicators necessary for normal train operation shall be discrete devices.

- 5.3.1.19. In the event that the CBTC TOD fails, a selector switch on the console shall allow the Train Operator to switch the CBTC TOD screen onto the MDS TOD with no loss of functionality.
- 5.3.1.20. A CCTV Control key switch shall be provide on the cab console. When the switch is in the OFF position the CCTV TOD shall be turned off. When the switch is in the ON position the Passenger Area CCTV Screens shall be available.
- 5.3.1.21. In the event that the CCTV TOD fails, a soft key on the MDS TOD shall allow the Train Operator to switch the CCTV TOD screen to the MDS TOD under the restrictions described in Section 13.9.1.15.

5.3.2. Cab Console

- 5.3.2.1. The cab console shall be located at the right side of the cab, behind and centered on the windshield.
- 5.3.2.2. The cab console shall include controls and indications for train activation, train supervision, and train operation as specified in this Section. These shall include:
 - a) Individual switches, pushbuttons, and indicators.
 - b) Integrated controls and indicators implemented via the TODs.
- 5.3.2.3. The cab console panel shall be black with white engraved lettering.
- 5.3.2.4. The cab console panels shall be:
 - a) Fabricated from a corrosion proof material.
 - b) Finished with a heavy-duty surface treatment that resists scratches, burns, wear, and the effects of UV exposure.
 - c) Non-reflective.
- 5.3.2.5. The cab console operating face angle and operating face height shall be positioned to accommodate a seated Train Operator.
- 5.3.2.6. The cab console operating face not occupied by controls or indicators shall be covered by an easily replaceable metallic upset/textured surface as approved by NYCT. The surface shall be secured with tamperproof screws.
- 5.3.2.7. Console indicators shall be positioned to be in the line of sight of the Train Operator when the Train Operator is in the normal seated operating position.
- 5.3.2.8. Those controls that must be manipulated while coupling and uncoupling cars shall be arranged for safe and convenient operation by a Train Operator standing up next to the console looking at the coupler through the opened end door.

5.3.3. Cab Console Individual Controls and Indications

- 5.3.3.1. As a minimum, the individual controls and indicators listed in Table 5-1 shall be included on each console:

Table 5-1: List of Cab Console Controls and Indicators

Item	Name	Type	Specification Reference
1	CBTC Mode (Normal/Restricted Manual/AWP)	3-Position Selector Switch	Section 14.4.3
2	ATO Start	Pushbutton w/Guard	Section 14.4.3
3	Alerter	Pushbutton w/ Integral Indicator	Section 14.4.3
4	Carbody Lights On/Off	3-Position Momentary Selector Switch	Section 8.3.1.2
5	Cab Light (Off/On)	2-Position Selector Switch	Section 8.3.1.5
6	HVAC (On/Off)	3-Position Momentary Selector Switch	Section 7.3.4.1
7	Windshield Defroster	Alternate-action Pushbutton w/ Integral Indicator	Section 5.7.10
8	Windshield Wiper (Off/Int./Low/High)	4-Position Selector Switch	Section 5.7.12
9	Windshield Washer	Pushbutton	Section 5.7.13
10	Horn	Yellow Mushroom Pushbutton	Section 12.4.7.1
11	Buzzer	Pushbutton	Section 13.7.3
12	Uncouple Key Switch	Key Switch	Section 4.1.5
13	Uncouple	Pushbutton	Section 4.1.5
14	Advance	Pushbutton	Section 4.1.5
15	Isolate	Pushbutton	Section 4.1.5
16	Left Door Key Switch	Key Switch	Section 6.4
17	Left Door Open	Pushbutton	Section 6.4
18	Left Door Close	Pushbutton	Section 6.4
19	Left Door Enable	Pushbutton w/ Integral Indicator	Section 6.4
20	Right Door Enable	Pushbutton w/ Integral Indicator	Section 6.4
21	Door Closed Interlock Bypass	Pushbutton w/ Integral Indicator	Section 6.4
22	Lamp Test	Pushbutton	Section 5.5.12.1
23	Door Closed & Locked	Indicator	Section 6.4.19.6

Item	Name	Type	Specification Reference
24	Push To Talk	Pushbutton	Section 13.3.2
25	Reading Light Dimmer	Control Dimmer	Section 8.3.1.6
26	CBTC TOD Select (Normal/Back Up)	2-Position Selector Switch	Section 14.4.5.2
27	CCTV Control Key Switch	Key Switch	Section 5.3.1.20

- 5.3.3.2. The ATO Start pushbutton shall be protected by a green cover similar to that used on the R160 or R179 cars. The NYCT commodity number for the ATO Start Pushbutton is 13-43-0724.
- 5.3.3.3. The CCTV Control Key Switch shall utilize a tamper-proof and copy-proof security lock compatible with a standard NYPD key. Information on this key will be provided by NYCT to the Contractor before PDR.

5.4. Train Operator Displays

5.4.1. General

- 5.4.1.1. Each cab console shall be provided with three TODs as follows (refer to Figure 5-2):
 - a) One CBTC TOD.
 - b) One MDS TOD.
 - c) One CCTV TOD.
- 5.4.1.2. The positions of the TODs shall be essentially symmetrical with respect to the Train Operator’s seated position so that each TOD may be used with equal ease.
- 5.4.1.3. The TODs shall be arranged to be clearly visible to the Train Operator in both the sitting and standing positions and under all lighting conditions encountered in normal operation.
- 5.4.1.4. Detailed layouts of the TOD locations shall be proposed by the Contractor during Preliminary Design Review and approved by NYCT. [CDRL]
- 5.4.1.5. Each TOD shall act as both a display and manual input device for the Train Operator and other authorized NYCT personnel.
- 5.4.1.6. Each TOD shall be a high contrast, color, infrared touch screen display or other approved type with associated processors and logic. Each TOD shall be provided with anti-sun glare protection.
- 5.4.1.7. The TOD construction shall be suitably rugged for the application and shall require no adjustment or maintenance, except that which is consistent with NYCT current practice for cab mounted equipment.
- 5.4.1.8. The viewing area of the TOD screens shall be no less than 12.1 (307 mm) inches in the diagonal with a minimum of 1080p resolution. Alternative resolutions may be proposed to NYCT for consideration. The actual screen size shall be determined during cab design and mock-up.
- 5.4.1.9. The TODs shall support both text and graphical presentation of information. Information shall be displayed textually and/or graphically depending on the clearest and most efficient way to present each item of information.
- 5.4.1.10. The touch screen function shall be suitable for easy manual actuation including actuation by a Train Operator wearing gloves.

- 5.4.1.11. The human interface for the TODs shall comply with MIL-STD-1472 "Design Criteria Standard: Human Engineering".
- 5.4.1.12. Each TOD shall constitute a separate logical and physical node on the train network. Refer to Section 16, Trainline and Car Control Architecture, for the train network requirements.
- 5.4.1.13. Fixed shields, display dimming, window tinting, and/or similar methods shall be employed as required and shall be approved by NYCT. Display dimming, if employed, shall be automatic and require no action on the part of the Train Operator.
- 5.4.1.14. Pre-set brightness levels shall be adjustable by the operator via each TOD, with the minimum brightness level still clearly visible on the display.
- 5.4.1.15. The TODs shall be self-contained, requiring no external controls other than clearly indicated touch screen interface buttons and/or menus to allow the crew and maintenance personnel to communicate with the CBTC system, the MDS, the CCTV system, and other car systems.
- 5.4.1.16. The touch screen of each TOD and the display unit itself shall each be a repairable LRU supported by its Portable Test Equipment (PTE) and Bench Test Equipment (BTE). The touch screen shall be removable such that it can be replaced and repaired without removing the entire display unit from the console, and shall be available from a minimum of two sources.
- 5.4.1.17. The TODs shall perform logical processing related only to the presentation of information on its screen, to the interpretation of Train Operator inputs from its screen, and to communication with other processors and devices on the car. No other control or monitoring function shall be implemented within the TODs unless approved by NYCT.
- 5.4.1.18. Each TOD shall have a "sleep" mode with an adjustable timer.
 - a) The timer adjustment shall include a setting for "never sleep".
 - b) The sleep mode timer shall be adjustable by authorized personnel through use of the PTE.
 - c) The "sleep" mode shall initiate a screen saver with a subway or train oriented motif when the train is keyed up but stopped for a specific period of time with no user interaction or updated CBTC data.
 - d) The cars shall be delivered with the sleep mode timer set to "never sleep".
 - e) The screen shall "wake-up" from screen saver mode if there is Train Operator interaction or a change in CBTC data.

5.4.2. Information to be Displayed

- 5.4.2.1. Each screen, except the MDS Operating Screen, may employ one or more levels of subsidiary screens that present more detailed information and control choices.
- 5.4.2.2. Subsidiary screens shall be arranged hierarchically with a consistent interface to facilitate moving up and down the hierarchy.
- 5.4.2.3. Subsidiary screens shall only be used when the scope and complexity of the information being presented preclude its inclusion directly on a higher level screen.
- 5.4.2.4. Where the same information (text, graphics, and color) is provided on several different screens, it shall be presented in the same manner and in the same location, but not necessarily at the same size.
- 5.4.2.5. Information shall be divided among and presented on screens in a logical and orderly manner.
- 5.4.2.6. All text shall be in English and presented in a manner that is easily understandable by the Train Operator. Abbreviations, reference designators, and mnemonic codes already conventional in NYCT operations may be employed with NYCT approval.

- 5.4.2.7. No information shall be displayed on screens in any code, such as hexadecimal numbers or arbitrary alphanumeric designators, which are not immediately understandable by the Train Operator.
- 5.4.2.8. Each of the MDS TOD screens shall be of the same in layout regardless of where it is displayed, but selected control functions may be locked out and indicated by a “graying-out” of the affected screen areas or by comparable techniques. Screens and controls to be locked out shall be presented to NYCT during the Preliminary Design Review.
- 5.4.2.9. Activation of a touch screen area shall be acknowledged by the highlighting of the area and the emitting of an audible tone.
- 5.4.2.10. As part of the design process, the Contractor shall provide preliminary screen layouts for the MDS TOD, the CBTC TOD, and the CCTV TOD for NYCT approval. [CDRL]
- 5.4.2.11. All TODs in a cab shall be activated only:
 - a) When the Master Controller Key Switch in that cab is placed in an active position.
 - b) When the Master Door Controller is zoned up.
 - c) When the Maintenance Key is used by maintenance personnel to enable access to the maintenance screen in that cab.
- 5.4.2.12. Additional CCTV TOD display activation requirements are detailed in Section 13.9.1.
- 5.4.2.13. Additional CBTC TOD display activation requirements are detailed in Section 14, Train Control System.

5.4.3. Monitoring and Diagnostics Train Operator’s Display Information

MDS TOD General

- 5.4.3.1. The MDS TOD shall provide four primary screen displays for interface with the train crew and maintenance personnel as follows:
 - a) Operating Screen.
 - b) Control Screens.
 - c) Trouble Screens.
 - d) Maintenance Screens.
- 5.4.3.2. At a minimum the functions listed in Table 5-2 shall be provided as part of the MDS TOD.

Table 5-2: MDS TOD Control Functions

Item	Function	Active Screen	Specification Reference
1	Fault Acknowledge	Operating Screen	Section 5.4.3.5
2	Route and Destination Set-Up	Control Screen	Section 13
3	Time and Date Set-up	Control Screen	Section 13.5.3.11
4	Interior Message and Announcement Selection	Control Screen	Section 13
5	CCTV TOD Selection	Operating Screen	Section 13
6	Cab Heater (Off/Low/High)	Operating Screen	Section 7.4.4.5
7	Snow Brake (On/Off)	Operating Screen	Section 12.3.6.1

5.4.3.3. At a minimum the indications listed in Table 5-3 shall be capable of being displayed on the MDS TOD.

Table 5-3 MDS TOD Indications

Item	Indication	Active Screen	Specification Reference
1	Snow Brake On/Off Indication	Operating Screen	Section 12.3.6
2	Energy Saving Mode On/Off Indication	Operating Screen	Section 10.2.4.2
3	Next Stop (as displayed on interior message displays)	Operating Screen	Section 13
4	Distance from previous station	Operating Screen	Section 13
5	Fault Indication (flashing)	Operating Screen	Section 17
6	Passenger Emergency Handle Unit (PEHU) (with exact location)	Trouble Screen	Section 12.3.4
7	Consist Indication (cars in train, with car numbers shown in order and lead car indicated)	Operating Screen Trouble Screen Maintenance Screen	Section 17
8	Odometer Display	Maintenance Screen	Section 10.3.12
9	Location of applied friction brake/parking brake	Trouble Screen	Section 12
10	Route and Destination	Control Screen	Section 13
11	Regenerative Brake Cutout	Control Screen	Section 10
12	Time and Date	Control Screen	Section 17
13	C/R Indication	Maintenance Screen	Section 17
14	Trainline and Network Controller Mode	Operating Screen	Section 14
15	CBTC Bypassed	Operating Screen	Section 14
16	CBTC Restricted Manual (RM) Mode	Operating Screen	Section 14
17	CBTC RM Released	Operating Screen	Section 14
18	CBTC RM Overspeed	Operating Screen	Section 14
19	Air/Parking Brake Release Indicator	Operating Screen	Section 12
20	CCTV System Failed	Operating Screen	Section 13
21	HVAC State (Hot car/Cold Car and location)	Trouble Screen	Section 7

5.4.3.4. It shall be possible to access the Operating or Trouble Screen directly from any screen.

5.4.3.5. Each time a cab is activated, the “Fault Acknowledge” button on the Operating Screen shall flash if there are unacknowledged faults.

5.4.3.6. Display and menu activity shall occur concurrently with normal data collection and processing activities without impacting any of the functions.

MDS TOD Operating Screen

- 5.4.3.7. The Operating Screen shall present information and control functions useful to the Train Operator when the train is in motion or during a normal station stop.
- 5.4.3.8. Information displayed on the Operating Screen shall be arranged according to relevance to operation of the train.
- 5.4.3.9. Displayed items of greater importance to the Train Operator shall be the largest and be centrally located on the screen. Items of lesser importance to the Train Operator shall be smaller and on the periphery of the screen.
- 5.4.3.10. Displayed items that require urgent attention shall flash to attract the Train Operator's attention. The flashing of such items shall be canceled by the activation of a Fault Acknowledge soft key control on the MDS TOD.
- 5.4.3.11. When the onboard CBTC equipment is off or when the train is operated in Bypass or Restricted Manual (RM) Mode, the train speed shall be displayed on the Doppler Speedometer Display. When the train is in all other CBTC modes, the train speed shall be displayed only on the CBTC TOD as described in Section 14, Train Control System.

MDS TOD Control Screens

- 5.4.3.12. The Control Screens shall present information and control functions relevant to set up, configuration, or preparation of the train for service but which are not needed often enough to warrant their inclusion in the Operating Screen.
- 5.4.3.13. Setup functions accessed from the control screens shall be limited to monitoring and diagnostics, signs, and announcements.
- 5.4.3.14. At a minimum the Control Screens shall display the following information:
 - a) Route and Destination as described in Section 13, Communications.
 - b) Interior Message and Announcement Selection controls as described in Section 13, Communications.

MDS TOD Trouble Screens

- 5.4.3.15. The Trouble Screens shall provide pertinent information to the Train Operator or Road Car Inspector concerning conditions that affect the immediate operation of the train.
- 5.4.3.16. The Trouble Screens are described in more detail in Section 17, Monitoring and Diagnostic System.

MDS TOD Maintenance Screens

- 5.4.3.17. The Maintenance Screens shall provide pertinent information to maintenance personnel to assist in maintaining, troubleshooting, and repairing the equipment in the shop environment.
- 5.4.3.18. The Maintenance Screens are described in more detail in Section 17, Monitoring and Diagnostic System.

5.4.4. CBTC TOD Screens

- 5.4.4.1. The CBTC TOD shall display information from the onboard CBTC equipment.
- 5.4.4.2. The CBTC screens are described in more detail in Section 14, Train Control System.

5.4.5. CCTV TOD Screens

- 5.4.5.1. The CCTV TOD shall provide two screen displays for interface with the train crew and authorized personnel as follows, see Section 13, Communications:
 - a) Onboard Train CCTV System (OTCS).
 - b) Provisions for Platform Edge CCTV.
- 5.4.5.2. The CCTV TOD shall support the display of video in a variety of formats including but not limited to the following:
 - a) Single maximum resolution video screen.
 - b) Quarter resolution quad screen
 - c) Reduced resolution quad screen
- 5.4.5.3. The CCTV TOD screens shall include soft key selection and navigation buttons at the bottom of the screen. The soft keys shall be retained in each of the video formats described in 5.4.5.2.
- 5.4.5.4. The CCTV TOD shall be capable of streaming video from any selected combination of passenger area CCTV cameras located on the train.
- 5.4.5.5. The CCTV TOD shall only allow access to these screens via a special CCTV Control key switch located on the cab console, or other NYCT approved location.
- 5.4.5.6. Only one CCTV TOD in a train may be activated at any time.
- 5.4.5.7. The CCTV TOD shall remain activated for a configurable period of time after the CCTV Key is removed from the vehicle; this timer shall initially be set at 0 minutes, i.e. no delay.
- 5.4.5.8. The CCTV TOD shall be capable of displaying Platform Edge CCTV video in the same formats described in Section 5.4.5.2 without the use of the CCTV Control key switch.
- 5.4.5.9. The Platform Edge CCTV feature is intended for use with a provisional wayside system that is not available at this time. The car equipment must be capable of supporting such an interface with minimal changes in the future. The Contractor shall provide documentation identifying how the OTCS will support this feature at CDR.
- 5.4.5.10. The CCTV TOD shall be capable of displaying the Platform Edge CCTV video when the Platform Edge CCTV system determines that the train is stopped and a wayside signal is being received.
- 5.4.5.11. CCTV TOD screen layouts shall be defined during design review.

5.5. Other Controls and Indications

5.5.1. Emergency Brake Control

- 5.5.1.1. Each cab shall include a Conductor's Emergency Brake Valve (CEBV) with two handles.
- 5.5.1.2. A handle shall be centered over each cab side window and arranged for easy actuation by a Conductor standing next to the window.
- 5.5.1.3. Activation of the CEBV shall immediately exhaust air pressure from the brake pipe and immediately cause an emergency brake application to be initiated.
- 5.5.1.4. The CEBV shall be active at all times.
- 5.5.1.5. The force required to operate the CEBV shall be between 20 and 50 lbs. (89 and 224 N).
- 5.5.1.6. Release of an emergency brake application shall be accomplished by moving the Master Controller handle from the EMERGENCY BRAKE position to the FULL SERVICE BRAKE position while the train is at zero speed, following a 17 second penalty. See Section 12.3.3.

- 5.5.1.7. Reset of the CEBV shall be accomplished by raising the activated handle back to its original position close to the cab ceiling.
- 5.5.1.8. Detailed requirements for emergency brake system operation are given in Section 12, Friction Braking and Air Supply Systems.

5.5.2. Master Door Control Panels

- 5.5.2.1. Two Master Door Control (MDC) panels, one adjacent to each cab side window, shall be provided in each cab.
- 5.5.2.2. The MDC panel on the right side of the Train Operator's cab shall be located forward of the cab side window. The lower portion of the right side MDC shall be set at an angle facing towards the Train Operator.
- 5.5.2.3. The right side MDC Master Key Switch (MKS) shall be positioned at an additional angle towards the Train Operator.
- 5.5.2.4. The arrangement of the MDCs shall be approved by NYCT. [CDRL]
- 5.5.2.5. The MDC panel color shall match that of the surrounding area.
- 5.5.2.6. The MDCs shall contain, as a minimum, the following controls and indicators:
 - a) Side door controls and indicators as specified in Section 6, Side Door System.
 - b) Communications controls and indicators as specified in Section 13, Communications.
 - c) Door Enable indication as specified in Section 6, Side Door System.
- 5.5.2.7. The controls and indications for the MDCs are described in Section 6, Side Door System.

5.5.3. Communications Control Panel

- 5.5.3.1. One Communication Control Panel (CCP) shall be provided in each cab. The CCP shall be located above the left side of the Train Operator's console.
- 5.5.3.2. Refer to Section 13.4.9 for specific details on the CCP.

5.5.4. Conductor Panels

- 5.5.4.1. Two Conductor Panels shall be provided in the cab and shall be installed on the rear bulkhead, adjacent to each cab side window.
- 5.5.4.2. Refer to Section 13.4.10 for specific details on the Conductor Panel.

5.5.5. Bypass and Cutout Panel

- 5.5.5.1. A Bypass and Cutout Panel incorporating all required bypass and cutout switches shall be provided in each car as specified below.
- 5.5.5.2. If needed, the Bypass and Cutout Panel in B cars shall be located in a readily accessible, secure locker within the passenger compartment at the No. 1 End of the car.
- 5.5.5.3. In A Cars the Bypass and Cutout Panel shall be located in a separate locker at a convenient location at the right side of the cab, behind the Train Operator's position.
- 5.5.5.4. Each Bypass and Cutout Panel shall be equipped with a substantial self-latching door that shall be opened using the standard Master Door Controller key (NYCT commodity number 19-68-9950, see Appendix D-26, VB #04-01).
- 5.5.5.5. Switches in the Bypass and Cutout Panel shall comply with the requirements of Section 19.31.3.
- 5.5.5.6. Switches in the Bypass and Cutout Panel shall be sealable in either the Normal or Cutout/Bypass position to prevent unauthorized use.

- 5.5.5.7. The following switches shall be provided in A Cars only and shall be enabled only when the Master Controller Key Switch is in an active position in the same cab:
- a) Not used.
 - b) Brake Release Bypass switch (see Section 12, Friction Braking and Air Supply Systems).
 - c) Regenerative Brake Cutout switch (see Section 10, Propulsion System).
 - d) Energy Conservation Mode switch (see Section 10, Propulsion System).
 - e) Auxiliary Isolation switch, which shall isolate buzzer trainline and selected train networks as approved by NYCT.
- 5.5.5.8. Orange indicator lights, located above the respective switches, shall be provided in the Bypass and Cutout Panel for the following switches:
- a) Brake Release Bypass switch.
 - b) Regenerative Brake Cutout switch.

5.5.6. Circuit Breaker Panels

- 5.5.6.1. Separate circuit breaker panels for all low voltage dc and single-phase and/or three-phase ac auxiliary circuits shall be provided in the cab.
- 5.5.6.2. Each circuit breaker shall be labeled to identify the circuit(s) it protects.
- 5.5.6.3. The event recorder circuit breaker and CBTC circuit breakers shall incorporate clear covers that are sealable in the closed (ON) position.
- 5.5.6.4. Refer to Section 9.4.16 for general cab Circuit Breaker Panel requirements.
- 5.5.6.5. The circuit breaker panel arrangement shall be presented for NYCT approval. [CDRL]

5.5.7. Electric End Door Lock

- 5.5.7.1. An Electric End Door Lock switch shall be provided in the cab on the back wall, behind the Train Operator.
- 5.5.7.2. The switch shall lock and unlock:
- a) All cab partition doors in the train.
 - b) Carbody end doors at locations where Units are coupled.
- 5.5.7.3. The Electric End Door Lock switch shall be a 3-position, rotary, momentary return-to-neutral, selector switch with the following positions:
- a) Unlock.
 - b) Lock.
- 5.5.7.4. The Electric End Door Lock system shall be provided with an amber indicator that shall illuminate when the electric door locks of any of the doors described in 5.5.7.2 are unlocked.

5.5.8. Duplex Air Gauge

- 5.5.8.1. A Duplex Air Gauge shall be provided in each cab to display the Brake Cylinder Pressure and Brake Pipe pressure.
- 5.5.8.2. The Duplex Air Gauge shall be mounted on the left side above the console, angled, and at a height that is in the line of sight of the Train Operator from either a seated or standing position. Refer to Figure 5-2. Alternate locations for the Duplex Air Gauge may be proposed by the Contractor for NYCT review and approval.

5.5.8.3. Refer to Section 12.4.6 for specific Duplex Air Gauge requirements.

5.5.9. CBTC Bypass Panel

5.5.9.1. A CBTC Bypass Panel shall be provided on the left side of the cab.

5.5.9.2. The CBTC Bypass Panel shall have a clear hinged cover door, locked using the Master Door Controller key.

5.5.9.3. The CBTC Bypass Panel shall contain the following controls and indications:

- a) **CBTC Bypass Switch:** A 2-position selector switch capable of being sealed in either position.
- b) **Restricted Manual Switch:** A 2-position selector switch capable of being sealed in either position using NYCT Commodity # 59-10-9065, manufactured by AMEREX COR.
- c) **CBTC Bypass Indicator:** Orange in color and illuminated when the CBTC Bypass Switch is in the Bypass position.

5.5.9.4. Refer to Section 14.4.3 for specific requirements of the CBTC Bypass Panel.

5.5.10. Conductor Remote Display

5.5.10.1. A Conductor Remote Display shall be provided adjacent to the Master Door Control Panel on the left side of the cab.

5.5.10.2. The Conductor Remote Display shall be mounted at a height such that the Conductor can easily view the information displayed while in a standing position.

5.5.10.3. Refer to Section 14.3.11 for specific requirements of the Conductor's Remote Display.

5.5.11. Doppler Radar Speedometer

5.5.11.1. The Doppler Radar Speedometer display shall be driven by the Doppler Radar speed measuring system per see Appendix C-45 (NYCT Specification 2083-PROD-95, Specification for Doppler Radar Speed Indication Systems) when CBTC is not operational.

5.5.11.2. When CBTC is operational, the Doppler Radar Speedometer display shall be blank. Note that the referenced NYCT specification is provided for technical information only. Requirements in Specification 2083-PROD-95 specific to the stand-alone procurement of speedometers are superseded by the requirements of this Contract.

5.5.11.3. The Doppler Radar speed measuring system shall provide outputs to the console-mounted speedometer and the Monitoring and Diagnostic System.

5.5.11.4. An additional output shall be provided to permit the Doppler Radar speed measuring system to be connected to the Event Recorder.

5.5.11.5. Interface to the Doppler Radar speed system shall be such that speeds below a pre-determined low speed threshold shall cause the Doppler Radar Speedometer Display to read zero. This will avoid non-zero speed readings at standstill caused by measuring system errors.

5.5.11.6. The Doppler Radar speed system shall be active in all cabs of the train, including coupled cabs.

5.5.12. Miscellaneous Controls

- 5.5.12.1. An indicator test function shall be provided, initiated by a momentary "Lamp Test" pushbutton located on the console. Depressing the pushbutton shall result in a momentary display of "ON" for all indicators except for the Left and Right Door Enable and Doors Closed and Locked indicators. The indicator test function and all indicators and circuitry shall:
- a) Test all indicators located within the cab.
 - b) Be enabled only when the train is not in motion.
 - c) Be arranged in such a way that a fault in the indicator test function shall not interfere with the function of any other car system, function, or interlock.
- 5.5.12.2. Car servicing controls shall be provided to enable train systems to be activated without the use of a key. These controls shall operate as follows:
- a) When a train is not activated (i.e. not keyed-in), the console controls for the HVAC system and the car body lighting shall activate the respective system on a train-wide basis for a software-adjustable period of time that shall be initially set to sixty minutes.
 - b) Activation of the car servicing function(s) shall also cause the energizing of other car systems, such as auxiliary power, as necessary to support operation of the HVAC and lighting systems.
 - c) The timer shall be capable of being reset by moving the respective switch to the momentary OFF position then back to the momentary ON position.
 - d) The functions shall be available from any console.
 - e) At the end of the time period, the respective equipment shall automatically return to its previous status.
 - f) Activation of a cab by any Master Controller Key Switch shall immediately cancel the car servicing function(s).
 - g) Load shedding shall take precedence over the car servicing functions.

5.5.13. Audible Indications

- 5.5.13.1. Audible indications shall be provided in the cab for at least the following events:
- a) Passenger Emergency Intercom (see Section 13, Communications).
 - b) Buzzer (see Section 13, Communications).
 - c) Parking Brake Applied with Train in Motion (see Section 12, Friction Braking and Air Supply Systems).
 - d) Direction set to Reverse (see Section 13, Communications).
 - e) Passenger Emergency Handle Unit (PEHU) activation (see Section 12, Friction Braking and Air Supply Systems).
 - f) Radio Transmit Timeout (see Section 13, Communications).
 - g) CBTC RM Mode Overspeed (see Section 14, Train Control System).
 - h) CBTC Overspeed Warning (see Section 14, Train Control System).
 - i) CBTC Overspeed Alarm (see Section 14, Train Control System).
 - j) CBTC Alerter Audible Alarm (see Section 14, Train Control System).

- 5.5.13.2. Each audible indicator shall have a distinctly different sound and shall be a minimum of 15 dB greater than the ambient sound levels in the cab, as approved by NYCT.
- 5.5.13.3. The Contractor shall submit, for approval, an audible alarm scheme that shall include an audible demonstration of all of the proposed tones and combinations therein. [CDRL]

5.5.14. Identification

- 5.5.14.1. The function of each device in the cab shall be clearly identified.
- 5.5.14.2. All controls and indicators not implemented on the active displays shall be identified by etched or engraved panels. The panels shall be black with white lettering.
- 5.5.14.3. Adhesive bonded tags or silk-screen printed identifications shall not be used.
- 5.5.14.4. Multi-position controls shall have all positions identified.
- 5.5.14.5. Continuously variable controls shall have all salient positions identified.
- 5.5.14.6. Device identification shall be:
 - a) Clear.
 - b) Legible.
 - c) Not deteriorate over time.
 - d) Highly visible in all lighting conditions.

5.6. Master Controller Group

5.6.1. General

- 5.6.1.1. The Master Controller Group shall be located in front of the Train Operator. Refer to Figures 5-2 and 5-3 (note that these figures show a Master Controller to the right of the Train Operator).
- 5.6.1.2. Not used.
- 5.6.1.3. The Master Controller Group shall include the following equipment:
 - a) Master Controller.
 - b) Master Controller Key Switch.
 - c) Reverser Switch.
 - d) Support pad for the Train Operator's arm.

5.6.2. Master Controller

- 5.6.2.1. Control of both propulsion and braking shall be accomplished through an all-electric, single-handle Master Controller.
- 5.6.2.2. The Master Controller main handle shall operate longitudinally with maximum power in the forward-most position, coast in the middle position and emergency brake in the rear-most position.
- 5.6.2.3. The Master Controller main handle design shall minimize strain and fatigue on the Train Operator.
- 5.6.2.4. The Master Controller shall use cam-operated switches of modular construction for performing digital controlling functions.
- 5.6.2.5. As a minimum, separate cam-operated switches shall be provided for the following:

- a) Power/Brake mode.
 - b) Deadman Function.
 - c) Emergency Brake Function.
- 5.6.2.6. Cam-operated switches shall be of heavy rail transit-duty propulsion equipment quality, and shall be designed to provide a life of at least 3×10^7 cycles.
- 5.6.2.7. The Tractive Effort/Brake Effort interface (an encoder or equivalent) shall be duplicated with redundant connections to the car and train network. The redundant connections shall be provided in such a way that there can be no single point failure modes.
- 5.6.2.8. Each set of Master Controller components shall be fed by an independent circuit breaker.
- 5.6.2.9. Each set of components shall constitute a separate logical and physical node on the Car Network (see Section 16, Trainline and Car Control Architecture).
- 5.6.2.10. All Master Controller parts shall be replaceable using common hand tools.
- 5.6.2.11. The Master Controller as a whole shall be arranged as a modular unit with electrical quick disconnects.
- 5.6.2.12. The Master Controller shall be secured with a minimum number of fasteners to facilitate replacement in the field.
- 5.6.2.13. The Master Controller shall incorporate diagnostic capability with built-in indicator(s) made visible by opening the console.
- 5.6.2.14. The Master Controller shall interface with the Monitoring and Diagnostic System as described in Section 17, Monitoring and Diagnostic System.
- 5.6.2.15. The Master Controller handle shall have positive detent positions as defined in Table 5-4.

Table 5-4: Master Controller Positions

Position (Label)	Reference
MAXIMUM POWER (MAX PWR)	Maximum acceleration rate as stated in Section 2.7.2
MINIMUM POWER (MIN PWR)	Minimum acceleration rate as stated in Section 2.7.2
COAST (COAST)	Nominal zero acceleration and zero deceleration
MINIMUM BRAKE (MIN BRK)	Minimum service brake deceleration rate as stated as Section 2.7.4
FULL SERVICE BRAKE (FS BRK)	Maximum service brake deceleration rate as stated in Section 2.7 or ATO controlled by CBTC
EMERGENCY BRAKE (EMER)	Emergency brake application

- 5.6.2.16. The Master Controller shall provide continuously variable linear acceleration between the following Master Controller handle positions:
- a) MAX PWR and MIN PWR positions.
 - b) MIN BRK and FS BRK positions.
- 5.6.2.17. There shall be a detent between the MIN PWR and COAST positions and a detent between MIN

BRK and COAST.

- 5.6.2.18. There shall be a detent between the FS BRK and EMER positions which shall require a greater force to overcome than the detents at the COAST position.
- 5.6.2.19. The Master Controller shall be designed so that liquid spilled on the surface will not damage or interfere with the operation nor damage wiring. The Master Controller shall be designed to divert liquids away from any operating components.

5.6.3. Master Controller Deadman Control

- 5.6.3.1. The Master Controller handle shall incorporate a twist-type deadman feature.
- 5.6.3.2. The deadman control shall detect the incapacitation or inattentiveness of the Train Operator.
- 5.6.3.3. Release of the Master Controller handle deadman feature shall result in immediate emergency brake application. Recovery from the emergency brake application shall be as specified in Section 5.5.1.5.
- 5.6.3.4. The deadman twist feature shall not require any awkward or uncomfortable position or motion of the hand when initially grasping the handle.
- 5.6.3.5. The deadman feature shall be highly resistant to deliberate attempts to defeat its operation.
- 5.6.3.6. The deadman feature design shall incorporate hysteresis in the deadman detection and reset points.
- 5.6.3.7. The deadman feature shall be rendered ineffective under any of the following conditions:
 - a) The Master Controller Key Switch is in other than RUN.
 - b) The Master Controller handle is in EMER.
 - c) The Master Controller handle is in FS BRK.

5.6.4. Master Controller Key Switch

- 5.6.4.1. Each Master Controller control group shall be provided with a key-locked, three-position switch to select the cab status.
- 5.6.4.2. The key lock may be integral with the switch or may be a separate assembly mechanically interlocked with it.
- 5.6.4.3. The key switch shall accept only an approved Master Controller Key.
- 5.6.4.4. The positions of the switch shall be as follows:
 - a) OFF.
 - b) RUN.
 - c) SPECIAL CHARGE (SPL CHG).
- 5.6.4.5. Each switch position shall be a maintained position.
- 5.6.4.6. The Master Controller Key shall be removable only in the OFF and SPL CHG positions.
- 5.6.4.7. With the Master Controller Key Switch in the OFF position and the train at a complete stop:
 - a) Cab controls shall be inactive unless activated via other approved means. Once the console controls are defined, NYCT will designate the manner of activation of each control.
 - b) The Propulsion System shall not be energized.
 - c) Train operation shall not be possible.
 - d) Systems other than propulsion shall remain in their previously commanded state.

- 5.6.4.8. With the Master Controller Key Switch in the RUN position:
- All systems shall be energized and train operation shall be possible.
 - Cab controls shall be active.
- 5.6.4.9. With the Master Controller Key Switch in the SPL CHG position:
- The Brake System shall maintain brake pipe at 70 psi. Refer to Section 12.3.3 for details.
 - The Propulsion System shall be locked in neutral to prevent train operation.
- 5.6.4.10. The term "active cab" used elsewhere in this Specification indicates a cab in which the Master Controller Key Switch is in the RUN position. The train subsystems shall not react to commands when two or more cabs are active at the same.
- 5.6.4.11. Provision shall be made for implementation of a "sleep" mode in which the car systems shall shut down after a pre-determined period of time after a cab is deactivated.

5.6.5. Master Controller Reverser Switch

The Master Controller group shall contain a 3-position Reverser Switch. This switch shall be used to set the direction of train travel.

- 5.6.5.1. The Reverser Switch shall have the following positions:
- Forward (FWD).
 - Neutral (NEUT).
 - Reverse (REV).

5.6.6. Master Controller Group Interlocking

- 5.6.6.1. Interlocking between the Reverser Switch, the Master Controller Key Switch, and the Master Controller main handle in each cab shall be by direct mechanical means.
- 5.6.6.2. The interlocking shall be robust enough to withstand attempts at out-of-sequence operation.
- 5.6.6.3. The following interlocking shall be provided:
- It shall be possible to move the Master Controller handle out of the EMER position only when the Master Controller Key Switch is in the RUN position.
 - It shall be possible to move the Master Controller Key Switch to the RUN position only when the Master Controller handle is in the EMER position,
 - It shall be possible to move the Master Controller Key Switch to the SPL CHG position only when the Master Controller handle is in the FS BRK position.
 - It shall be possible to remove the Master Controller Key from the switch only when the switch is in the OFF or SPL CHG positions.
 - Interlocking with the reverser switch shall be such that the reverser cannot be moved unless the Master Controller Key Switch is in RUN and the Master Controller is in the FS BRK, EMER or COAST positions.
 - It shall be necessary to move the Reverser Switch to Neutral in order to rotate the key to a position other than RUN.
 - It shall only be possible to charge the brake pipe with the Reverser switch in the FWD position, the Master Controller Key switch in the RUN position, and the Master Controller in the FS BRK position, except for SPL CHG.
- 5.6.6.4. Control circuits shall be arranged such that brakes will not release when more than one Master

Controller Key Switch in the train is in a position other than the OFF position.

- 5.6.6.5. The Master Controller Group shall be designed to interface with the Trainline and Network Controller specified in Section 16, Trainline and Car Control Architecture and the Communications Based Train Control (CBTC) System to implement the train operating modes specified in Section 14, Train Control System.

5.7. Cab Equipment

5.7.1. CCTV Cameras

- 5.7.1.1. Three CCTV video cameras shall be installed in each cab as required in Section 13, Communications.

5.7.2. Cab Seat

- 5.7.2.1. A contoured, adjustable Train Operator seat shall be provided in the cab.
- 5.7.2.2. The cab seat shall be positioned to maximize the Train Operator's forward visibility.
- 5.7.2.3. The cab seat shall be a folding type and be supported from the bulkhead wall behind the Train Operator's position.
- 5.7.2.4. When not in use, the cab seat shall fold against the bulkhead wall. Provisions shall be included for the cab seat to be locked in the folded position.
- 5.7.2.5. The design of the cab seat, cab seat cushion, and cab seat upholstery shall be similar to the one used on the R160 or R179 cars, with provision for lumbar support.
- 5.7.2.6. The cab seat design and location shall be reviewed during the cab mock-up review.
- 5.7.2.7. The operating levers for the cab seat adjustment shall be designed to prevent unauthorized removal of knobs.
- 5.7.2.8. Cab seat adjustment controls shall be operable from the seated position.
- 5.7.2.9. All adjustment control locking mechanisms shall have positive engagements.
- 5.7.2.10. The cab seat construction shall meet the requirements of Section 19, including Flammability and Smoke Emission requirements.
- 5.7.2.11. The cab seat upholstery material shall be reinforced against abrasion at known high wear areas, particularly at the leading edges of the seat bottom cushion.
- 5.7.2.12. The cab seat upholstery material shall be John Holdsworth & Co. 1001 TD/G or NYCT approved equal.

5.7.3. Coat Hook

- 5.7.3.1. A flush mounted, folding coat hook shall be provided in each cab on the rear cab partition wall.

5.7.4. Air Comfort

- 5.7.4.1. Two adjustable forced air diffusers, as described in Section 7.4.3, shall be provided in each cab ceiling.
- 5.7.4.2. Cab floor heating, shall be provided as described in Section 7.2.2.

5.7.5. Cab Lights

- 5.7.5.1. Overhead LED lighting, as described in Section 8.3.1.5, shall be provided in the ceiling of the cab.

- 5.7.5.2. LED cab reading lights, as described in Section 8.3.1.6, shall be provided in the ceiling of the cab.

5.7.6. Convenience Receptacle

- 5.7.6.1. A 120 ac duplex receptacle shall be provided in each cab, as described in Section 9.4.20.

5.7.7. Centralized PTE Port

- 5.7.7.1. Each cab shall include a centralized PTE port as specified in Section 22.8.7.
5.7.7.2. The port shall be conveniently located in the cab.
5.7.7.3. The port shall be the standard PTE connector as specified in Section 22.8.7.

5.7.8. Cup Holder

- 5.7.8.1. A retractable, heavy-duty cup holder shall be provided in the cab.
5.7.8.2. The cup holder shall be ergonomically located so that the Train Operator can easily reach it from the seated position.
5.7.8.3. The cup holder shall be located to mitigate equipment damage in the event of fluid spill.
5.7.8.4. The cup holder shall be capable of securely holding a variety of container sizes and shapes as approved by NYCT.
5.7.8.5. The integrated cup holder design shall be based on the previously approved R160 or R179 design.

5.7.9. Shoe Paddles

- 5.7.9.1. Five contact Shoe Paddles shall be provided and mounted in each cab. Refer to NYCT drawing 152-9001, see Appendix D-27.
5.7.9.2. The Shoe Paddles shall be made from wood, as specified in Section 19.10.3, and shall be thoroughly coated with an approved insulating paint per Section 19.22.

5.7.10. Heated Windshield

- 5.7.10.1. A heated windshield, as described in Section 15.6.2, shall be provided in each cab.
5.7.10.2. The heated windshield shall be enabled only in an active cab.
5.7.10.3. An ON/OFF control pushbutton shall be provided on the console as specified in Table 5-1.
5.7.10.4. Visual indication of windshield heater activation shall be provided on the console.
5.7.10.5. The windshield heater element shall include a control function that will deactivate the heater at a set time after the Master Controller is keyed-out. The set time shall be programmable via the MDS maintenance screen.
5.7.10.6. The windshield and heating element shall be protected by a resettable, high temperature protection device. The device shall protect the windshield from overheating at any ambient temperature.

5.7.11. Windshield Glare Control

- 5.7.11.1. The Contractor shall provide a means to control glare through the front windshield.
5.7.11.2. The glare control method employed shall be presented to NYCT for approval. **[CDRL]**
5.7.11.3. If a visor is used it shall:
a) Cover the width of the windshield and the separate side window.

- b) Be positioned at full height.
- c) Be similar to the one used on R160, R179, or as approved by NYCT.
- d) Hold the visor's adjusted position under normal car vibration and motions.

5.7.12. Windshield Wiper

- 5.7.12.1. Windshield wipers shall be provided for the right side cab windshield.
- 5.7.12.2. At least 75% of the width, and 60% of the height of the windshield area visible from inside the cab shall be swept without hitting the windshield frame.
- 5.7.12.3. The windshield wipers shall be functional at all car speeds.
- 5.7.12.4. The windshield wipers shall be enabled only in the active cab.
- 5.7.12.5. The windshield wiper drive units shall provide two speeds of operation, plus a fixed five-second intermittent mode of operation.
- 5.7.12.6. In the OFF position, the wiper blades shall return to a parked position at the extreme inboard ends of their sweep.
- 5.7.12.7. The windshield wiper drive units shall be electrically powered from the LVPS.
- 5.7.12.8. The windshield wiper drive motor shall be designed to sustain stalled conditions.
- 5.7.12.9. The windshield wiper operating mechanisms and drive units shall be accessible for repair and replacement from inside the cab.
- 5.7.12.10. The windshield wiper operating mechanisms shall be enclosed.
- 5.7.12.11. The windshield wiper drive shaft shall be located above the windshield glass.
- 5.7.12.12. The windshield wiper control switch shall be located on the cab console as specified in Table 5-1. Switch positions shall be OFF, INT, LOW, and HIGH.

5.7.13. Windshield Washer

- 5.7.13.1. A windshield washer system shall be supplied for the windshield.
- 5.7.13.2. The spray head shall be mounted on the wiper arm unit and shall uniformly distribute the fluid over the windshield unless otherwise approved by NYCT.
- 5.7.13.3. The windshield washer function shall be interlocked with the wiper to prevent washer activation when the wiper is not operating.
- 5.7.13.4. A stainless steel reservoir with a 2-gallon (7.6 L) minimum capacity shall be provided.
- 5.7.13.5. The reservoirs shall be located to permit filling from inside the cab.
- 5.7.13.6. The reservoir fill cap shall incorporate a gasket to prevent liquid leaking into the car and shall be permanently tethered to the tank.
- 5.7.13.7. The tank fill opening shall include a screen to prevent debris from entering the tank.
- 5.7.13.8. The tank full opening shall include a protective cover plate such as that described in NYCT System Upgrading Bulletin #359.07, included in Appendix C-8, if required.
- 5.7.13.9. The tank shall be externally vented to prevent washer fluid fumes from entering the cab.
- 5.7.13.10. Overfill protection shall be incorporated into the design. Overfill shall drain directly outside the car and not in the door pocket drain pan.
- 5.7.13.11. The windshield washer control pushbutton shall be located on the cab console as specified in Table 5-1.

5.7.14. Schedule Holder

- 5.7.14.1. A schedule holder, sized to fit the NYCT's standard 5 x 8 inch (127 x 203 mm) schedules, shall be provided at a location convenient to the Train Operator's position.

5.8. Validation Requirements

5.8.1. Layouts and Mockups

- 5.8.1.1. The Contractor shall submit for approval specific data on the Master Controller, including the following: [CDRL]
- a) Size of the handle's spring load.
 - b) The force required to overcome detents.
 - c) The amount of handle travel between detents.
 - d) The force required to forestall the deadman feature.
 - e) Ergonomic aspects.
 - f) Operational features.
- 5.8.1.2. A sample Master Controller shall be submitted for approval.
- 5.8.1.3. Ergonomic studies of all cab elements shall be performed that include investigation for a Train Operator size range of a 5% female to a 95% male, and shall include consideration of MIL-STD-1472, Design Criteria Standard: Human Engineering. [CDRL]
- 5.8.1.4. The following items shall be submitted for NYCT approval:
- a) The Contractor shall submit layouts of the cab and cab equipment for approval by NYCT. The initial design shall be similar to the R160 or R179 Car. [CDRL]
 - b) The Contractor shall submit layouts for all Operator screens for approval by NYCT. [CDRL]
 - c) The Contractor shall submit an Audible Alarm Scheme for approval by NYCT. [CDRL]
 - d) Upon approval of the cab layout, the design shall be incorporated in a full cab mock-up for final approval.
- 5.8.1.5. The Master Controller shall be tested to the requirements of Section 24, Test Program.

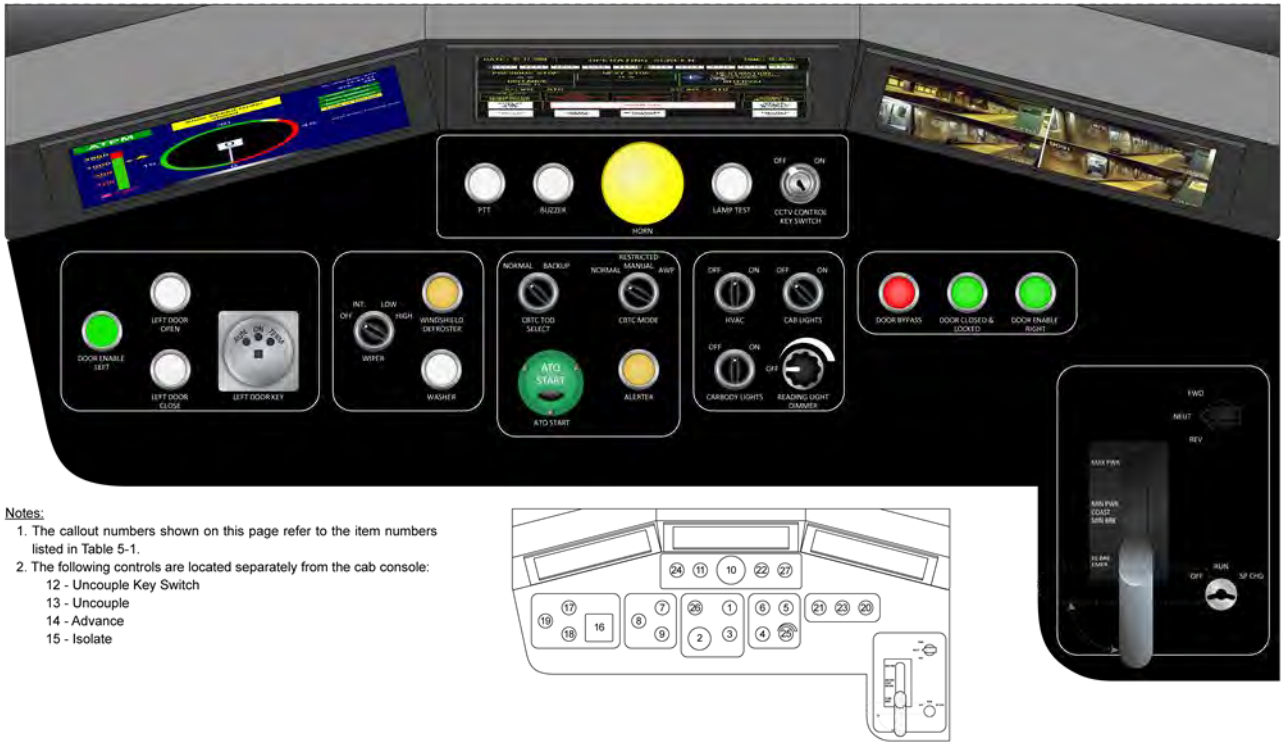
5.8.2. Water-tightness

- 5.8.2.1. All cab components which will be exposed to water as a result of car washing water or wind-driven rain entering through an open cab side window shall be tested to ensure that damage, oxidation, or premature failures do not occur as a result of repeated exposure. See Section 24.6.2 for testing requirements.

5.9. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
5-01	5.1.2.10	Layouts of the cab and cab equipment	PDR
5-02	5.4.1.4	The location of the all TODs	PDR
5-03	5.4.2.10, 5.8.1.3	Preliminary screen layouts for the MDS TOD, the CBTC TOD, and the CCTV TOD	PDR
5-04	5.5.2.4	Arrangement of the MDCs	PDR
5-05	5.5.6.5	Circuit Breaker Panel arrangement	PDR
5-06	5.5.13.3	Audible Alarm Scheme including an audible demonstration of all of the proposed tones and combinations therein	PDR
5-07	5.7.11.2	Windshield glare control method	PDR
5-08	5.8.1.1	Specific data on the Master Controller	PDR
5-09	5.8.1.4	Ergonomic studies for cab layout	PDR



Notes:

1. The callout numbers shown on this page refer to the item numbers listed in Table 5-1.
2. The following controls are located separately from the cab console:
 - 12 - Uncouple Key Switch
 - 13 - Uncouple
 - 14 - Advance
 - 15 - Isolate

Figure 5-1 Conceptual Console Layout



Figure 5-2 Conceptual Arrangement of Train Operator's Position



95th Percentile Male



5th Percentile Female

Figure 5-3 Conceptual Side View of Train Operator's Position

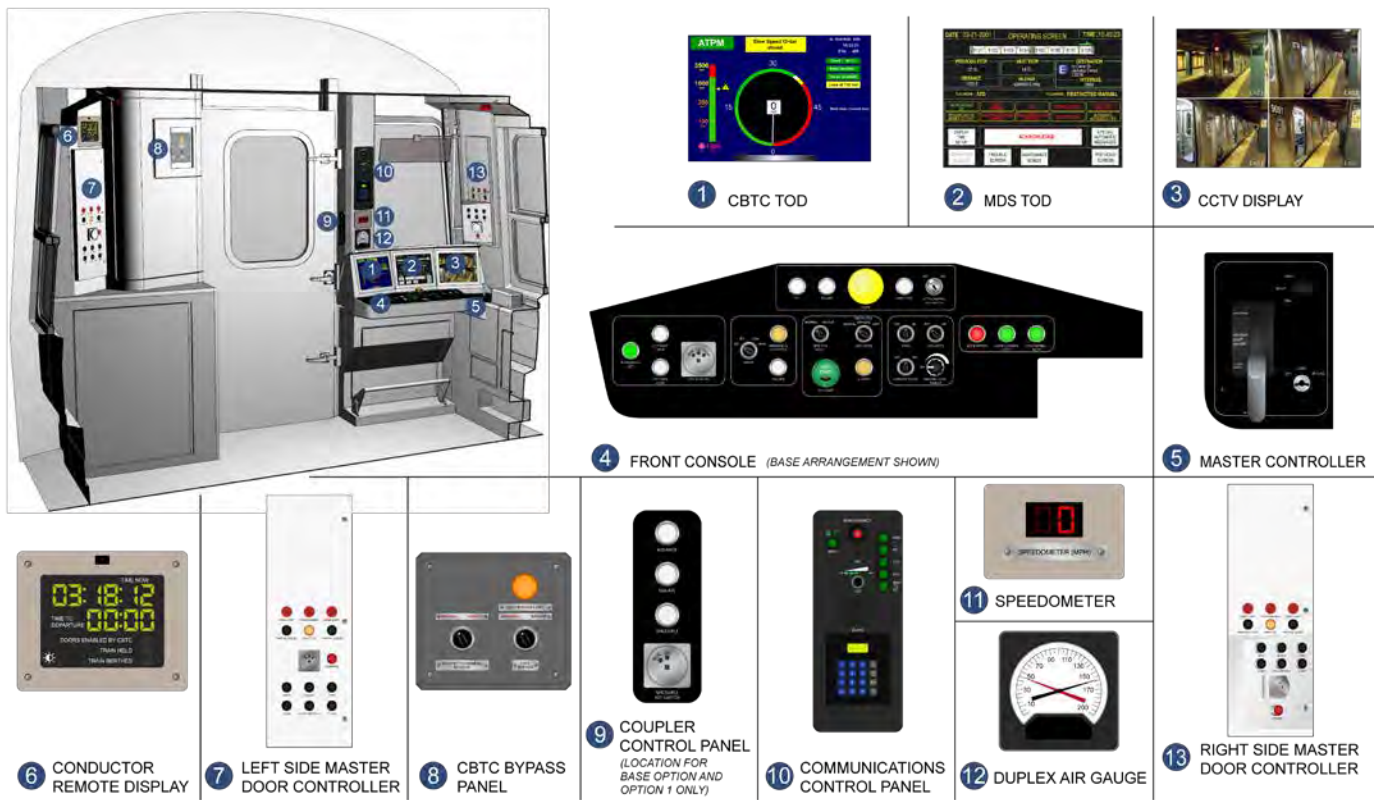


Figure 5-4 Conceptual Cab Layout



Figure 5-5 Conceptual Cab Layout – Backwall

Section 6

Side Door System

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6. Side Door System

6.1 Introduction

This section defines the requirements for the powered passenger side doors, door system operation and control, and associated signals and safety circuit devices for the R211 car. The requirements are divided into categories of General, Performance, Functional, Maintainability, Validation, and Deliverable Requirements. Reference the following sections for car systems and components interfacing with the Side Door System and overall requirements:

- a) Design and Performance Criteria – Section 2.
- b) Carbody Structure – Section 3.
- c) Cab and Cab Controls – Section 5.
- d) Monitoring and Diagnostic System – Section 17.
- e) Materials, Processes, and Workmanship – Section 19.
- f) Reliability, Maintainability, and System Assurance – Section 21.
- g) System Support – Section 22.
- h) Testing Program – Section 24.

6.1.1 General Requirements

- 6.1.1.1 The side door system shall include, but not be limited to, side door panels, overhead door operators, mechanical linkages, Master Door Controllers (MDC), Crew Switches (CS), Door Control Relay Panel (DCRP), Door Monitoring and Control Units (DMCU), discrete panel locks (see Section 6.4.3), Mechanical Cutout Locks (see Section 6.4.18), Door Enable controls, Obstruction Detection, and a safety circuit summary indication system that conveys continuous door panel closed and locked status.
- 6.1.1.2 Each car shall have eight bi-parting sliding pocket type side door panels. Each side door panel shall be driven by an overhead door operator, within four doorway openings on each side of the car. Doors and door openings shall be directly across from those on opposite side (see Section 2.3.1), and nominally level with the wayside platform.
- 6.1.1.3 Side door threshold plate requirements are contained in Section 15.4.7.
- 6.1.1.4 Solid state devices shall be proposed, subject to NYCT approval, for the DCRP, MDC, and DMCU. Where electromechanical relays are necessary for door operation such as zoning and de-zoning, the relays proposed shall be of transit grade and shall be submitted to NYCT for review and approval.
- 6.1.1.5 The side door system shall have operational interfaces with several train subsystems such as Trainline Controls (Section 16), Passenger Emergency Handle Unit (PEHU) (Section 12), Public Address Announcements (Section 13), and Monitoring and Diagnostics System (MDS) (Section 17) to ensure coordinated functioning of the train. There shall be sufficient isolation designed therein to ensure that none of these interfaces can deliver an unwanted signal into the door control or indication systems.
- 6.1.1.6 The door system performance, interlocks and safety features, shall be designed to operate in a fail-safe manner to prevent injury to passengers and maintenance personnel.

- 6.1.1.7 The design shall be fail-safe such that any failure condition within the door control system and circuitry shall command the doors to automatically close and lock. Upon restoration of door operator control, a door shall remain in the closed and locked position until open commands are sent by the Conductor, (or Train Operator in One Person Train Operation (OPTO)), from the MDC, or locally at the door from the Crew Switch.
- 6.1.1.8 The door control system shall be designed in accordance with system assurance and safety requirements of Section 21.3.

6.2 Performance Requirements

6.2.1 General Performance Requirements

- 6.2.1.1 Door panel motion shall be smooth and free of shock and impact.
- 6.2.1.2 Door panels shall be capable of opening and closing with worst case carbody tilt and grade as may occur on the NYCT system, as described in Section 2.5.1, in either direction.
- 6.2.1.3 Door panel speed shall be relatively constant throughout the opening and closing strokes, except for the ramp-up speed at the initiation of the opening stroke, and the ramp-down (damping) of speed at the end of the closing stroke.
- 6.2.1.4 Damping shall be provided at the end of the travel of each door panel in both the opening and closing directions.
- 6.2.1.5 Damping may be accomplished through use of end stops/bumpers in combination with electrical controls to provide braking, and to prevent bouncing of the door panel against the end stop.
- 6.2.1.6 Doors shall open and remain open upon receiving a valid DOOR OPEN command, until that command is interrupted.
- 6.2.1.7 The door operator shall positively retain the door panel in the closed position using a lock, which shall automatically engage when the door panel reaches the fully closed position.

6.2.2 Door Timings

- 6.2.2.1 The nominal opening time of the door, from the point of first movement to a point within 3 inches (75 mm) of the fully open position shall be initially set to 1.6 seconds \pm 10%. The nominal closing time of the door to move from the fully open to the fully closed position shall be initially set to 2.6 seconds \pm 10%.
- 6.2.2.2 An adjustment capability shall be provided to allow fine-tuning of both door opening and closing cycle time parameters over the range of 1.4 to 2.4, and 2.4 to 3.4 seconds respectively.
- 6.2.2.3 The door opening and closing times shall be independently adjustable via Portable Test Equipment (PTE) in accordance with the requirements of Section 22.8).

6.2.3 Door Forces

- 6.2.3.1 The maximum force of an impact on a person or obstruction shall be limited to a maximum of 30 pound-force (lbf) (134 N) per panel over the entire door travel throughout the opening and closing cycle, when operating normally. The closing force shall be measured between 50°F and 86°F (10°C and 30°C) car interior temperature in accordance with EN14752, Section 6.2.
- 6.2.3.2 Total door panel static friction, including seals (nosing rubbers, weatherstripping), measured when door panel is disconnected from the drive mechanism, shall not exceed 10 lbf (44.5 N), throughout the full range of door panel travel.

- 6.2.3.3 A force of 60 lbf (266 N) applied perpendicular to the door panel, at a vertical level of half the doorway height, shall not prevent the door from fully opening and fully closing.
- 6.2.3.4 The door operator shall always exert a minimum closing force over the entire door travel throughout the closing cycle to overcome door panel static friction, including seals and the internal resistance of the door operator. The minimum force shall be subject to NYCT review and approval during design review and confirmed during the validation of the door system.
- 6.2.3.5 Door panels shall be held fully open by friction with power available to, but withheld from, the door operators. If panels should drift away from their fully open rest position by more than 1.5 inches (38 mm), such as may occur when on a grade of up to 4 percent, the power shall be reapplied to reopen the panels.

6.2.4 Controls and Detection

- 6.2.4.1 The door control system shall be designed to withstand, detect, and annunciate single point safety failures without doors unlocking and opening.
- 6.2.4.2 When any unlock and/or open trainline or carline is activated, the Train Operator and Conductor’s Indication (All Doors Closed and Locked, see Section 6.4.20) shall be extinguished.
- 6.2.4.3 Separate electrical position sensing devices to detect that each door panel is fully closed and locked shall be provided. Alternative designs may be proposed for NYCT’s approval.
- 6.2.4.4 When a thin flexible object (such as thin cloth or tie) is held flat between the door panels at mid-height (see Section 6.4.10.5), the force required to remove the object shall be 20 lbf (89 N) or less, exerted perpendicularly to the door panel.

6.3 Functional Requirements

6.3.1 General Functional Requirements

- 6.3.1.1 The passenger side door system shall perform, but not be limited to, the functions listed in Table 6-1.

Table 6-1 Side Door System Functions.

Item	Name	Specification Reference
1	Open	Section 6.4.8
2	Close	Section 6.4.8
3	Door Enable	Section 6.4.8.5, 6.4.15
4	Obstruction Sensing	Section 6.4.8
5	Door Panel Locking Mechanism	Section 6.4.3
6	Local Recycle (automatic and crew initiated)	Section 6.4.12.33
7	Emergency Handle	Section 6.4.4
8	Test Switch	Section 6.4.16
9	Mechanical Cutout Lock	Section 6.4.18
10	Shuttle	Section 6.4.12.29 - 6.4.12.33
11	Crew Switch Operation	Section 6.4.11
12	Zone Control	Section 6.4.12.21 - 6.4.12.24
13	Fault Light Operation	Section 6.4.19.20 - 6.4.19.21
14	Guard Light Operation	Section 6.4.19.13 - 6.4.19.19
15	Train Operator Indication	Section 6.4.20

Item	Name	Specification Reference
16	Conductor Indication	Section 6.4.20
17	Door Closing Warning Signal	Section 6.4.19.22 - 6.4.19.25
18	Crew Door Opening	Section 6.4.11.11
19	Door System interlocks with Trainline Commands	Section 6.1.1.5, 6.4.20
20	Door Interlock Bypass Switches	Section 6.4.17
21	Door System interfaces with train MDS and Automatic Announcement System	Section 6.4.7, 6.4.19

6.4 Design Requirements

6.4.1 Side Door Panels

General Requirements

- 6.4.1.1 The side doors shall be consistent with the carbody contour, designed and constructed to have a service life of 40 years.
- 6.4.1.2 All door openings shall be furnished with weatherstripping. The type of weatherstripping shall be approved by NYCT.
- 6.4.1.3 Side door panels must be vibration and rattle-free while the train is underway and while doors are opening or closing.
- 6.4.1.4 The door panel shall be insulated as necessary to meet the thermal requirements of Section 15.2.2.2 and noise attenuation requirements of Section 2.9.2.
- 6.4.1.5 All materials in the construction of the door panels shall meet the flammability and smoke emission requirements of Section 19.1.10.
- 6.4.1.6 All materials used on the side door panels, including fasteners, shall be corrosion resistant.
- 6.4.1.7 The door panel skin, structure, and mounting hardware shall sustain a concentrated load of 200 lbf (890 N) applied perpendicularly to the center of door panel over an area not exceeding 16 in² (10,300 mm²). The maximum load shall be applied for a minimum of five minutes and, upon removal of the load, the door shall exhibit no permanent set or delamination of the skin from the door panel.
- 6.4.1.8 The allowable maximum deflection under these conditions, with the door simply supported at the top and bottom, shall be limited to 3/8 inch (9.5 mm) with no permanent deformation following removal of the force.

Side Door Panel Construction Requirements

- 6.4.1.9 Door panels shall be constructed so that all hardware, windows, and window glazing frames or strips are within the thickness of the door panel to allow the doors to operate freely without interference.
- 6.4.1.10 The door panel construction shall be stainless honeycomb core with interior and exterior surfaces furnished with stainless steel sheets with an approved, horizontal grain brush finish to match the carbody. Alternate lightweight panel constructions may be submitted to NYCT for review and approval.
- 6.4.1.11 All door surface finishing shall be free of all dimples, warping, welding depressions, delamination, and other deformities.

- 6.4.1.12 All edges and joints shall be thoroughly sealed to prevent the infiltration of moisture. Where appropriate, a drain hole shall be provided.
- 6.4.1.13 Fasteners used to attach hardware to the door panel that are visible or exposed to passenger area shall be countersunk (see Section 19.19). All locations where fastening hardware installs to the door panel shall be reinforced and fitted with threaded inserts or tapping plates.
- 6.4.1.14 The door panel shall contain a fixed window mounted in a continuous neoprene glazing strip. Other types of rubber may be proposed to NYCT for review and approval.
- 6.4.1.15 The side door windows shall be the same height as the side passenger windows and as wide as practical.
- 6.4.1.16 The side door windows shall meet the requirements of Section 15.6.3.
- 6.4.1.17 The glazing and mounting shall meet the requirements of NYCT Specification 3063-MATL-98 (attached in Appendix C-19), and ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code".
- 6.4.1.18 The glazing strip shall use zip-strip type retention for easy re-glazing from the car exterior, without the need for sealing compounds.
- 6.4.1.19 The zip-strip shall be an inherent part of the glazing strip and shall not project beyond the surface of the interior or exterior door panel skin.
- 6.4.1.20 The window frame glazing retention profile shall be rounded to facilitate cleaning and preclude build-up of dirt and debris.
- 6.4.1.21 The vertical leading edges of side doors shall be equipped with neoprene nosing seals of Shore Type "A" durometer 80 ± 5 , with a standard male-female profile (see reference drawing R143-1247 in Appendix D-4 for details) to keep out noise, weather elements, prevent drafts, and permit a car to be pressurized.
- 6.4.1.22 Nosing seals shall be mounted to allow easy mounting and removal without the need to disconnect the door panels.
- 6.4.1.23 Seals shall be configured in hardness and geometry to prevent the door panels from fully closing and locking on an object of the size stated in Section 6.4.10.

Mounting of Door Panels

- 6.4.1.24 The door panels shall be suspended from hangers attached to an overhead track. The bottom of the door panels shall be equipped with a door guide (see 6.4.1.31 through 6.4.1.36) that will ride within the mating slot in the threshold plate.
- 6.4.1.25 The upper door track/hanger shall be integral to the door operator which is bolted to the car secondary structure, and protected from the weather.
- 6.4.1.26 The hanger shall be a co-axial, or other NYCT approved type, low friction, low maintenance, anti-tilting type hanger specifically designed for use on top-hung door panels. Hangers shall be capable of withstanding normal repetitive door cycling, and periodic external forces which act thereupon, without transmitting external forces to the operator or other moving parts in a manner which could cause damage. Alternative approaches may be proposed for NYCT review and acceptance.
- 6.4.1.27 A provision shall be provided to allow for door panel adjustment in both horizontal and vertical directions with an eccentric nut, as approved by NYCT.
- 6.4.1.28 The door panel removal and replacement shall not require removal of the track, hanger, or any other door operator components.

- 6.4.1.29 Door travel shall be limited by the door operator. In case of a fault in the operator or motor position encoder, adjustable bump stops on the track or door pocket shall ensure that opening or closing of the doors does not cause any individual door panel to become misaligned or damaged.
- 6.4.1.30 The operation of the door operator, including the full travel of the door panels, shall not be impacted (i.e. door operator binding, interference at threshold plate) by normal carbody deflection caused by normal loading, wheel wear, or suspension failures.
- 6.4.1.31 The design of the bottom door guide and threshold plate shall act to prevent foreign material from affecting operation of the door.
- 6.4.1.32 The door guide shall not be adjustable in a vertical direction.
- 6.4.1.33 The door guide shall be concealed between the interior and exterior door panel stainless steel skins, and reversible about its vertical and longitudinal axes.
- 6.4.1.34 The leading edges of the door guide shall be tapered to prevent binding of the door guide in the mating slot in the threshold plate.
- 6.4.1.35 The door guide shall extend the full width of the door panel but not exceed the structural door panel width (i.e. not including door panel nosing rubbers).
- 6.4.1.36 The material of the guides shall be of low friction, high density material with a maintenance interval in accordance with NYCT Document SMS #08-002 "Generic Passenger Car Worksopce: R142, R142A, R143, and R160", see Appendix C-36.

6.4.2 Door Operator

- 6.4.2.1 Two individually powered door operators shall be provided at each doorway.
- 6.4.2.2 The door system shall allow the operation of one panel within a doorway when the adjacent panel is disabled or locked out.
- 6.4.2.3 The door panels, door operator mechanisms, door controls, and equipment shall be based on a service proven, high reliability design used on systems with comparable operating conditions to those of NYCT.
- 6.4.2.4 All numbering of doors openings, operators, and panels shall be in accordance with Section 2.2.4. Door location reporting to the MDS (Section 17) and physical identification shall not be affected by changes of components at the door opening.
- 6.4.2.5 A closed door shall not open when subject to the forces exerted by passengers pushing on, or leaning against the door panel, or by pressure pulses exerted by the train's movement.
- 6.4.2.6 Side door operator mechanisms must be vibration and rattle-free while the train is underway and while doors are opening or closing.
- 6.4.2.7 The door operator, hanger, and door controller shall be of modular design, packaged to allow quick removal and replacement.
- 6.4.2.8 Individual door operator system components shall not be mounted to the car structure.
- 6.4.2.9 The door control system shall include features to automatically adjust for normal wear, frictional changes, and environmental conditions listed in Section 2.5.1. Alternative approaches may be proposed for NYCT approval.
- 6.4.2.10 The door operator shall be equipped with position sensing devices to monitor the position of the door panel. Service proven limit switches or proximity type sensors rated for transit application, shall be proposed for NYCT approval. [CDRL]

6.4.2.11 Electrical wiring for all door control elements shall be as defined in Section 19, Materials, Processes and Workmanship.

6.4.3 Door Panel Locking Mechanism

6.4.3.1 A door lock shall be provided for each panel to automatically engage and positively retain the fully closed door in the locked position.

6.4.3.2 The lock shall be single action, independent of the door operator and linkage, and shall prevent an inadvertent unlocking of mating components when subject to varying stress, temperature, and vibration as specified in Section 2.9.6.

6.4.3.3 There shall be no electrical, mechanical, or software failure mode of the door operator that could cause an unintentional unlocking of the door panel.

6.4.3.4 Door unlocking shall be accomplished by an independent electromechanical device, such as a solenoid or similar component that energizes only after DOOR OPEN and DOOR UNLOCK trainline signals have been received indicating "doors unlocked" and "doors opened".

6.4.3.5 It shall not be possible for the lock to deploy unless the door panel is in the fully closed position.

6.4.3.6 The lock position alone shall not be used to indicate the position of the panel.

6.4.3.7 Alternate door locking techniques which have been proven to provide fail-safe, positive locking features may be proposed for NYCT review and approval.

6.4.4 Side Door Manual Emergency Release Handle

6.4.4.1 An Emergency Release Handle shall be provided at each door operator to allow the release of the door lock, and manual opening of the actuated door panel in an emergency.

6.4.4.2 The handle shall have two positions: NORMAL and OPEN.

6.4.4.3 The Emergency Release Handle shall be located behind a small, locked, hinged access panel accessible only to train crew or emergency responders, by unlocking of cover plate using an approved NYCT MDC key.

6.4.4.4 The Emergency Release Handle shall be red in color.

6.4.4.5 The handle shall be identified by a permanently affixed plate in an NYCT approved location showing simply and clearly how to operate the handle.

6.4.4.6 Methods for actuating the release mechanism shall be proposed to NYCT for review and approval.

6.4.4.7 Activation of the local Emergency Release Handle shall remove power from the local door opening circuitry, open the "door closed and locked" interlock, release the door locking mechanism, and partially open and allow the door panel to be manually opened, regardless of train speed or door command.

6.4.4.8 The force required to activate the Emergency Release Handle shall be 10 ± 4 lbf (45 ± 18 N).

6.4.4.9 The force required to open an unlocked door panel and slide it into the door pocket, exerted by a person within the car, or standing at platform level, with the car on straight and level track, shall not exceed 15 lbf (66 N).

6.4.4.10 Activation of Emergency Release Handle to the OPEN position shall result in loss of crew indication, and be displayed on the MDS showing unlocked door status. The corresponding Fault Light and car's Guard Light shall be energized.

6.4.4.11 Resetting the release mechanism to the NORMAL position and manually closing the doors shall automatically reset the Emergency Handle. Door panel operation shall automatically close and lock under power when resetting the Emergency Handle.

6.4.5 Power Supply Requirements

6.4.5.1 The Door System shall be entirely powered from the LVDN as specified in Sections 2.5.4 and 9.3.7, and shall meet performance requirements of this Section over the entire voltage range of the LVDN without affecting reliability and service life of the Door System.

6.4.5.2 All door control, monitoring, and indication elements noted in Section 6.1.1.1 shall be energized whenever low voltage power is present.

6.4.5.3 Circuit breakers for overload protection shall be provided for each door operator.

6.4.5.4 Circuit breakers shall be provided for wire and component overcurrent protection, but shall also function in specific circuit feed capacities, as follows:

- a) DC1, DC2 Door operator motor power B+.
- b) D81 Door control trainline B+.
- c) D82 Door control carbody B+ (for car isolation).
- d) 24 Door carbody and/or trainline closed status summary B+.
- e) DGL Door fault and guard light closed and locked status light B+.

6.4.5.5 All door wiring shall be arranged to not interfere with any other parts under any circumstances.

6.4.6 Door Motor and Coupling

6.4.6.1 The door operator motor shall be insulated with class F insulation or better, and be capable of remaining continuously energized when stalled, with maximum LVDN voltage applied, without overheating at an ambient temperature of 160°F (71°C).

6.4.6.2 The door motor shall be thermally protected with an automatic control function which limits the current to the motor, while allowing continued operation of the motor.

6.4.6.3 A car-level function shall be provided to cutout all door operators on that car. The motor cutout shall be a single switch available in the low voltage circuit breaker panels of A and B cars, to allow operating personnel to disable OPEN and CLOSE motor commands to an entire set of doors on a car.

6.4.7 Door Monitoring and Control Unit

6.4.7.1 A microprocessor and solid state relay based Door Monitoring and Control Unit (DMCU) shall be provided at each door operator.

6.4.7.2 A visual system status indication on each DMCU shall be provided, including labels with sufficient detail to identify system state(s) and assist maintenance personnel in troubleshooting and repairing defects.

6.4.7.3 Each DMCU shall be capable of responding to trainline and local door commands as required by overall system design.

6.4.7.4 The DMCU shall include a microprocessor based diagnostic system to monitor the operation of door control system, and to withstand, detect and annunciate related failures without doors unlocking or opening.

- 6.4.7.5 All failures or fault conditions shall be automatically stored (along with a time-date stamp for the incident) in the nonvolatile memory of the DMCU for each operator. At minimum, the following parameters, in real-time and historic events, which are recorded at the time of fault, shall be accessible via the PTE:
- The time and date of the fault or failure condition.
 - The door system command state during the fault.
 - The obstruction detection status.
 - Door system power status - nominal voltage, low voltage.
 - The door panel and door operator position during the fault.
 - Total number of door cycles per day, per year, and total number of cycles to date.
 - The fault data shall indicate details about the fault without the use of cross references.
- 6.4.7.6 The DMCU shall report door statuses and faults to the MDS in accordance with Section 17. In addition, the door diagnostic system shall be accessible via PTE, from both the centralized PTE port in the cab (see Section 22.8) and locally at the DMCU.
- 6.4.7.7 The DMCU shall periodically synchronize its time and date settings to the master clock via the MDS. See section 17.3.6.
- 6.4.7.8 The diagnostic system scheme, including real-time signal status monitoring, historic events and fault logs and other features shall be submitted to NYCT for review and approval. [CDRL]
- 6.4.7.9 Upon detection of a door system fault or failure condition, the Fault Light adjacent to the doorway and the car's Guard Light shall illuminate until the fault is cleared or the door panel is cutout. Any trouble indicators/readouts shall only be resettable manually and not through the Train Operator Display.
- 6.4.7.10 Turning off the car power shall not reset or cause the loss of failure/trouble indications, or the loss of information stored in nonvolatile memory.
- 6.4.7.11 The operation of diagnostics system or test shall not cause an unsafe door condition, nor interfere with the safe and normal operation of the door system.

6.4.8 Door Controls

- 6.4.8.1 Passenger side doors shall be controlled by the train crew from door control pushbuttons located on the MDC and cab console as specified in Section 6.4.12 and 6.4.13, Crew Switches as specified in Section 6.4.11, and the CBTC system specified in Section 14.
- 6.4.8.2 Door controls for each side of the train shall be independent.
- 6.4.8.3 Discrete trainlines shall also be used to monitor the door closed and locked status of all doors in the train, and to provide the required indications to the train crew.
- 6.4.8.4 A set of independent, solid state relay based logic and discrete trainline signals shall be required to control the side doors. These shall be UNLOCK, OPEN, and ENABLE trainlines for each side of the car.
- 6.4.8.5 The Door Enable signal, as described in Section 6.4.15.2, shall activate and permit side door control by the Conductor.
- 6.4.8.6 An OPEN door command issued by the Train Operator or Conductor shall generate the door OPEN and UNLOCK trainline signals, and unlock and open the selected door side.

- 6.4.8.7 A CLOSE door command issued by the Train Operator or Conductor shall de-energize DOOR OPEN and UNLOCK trainline signals.
- 6.4.8.8 Selected door commands and door control statuses may be transmitted by the train network (See Section 16.3.4), subject to NYCT's review and approval.
- 6.4.8.9 Door control and indication trainlines shall be isolated from other trainline circuits wherever possible.
- 6.4.8.10 The trainlines shall be shielded as specified in Section 19.23.4.
- 6.4.8.11 Door control and indication trainlines shall be split into zones fore and aft of the operating MDC position(s).
- 6.4.8.12 All door system trainlines shall be interrupted before reaching an open-end coupler electric head, such that a feed to an open-end electric coupler head contact shall not be able to be transmitted into the trainlines.
- 6.4.8.13 With the Door Enable trainline active, two valid trainline commands, OPEN and UNLOCK, shall be required to cause passenger side doors to open. Loss of either or both commands shall cause the doors to close and lock.
- 6.4.8.14 Switches and pushbuttons used for door controls shall be service proven and of heavy-duty, industrial, momentary contact type with life expectancy of at least 20 years in NYCT's operating environment.

6.4.9 Obstruction Detection

- 6.4.9.1 Each side door operator shall be equipped with an obstruction detection system capable of detecting obstructions as defined in Section 6.4.10.
- 6.4.9.2 The doors shall not lock and permit a doors closed indication if an obstruction is detected.
- 6.4.9.3 In the event of loss of control power or Door Enable signal, the doors shall remain in, or be commanded to close to, a safe state (door closed and locked) with obstruction detection still active.
- 6.4.9.4 A method, subject to NYCT approval, for detecting an obstruction (as defined in Section 6.4.10) and preventing the closure of a side door shall be included as part of the design of the door system.
- 6.4.9.5 Upon sensing an obstruction, the local controls shall cause the door operator to immediately reverse and reopen the affected panel approximately 3 inches (76 mm) from the detected obstruction.
- 6.4.9.6 The door panel shall then pause for 0.5 seconds before commencing the reclose cycle.
- 6.4.9.7 The door panel shall continue to recycle in this manner until the obstruction is cleared and the panel successfully closes, until the recycle limit is reached.
- 6.4.9.8 The recycle limit shall be selectable between 0 and 3 cycles.
- 6.4.9.9 If the obstruction is still detected after the recycle limit is reached, the door shall remain closed on the obstruction with obstruction detection protection remaining active.
- 6.4.9.10 If only one door panel is obstructed in a doorway, the unobstructed panel shall close and lock.
- 6.4.9.11 The use of nosing seals with air chambers or electrical contacts to activate a pressure wave switch is not acceptable for implementing obstruction detection.

6.4.10 Obstruction Detection Sensitivity

- 6.4.10.1 Please refer to the Engineering Alert EA # 06-10 dated August 1, 2006 (see Appendix C-9, Gauging of obstruction detection switches).
- 6.4.10.2 The obstruction detection system shall be capable of detecting a flat bar, 0.375 inch (9.5 mm) thick and 3 inches (76 mm) wide, or an object 0.44 inch (11.1 mm) in diameter, held between and perpendicular to the door.
- 6.4.10.3 This sensitivity for the 0.375 inch (9.5 mm) flat bar shall be required along the entire length of the leading edge.
- 6.4.10.4 This sensitivity for the 0.44 inch (11.1 mm) diameter round object shall be required along the length of the leading edge except the uppermost and lowermost 4 inches (101.6 mm) of the door leading edges.
- 6.4.10.5 Refer to NYCT drawing No. 554-2042, (see Appendix D-5), for requirements of solid obstruction gauge to be used to verify conformance with door obstruction sensitivity requirements.
- 6.4.10.6 The equipment shall permit a thin flexible object not detected by the detection system to be pulled free from the leading edges with the doors fully closed and locked, per the requirements of Section 6.2.4.4.
- 6.4.10.7 Refer to NYCT drawing No. 553-2038, (see Appendix D-6), for requirements of the thin flexible object (cloth gauge) to be used to verify conformance with door obstruction sensitivity requirements.

6.4.11 Crew Switch

- 6.4.11.1 Crew Switches operable with a crew key shall be provided inside and outside the car at the door panel closest to the No. 1 end on both sides of each A-Car.
- 6.4.11.2 On each B-car, Crew Switches shall be provided inside and outside the car at diagonally opposite sides of the car, at locations approved by NYCT.
- 6.4.11.3 Each interior and exterior Crew Switch shall be located at a height convenient to personnel standing on the station platform or inside the car. The location and configuration of the Crew Switches, along with sample cover, shall be submitted for approval by NYCT.
- 6.4.11.4 The exterior Crew Switch shall be tamperproof, inaccessible to passengers and protected from the weather. Exterior Crew Key Switch shall be fitted with a sealed, stainless steel, spring-loaded cover to protect the Crew Key Switch assembly.
- 6.4.11.5 The Crew Switch shall be wired in a double break manner and shall only be operated by the NYCT Master Door Controller Key.
- 6.4.11.6 The Crew Switch, by default, shall operate both local door panels closest to the switch in the adjacent door opening. The Crew Switch control shall be configurable to allow operating of only one door panel in the adjacent door opening. Enabling of this feature shall be via the PTE.
- 6.4.11.7 The Crew Switch shall have three operating positions: OPEN, NEUTRAL and CLOSE. The positions shall not be labeled.
- 6.4.11.8 Inserting or removing the crew key shall only be possible when the Crew Switch is in the NEUTRAL position.
- 6.4.11.9 The Crew Switch shall be spring-loaded to return the NEUTRAL position.
- 6.4.11.10 In the NEUTRAL position, the door panel controlled by the Crew Switch shall remain in the last valid commanded position.

- 6.4.11.11 The OPEN and CLOSE positions shall have momentary contacts. The OPEN position shall cause the unlocking and opening of the closest door in the adjacent doorway, while the CLOSE position shall cause the closing and locking of the closest door in the adjacent doorway. The closing and opening times shall be as specified in Section 6.2.2.
- 6.4.11.12 The Crew Switch control logic shall allow opening and closing of the corresponding door panel from interior and exterior location respectively, and vice-versa.
- 6.4.11.13 When doors have been opened (or closed) by a Crew Switch, it shall be possible to subsequently control them from trainline commands, or by the Crew Switch.
- 6.4.11.14 The door operators and the adjacent Crew Switches shall be powered directly from the Low Voltage Distribution Network (LVDN) and shall function when the car is unpowered, as per requirements of load shedding specified in Section 9.4.19.
- 6.4.11.15 The Crew Switch control logic shall interrupt the "Door Summary Circuit" (Section 6.4.20) and then illuminate the Guard Light (Section 6.4.19.13) in cases when the exterior switch is moved to the OPEN or CLOSE position(s), and/or when the interior switch is moved to the OPEN position.
- 6.4.11.16 In the event of conflicting, simultaneous commands from the Crew Switches and trainlines, the close command shall govern.

6.4.12 Master Door Controller Panel

- 6.4.12.1 Two Master Door Control (MDC) panels shall be provided in each cab for controlling the doors in a train.
- 6.4.12.2 An MDC shall be located on each side of the cab as described in Section 5.5.2.
- 6.4.12.3 The MDC shall operate the doors on the side of the train on which it is located, and be completely segregated from the controls on the opposite side of the train.
- 6.4.12.4 Communication controls and indicators, as specified in Section 13, shall be incorporated into, or interfaced with, the MDC.
- 6.4.12.5 The MDC panel shall be designed using ergonomic principles, with the specific aim of minimizing the risk of wrong side or inadvertent operation.
- 6.4.12.6 The controls for the left-hand side doors shall be mounted on the left side of the cab, and controls for the right-hand side doors mounted on the right side of the cab, adjacent to respective left and right side cab windows.
- 6.4.12.7 The right-side MDC shall be set at an angle facing the Operator and be positioned such that it can be operated from the standing position at the location which allows the Conductor to lean out of the window while simultaneously opening or closing the door, or in the seated position. When the Train Operator is in the seated position, the MDC controls shall be angled to allow for ergonomic ease of operation.
- 6.4.12.8 The controls of passenger side doors shall be enabled when the cab is zoned-in, Door Enable has been activated, and when the Master Key Switch is placed in the ON position.
- 6.4.12.9 A metal etched engraving or similar shall be utilized on the MDC enclosure to identify each controls button. The MDC panel shall be finished with a permanent contrasting surface treatment.

6.4.12.10 Each MDC shall incorporate the following:

- a) One (1) "Master Key Switch", three position control (RUN, ON, TERM).
- b) Four (4) momentary type pushbuttons, for "OPEN" and "CLOSE" control.
- c) One (1) momentary type pushbutton LED illuminated, for "Dezoning" control.
- d) One (1) momentary type pushbutton LED illuminated, for "SHUTTLE" control.
- e) One (1) momentary type pushbutton, for "Local Recycle" control.
- f) Two (2) momentary type pushbuttons, for "Door Partial Close" control.
- g) Two (2) LED illuminated indicators, for "Zone Signal Lights" status.
- h) One (1) LED illuminated indicator, for "DOOR ENABLE" status.
- i) One (1) momentary type pushbutton, for Buzzer.

6.4.12.11 Solid state devices shall be proposed for use in the MDCs.

Master Key Switch

6.4.12.12 One heavy-duty, key-operated Master Key Switch (MKS) shall be incorporated in each MDC and on the left side of the vertical face of the console to control the circuit connections for the passenger door controls (See rendering in Section 5, Cab and Cab Controls).

6.4.12.13 The MKS shall be of transit-equipment quality and compliant with the requirements of Section 19, Materials, Processes, and Workmanship. The MKS shall be designed to provide a life of at least 500,000 mechanical cycles in this application.

6.4.12.14 The MKS key shall be the NYCT's standard, square-type MDC key as described in Section 15.5.2.

6.4.12.15 The MKS shall utilize a minimal number of contacts and be used to drive electronic control logic only, which will command the solid state relays and in turn, connect to and subsequently command the door control and indication trainline circuits.

6.4.12.16 The switch shall have three maintained positions labeled in the following clockwise order: RUN, ON and TERM.

6.4.12.17 The key shall be insertable and removable only in the RUN and TERM positions.

6.4.12.18 **RUN Position Functionality**

- a) When the MKS is in the RUN position, all MDC pushbutton controls are disabled, except for the Dezoning Pushbutton on both MDCs in a zoned-in operating cab (see Section 6.4.12.19).
- b) T/O indication trainline contacts in the MDC shall be closed only when the MKS is in RUN position. When an individual MKS in a cab is turned from ON to RUN, the zone indication function shall remain.
- c) The Zone Status indicator lights included as part of the Dezoning Pushbutton shall remain illuminated as long as the MDCs in that cab are zoned-in.
- d) Turning the MKS from the ON to RUN position with the doors open on that side shall result in the removal of LVDN power from the door unlock and open trainlines, causing doors on that side to close.

6.4.12.19 ON Position Functionality

- a) When either MKS in a non-zoned cab is first placed in the ON position from the RUN position, both MDCs in that cab shall zone-in.
- b) Door control and status indication trainlines shall break at this cab, automatically establishing four door control zones: two forward of this cab, one for each side; and two aft of this cab, one for each side; and two zone light zones: one forward of this cab for both sides, and one aft of this cab for both sides.
- c) The Zone Status lights of both MDCs shall illuminate to indicate that door control status is established at both MDCs, until this cab is de-zoned. All MDC door system pushbuttons and status indicators in the MDC with the MKS in ON shall be electrically enabled, except for the Shuttle Pushbutton and Dezoning Pushbutton which shall remain electrically disabled.
- d) The Train Operator's DOOR CLOSED indication shall be interrupted.
- e) Door system control pushbuttons and switching device shall be electrically disabled until such time as the MKS is placed in the ON position except as noted elsewhere.

6.4.12.20 TERM Position Functionality

- a) When the switching device is placed in the TERM position from the ON position, all MDC door system pushbuttons shall be disabled, except for the Shuttle Pushbutton (see Section 6.4.12.29) which shall be enabled.
- b) The MDC shall remain zoned-in to allow the conductor to leave the train with the doors open and key removed. The Zone Signal Lights (see Section 6.4.12.37) shall be extinguished. The doors shall remain in the last valid commanded position when the MKS was in the ON position.

Dezoning Pushbutton

- 6.4.12.21 A Dezoning Pushbutton incorporating red LED illumination to serve as a Zone Status Indicator Light shall be provided in each MDC.
- 6.4.12.22 The Dezoning Pushbutton shall be of the momentary contact type and protected from accidental activation.
- 6.4.12.23 The Dezoning LED to indicate Zone Status shall be illuminated on both MDCs in a zoned-in cab.
- 6.4.12.24 The Dezoning Pushbutton shall function only when both MDCs in that cab are in the RUN position and the cab is zoned-in. When the Dezoning Pushbutton is depressed, that cab shall dezone and Dezoning LED illumination shall extinguish on both MDCs in that cab, thus re-establishing the continuous control and indication trainlines.

DOOR OPEN and CLOSE Pushbuttons

- 6.4.12.25 Two sets of non-illuminated OPEN and CLOSE Pushbuttons shall be provided, one set each for the fore and aft door control zones, and arranged to minimize the potential for accidental operation.
- 6.4.12.26 Passenger side door OPEN and CLOSE Pushbuttons shall be of the momentary contact type.
- 6.4.12.27 When activated, the OPEN Pushbutton shall cause all doors in the associated zone to unlock and open within the specified period of time in compliance with Section 6.2.2. This command shall be overridden by a simultaneous CLOSE command.

6.4.12.28 When activated, the CLOSE Pushbutton shall de-energize any door OPEN and UNLOCK trainlines, and shall cause all doors not closed and locked in the associated zone to close and lock within the specified period of time in compliance with Section 6.2.2. This command shall override any simultaneous OPEN or Partial CLOSE command.

Shuttle Pushbutton

6.4.12.29 The Shuttle Pushbutton shall be of the illuminated amber color momentary contact type.

6.4.12.30 The Shuttle Pushbutton shall be enabled only when the MKS is in the TERM position and doors on the associated side of the train are open and the drum switch is in the ISOLATE position, and shall illuminate when activated.

6.4.12.31 When momentarily activated, the Shuttle Pushbutton shall cause the DOOR OPEN and DOOR UNLOCK command on that side of the train to be preserved when the MKS is returned to the RUN position.

6.4.12.32 Shuttle cancel function shall be provided by activation of the Buzzer.

Local Recycle Pushbutton

6.4.12.33 When activated, the Local Recycle Pushbutton shall cause the obstructed panels (all panels not closed and locked in the zone activated by the close button) on the same side of the train to immediately fully open and immediately close. If the obstruction remains, the door shall remain closed on the obstruction with obstruction detection remaining active. All other doors shall remain closed and locked.

Door Partial Close Pushbutton

6.4.12.34 When activated, the Partial Close Pushbutton shall cause all non-crew door panels on the same side of the train within that zone to close. This command shall be overridden by a Close command.

6.4.12.35 Non-Crew door panels closed by activation of the Partial Door Close Pushbutton shall fully reopen when the Open Pushbutton associated with that zone is subsequently activated.

6.4.12.36 Crew door panels remaining open due to activation of the Partial Door Close Pushbutton shall fully close when the Close Pushbutton associated with that zone is subsequently activated.

Zone Signal Lights

6.4.12.37 Each MDC shall include two Red illuminated Zone Signal Lights, one for the zone forward of the cab, and one for the zone to the aft of the cab.

6.4.12.38 Zone Signal Lights shall be LED illuminated and shall indicate that all doors in the zone are closed and locked.

6.4.12.39 Zone Signal Lights, on both MDCs in a cab, shall be functional whenever that cab is zoned-in and shall not function when either MKS is in the TERM position.

Door Enable Indicator

6.4.12.40 Each MDC shall have a Door Enable indicator, which shall function as described in Section 6.4.15.

6.4.12.41 The Door Enable indicator shall illuminate red on any active MDC when door operation has been enabled by the Train Operator or by the CBTC system when operating in CBTC mode.

6.4.13 Cab Console Door Controls and Indications

6.4.13.1 The Train Operator console shall also include all controls required to operate the doors for OPTO.

Left Side Door Key Switch, Open and Close Pushbuttons

- 6.4.13.2 One (1) MKS and two (2) momentary type pushbutton for left side door open and close control shall be mounted on the cab console (see Section 5.3.3) to adapt to function in OPTO.
- 6.4.13.3 The MKS on the console shall be labelled as "Left Door Key Switch". The two pushbuttons shall be labelled as "Left Door Open" and "Left Door Close".

Door Enable Pushbuttons

- 6.4.13.4 Two green, LED type "Door Enable Indicators" shall be provided as part of the console's Door Enable pushbuttons.
- 6.4.13.5 Each indicator shall illuminate when the DOOR ENABLE trainline is energized for a particular side of the train.
- 6.4.13.6 Each indicator shall be extinguished when the DOOR ENABLE trainline is de-energized for a particular side.
- 6.4.13.7 The indication shall function irrespective of pushbutton position.

6.4.14 Door Control Relay Panel

- 6.4.14.1 Each side of each car shall be equipped with a DCRP to monitor and interpret all door trainline commands, and transmit them to each doorway within the car.
- 6.4.14.2 Each DCRP shall also be equipped with logic to indicate door closed summary status on per car basis, and the relay logic necessary to control the Conductor Zone Lights.
- 6.4.14.3 Solid state devices for use in the DCRP shall be proposed for NYCT review and approval.
- 6.4.14.4 The DCRP shall be located within the passenger compartment unless otherwise approved by NYCT.
- 6.4.14.5 The DCRP shall output door panel status (OPEN or CLOSED) to the MDS network and the local car HVAC systems directly for demand control (see Section 7).

6.4.15 Door Enable Function

- 6.4.15.1 A Door Enable function shall be provided to permit the control of side door operation from a zoned-in MDC.
- 6.4.15.2 A Door Enable signal shall be generated to activate and permit the side door control in following cases:
 - a) When operating in two-person train operation mode (the Train Operator presses and holds the Door Enable pushbutton in the active cab and, the Conductor turns the MKS to the ON position in the Conductor's cab), the Door Enable circuitry shall be latched such that the MDC door control for that side of the train remains enabled after the Train Operator releases the pushbutton.
 - b) When operating in One Person Train Operation (OPTO) mode, the Train Operator turns MKS to the ON position in the active cab to generate a door enable signal for selected side of the train.
 - c) Under CBTC control, the Door Enable command shall be generated by the CBTC system (see Section 14.2).
 - d) The Contractor shall provide provisions to accept external signals provided by a future Door Enable Protection System and open only the correct platform side doors.
- 6.4.15.3 Once the door operation for the platform side is enabled, the Door Enable Indicator on corresponding MDC shall be illuminated.

- 6.4.15.4 Depressing of the Door Enable pushbutton in the active cab shall cause the All Doors Closed and Locked signal light on the console to extinguish, and remain extinguished for as long as the Door Enable circuit is latched.
- 6.4.15.5 Successive depressing of the Door Enable pushbutton in an active cab shall have no effect on the latched Door Enable signal.
- 6.4.15.6 The Door Enable signal shall be deactivated and the All Doors Closed and Locked signal light shall illuminate once the MKS is placed in the RUN position and all doors are closed and locked.

6.4.16 Manual Test Switch

- 6.4.16.1 A manual test switch shall be provided inside each DMCU to allow maintenance personnel to operate an individual door panel for test purposes.
- 6.4.16.2 The manual test switch shall not be used to issue a door open command.
- 6.4.16.3 The manual test switch shall be of pushbutton type with two operating positions: NORMAL and CLOSE. The switch positions shall be labeled.
- 6.4.16.4 With the switch in the NORMAL position, a door shall remain in state commanded by the last valid trainline (or Crew Switch) command.
- 6.4.16.5 When the switch is operated to a momentary CLOSE position, the door shall begin to close immediately regardless of the previous trainline (or Crew Switch) command.
- 6.4.16.6 All other door functions shall operate as they would if the door were being commanded from the MDC.

6.4.17 Door Interlock Bypass Pushbutton

- 6.4.17.1 Bypass devices shall be provided to circumvent specific door system faults so that a train can continue in revenue service, or be removed from service and returned to a maintenance facility.
- 6.4.17.2 A Door Interlock Bypass Pushbutton per Section 5.3.3 and corresponding console indicator shall be located in each cab.
- 6.4.17.3 When the Door Interlock Bypass Pushbutton is depressed, the door interlock circuit shall be bypassed.
- 6.4.17.4 The Door Interlock Bypass Circuit shall be provided with a hold-in function which shall latch when the Master Controller is moved to POWER or COAST with the Door Interlock Bypass Pushbutton depressed. The Door Interlock Bypass circuit shall unlatch (only in the controlling cab) when the Master Controller is subsequently moved from a POWER or COAST position and, then moved to a Brake position.
- 6.4.17.5 It shall be permissible to operate the Door Bypass Pushbutton in any active Master Controller position, but the circuit shall not latch until the Master Controller is moved to a POWER or COAST position.
- 6.4.17.6 The Door Bypass Pushbutton shall not affect the Train Operator's All Doors Closed and Locked indication in any way.

6.4.18 Mechanical Cutout Lock

- 6.4.18.1 A key-operated door Mechanical Cutout Lock shall be provided for each door panel to provide means to manually cutout a door.

- 6.4.18.2 Cutting out of a single door panel shall not interfere with the operation of the remaining door panel, mechanically or electrically, in that door opening.
- 6.4.18.3 The Mechanical Cutout Lock switches shall be located within the lower portion of respective side door posts, and readily accessible from within the car.
- 6.4.18.4 The Mechanical Cutout Lock escutcheon plates shall be mounted within the lower portion of respective side door posts in compliance with standard layout described in Appendix D-7.
- 6.4.18.5 Each door panel shall be equipped with a three position Mechanical Lock/Cutout Switch featuring the following positions: NORMAL, OFF, CUTOUT.
- 6.4.18.6 With the Mechanical Lock/Cutout Switch set to the NORMAL position, the corresponding door operator shall function and respond normally to all trainline commands.
- 6.4.18.7 With the Mechanical Lock/Cutout Switch set to the OFF position, the corresponding door panel shall not respond to any trainline command, and the series circuit loop consisting of panel position sensing switches shall be open.
- 6.4.18.8 When the Mechanical Lock/Cutout Switch set to the CUTOUT position, the corresponding door panel shall be mechanically locked in the fully closed position, power to the motor cut out, and the door operator shall ignore all door commands. In addition, the Emergency Handle shall be ineffective, the series circuit loop consisting of panel position sensing switches shall be bypassed, and the fault light shall not be illuminated.
- 6.4.18.9 The Mechanical Cutout Lock shall be operated by standard car key (see Section 15.5.2). The key shall be removable only when in the NORMAL and CUTOUT position

6.4.19 Door Annunciation

General

- 6.4.19.1 Signals, both visible and audible, shall be provided on the exterior and in the interior of the car to indicate door system status.
- 6.4.19.2 The location and configuration of all indicator lights shall be subject to review and approval by NYCT.
- 6.4.19.3 Interior indicator devices shall be configured and located such that they can be seen from any location inside the car.
- 6.4.19.4 Each door opening shall incorporate visual warning signal(s) to alert passengers of opening and closing doors. The timing of the visual warning signal shall be adjustable via PTE without the need to modify the software version.
- 6.4.19.5 All illuminated indicators shall meet the requirements in Section 2.14.2.

Door Closed Indication

- 6.4.19.6 An All Doors Closed and Locked signal light indicator shall be provided on the cab console (see Section 5.3.3).
- 6.4.19.7 The design shall not falsely annunciate a safe condition when a door panel is not fully closed and locked due to a mechanical failure and/or switch failure.
- 6.4.19.8 All the Closed and Locked position sensing devices shall be arranged in a series circuit for each side of the car. Each side loop circuit shall activate a summary door status solid state relay whose contacts are in series with the status loop circuit for the train. Alternatively, individual closed and locked loops may be provided on a car level basis with overall summary closed and locked status provided by a single trainline.

- 6.4.19.9 The All Doors Closed and Locked signal shall interface to the carborne CBTC, as described in Section 14.
- 6.4.19.10 The indicator shall be visible when all door panels throughout the train are sensed as being closed and locked, all Exterior Crew Switches are in their NEUTRAL positions, all Interior Crew Switches are in the NEUTRAL or CLOSE positions, and all zoned-up MDC Key Switches are in the RUN position.
- 6.4.19.11 The All Door Closed and Locked Indicator Light shall not be affected by the use of the Door Interlock Bypass Switch or by the status of any other system.
- 6.4.19.12 Two red LED "Zone Light" indicators shall be provided on each MDC to indicate the closed status of side doors in each zone on both sides of the train, one forward and one aft of a zoned-in cab.

Door Open Indication

- 6.4.19.13 Red LED cluster type Guard Lights shall be provided on the exterior and interior of each car. The type of LED Guard Lights shall be in compliance with requirements of Section 8.3.3.
- 6.4.19.14 The indicators shall illuminate anytime any passenger side door on the corresponding side of the train is not fully closed and locked, when an Emergency Handle is activated, when any OPEN or UNLOCK trainline or carline door controls are activated, including unauthorized single-point energization of the OPEN and UNLOCK trainlines, and when a Crew Switch key is activated.
- 6.4.19.15 On each exterior side of the car, a Guard Light with lenses facing to the front and rear of the car shall be provided to indicate the status of doors on the corresponding car independent of the side.
- 6.4.19.16 The exterior Guard Lights shall be placed at a location such that they are easily visible from any location outside the car.
- 6.4.19.17 Four interior Guard Lights shall be provided, with two (2) mounted on each end wall.
- 6.4.19.18 Each interior Guard Light shall be visible from any point in the car, and shall indicate the status of the doors on the associated side of the car.
- 6.4.19.19 Each interior and exterior Guard Light will illuminate when any door on the associated side is unlocked or open, and extinguish when all doors on the associated side are closed and locked.
- 6.4.19.20 A red LED illuminated Fault Light will be provided on the interior near the top of the wall adjacent to each door panel so that it is visible throughout the car.
- 6.4.19.21 The Fault Light will be illuminated anytime the adjacent door panel is not sensed as closed and locked.

Door Closing Warning Signal and Message

- 6.4.19.22 An automatically triggered audible door closing chime shall be provided to annunciate door closing upon initiation of the trainline command to close the doors. The tone of the audible signal shall be approved by NYCT.
- 6.4.19.23 The audible level of the Door Closing Warning chime shall be independently adjustable.
- 6.4.19.24 A manually triggered audible Door Closing Warning message shall be provided by the Automatic Announcement System (see Section 13.4.8) to annunciate door closing.
- 6.4.19.25 LED strips as described in Section 8.3.5 shall be provided as the Door Closing Warning Indicator at each doorway. The indicator shall be initially set to flash at a rate of 1 Hz. The indicator shall flash any time doors are commanded to close, and stop flashing when the door is fully locked.

Next Side Door Opening

- 6.4.19.26 Provision shall be made for a future capability to provide advanced notification of which side a train's doors will open at the next station.

6.4.19.27 The car systems shall have the ability to receive a signal from the CBTC system or a separate wayside system, and shall communicate this information to the communications system for audible and visual announcements (see Section 13) and to the lighting system for the door warning light strips (Section 8.3.5.1).

6.4.20 Door Closed Interlock

6.4.20.1 An electrical loop circuit in the form of Door Closed Interlock, shall be provided to monitor the closed and locked status for all doors, and to prevent the issuance of any propulsion trainline command when a door panel in a train is sensed as being unlocked or open, or when an Emergency Handle is activated, when any OPEN or UNLOCK trainline or carline door controls are activated, and when a Crew Switch is activated as described in Section 6.4.11.

6.4.20.2 If an attempt to take power is made with any door unlocked or open, with the Crew Switch operated, or with B+ on any OPEN or UNLOCK trainline or carline door control circuit the Master Controller command shall be limited to COAST, and it shall be necessary to cycle the Master Controller to any BRAKE position while a doors closed indication is received, or operate the Door Interlock Bypass Switch before power can be taken.

6.4.20.3 If the All Doors Closed and Locked signal is lost while the Master Controller is in POWER or COAST, subsequent Power commands shall be interpreted as COAST. The Door Closed Interlock shall not command the brakes in any way.

6.4.20.4 The Door Closed Interlock shall not provide a command for any braking should the Door Closed and Locked signal be lost while train is moving, regardless of operating mode.

6.5 Maintainability Requirements

6.5.1 Maintainability Design Requirements

6.5.1.1 The general maintainability objectives are contained in Section 21.2.

6.5.1.2 All door system equipment shall meet the maintainability design requirements of Section 2.14.4.

6.5.1.3 A door setup and adjustment procedure shall be submitted, describing the installation required to achieve fully functional door operation. The setup procedure shall include, but not be limited to, mounting of the door operator, door panels, and associated mechanical and electrical components. [CDRL]

6.5.1.4 All door equipment of like function and the same hand shall be interchangeable. To this end, all mounting holes for all door hardware shall be jig-drilled.

6.5.1.5 The door system shall be designed such that mechanical systems shall not require adjustments after installation and setup.

6.5.1.6 The mounting of all sensing devices shall be such that no adjustment shall be necessary when any given device is replaced.

6.5.1.7 The door panels shall be oriented so that they are readily removable from the inside of the car from the center of the doorway.

6.5.1.8 The door operator and its major components shall be designed for a minimum service life of 20 years.

6.5.1.9 All door fixtures shall be protected from tampering by their design, and direct contact by passengers with door operator elements shall not be possible.

6.5.1.10 The number of couplings and linkages in the door operator shall be minimized to reduce the number of failure points in the system.

- 6.5.1.11 Should the door operator utilize a speed reduction gear unit, or drive screw unit, or both, the components shall be readily available from multiple sources, unless otherwise approved by NYCT.
- 6.5.1.12 Lubrication of drive screws shall be ensured by the material properties of the components used. The use of oil, grease, dry-film, or other applied lubricants is prohibited.
- 6.5.1.13 The door operators shall be capable of providing continuous repetitive operation under the most severe operating conditions, with inspections and other scheduled attention performed in accordance with Appendix C-36 (NYCT Document SMS #08-002 "Generic Passenger Car Worksopce: R142, R142A, R143, and R160").
- 6.5.1.14 The door system shall be designed to allow replacement of individual components without requiring removal of adjacent components. Where possible, covers shall be retained by hinges. Hinges located on the car exterior shall be corrosion resistant.
- 6.5.1.15 All exposed fasteners used in the door system shall be tamperproof. Where maintenance access is needed, the tamperproof fasteners shall be quick release and captive.
- 6.5.1.16 All door system components shall be designed to provide ease of routine maintenance and inspections, including cleaning of track, gauging, safety verifications, adjustments, and component removal/replacement, if required.
- 6.5.1.17 Adjustment or removal of door components shall be from inside the car.
- 6.5.1.18 The PTE access port for diagnostic functions shall be provided according to Section 6.4.7.6.
- 6.5.1.19 Basic diagnostic functions shall be provided on the DMCU, e.g. local LED indicators, to provide general health status of DMCU, and allow quick diagnoses of door problems without the PTE.

6.6 Validation Requirements

6.6.1 General Validation Requirements

- 6.6.1.1 Door locking system, door locked detection technique, functional narrative, application drawing, and detailed layout shall be submitted for review and approval by NYCT. [CDRL]
- 6.6.1.2 The doors and all of its components shall be tested to verify compliance with all specified design, performance and reliability requirements (see Section 24, Testing Program).
- 6.6.1.3 Door system design qualification tests shall include an accelerated life test of 2.0 million cycles for one complete set of door hardware. The accelerated life test shall include within it the specific testing requirements denoted below. These tests shall be completed before the first car is delivered to NYCT. Failures recorded during testing must correlate within specified reliability values.
 - a) Perform 100,000 cycles of mid-close recycle actions;
 - b) Perform 200,000 cycles with the test fixture tilted at a worst case tilt and grade per Section 6.2.1.2;
 - c) Perform portions of the test across the entire operating voltage range.
- 6.6.1.4 Door speed and noise tests shall be performed at the beginning, mid-point, and end of the accelerated life test for comparative evaluation.
- 6.6.1.5 The Contractor shall make available sample door fixtures, LED indicators with lenses for approval. [CDRL]
- 6.6.1.6 The initiation method of Door Closing Warning signal and message shall be submitted for review and approval. [CDRL]

6.6.1.7 The design of the door closed interlock and bypass function shall be submitted for review and approval. [CDRL]

6.7 Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
6-1	6.4.2.10	Position sensing arrangement	PDR
6-2	6.4.7.8	Door diagnostic system scheme	CDR
6-3	6.5.1.3	Door setup and adjustment procedure	CDR
6-4	6.6.1.1	Door Operator Design and Functional Description including locking system	PDR
6-5	6.6.1.5	Sample door fixtures and LED indicators	CDR
6-6	6.6.1.6	Door closing warning method	CDR
6-7	6.6.1.7	No-Motion detection, interlock and bypass scheme	PDR

Section 7

**Heating, Ventilation, and Air
Conditioning**

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7. Heating, Ventilation and Air Conditioning

7.1. Introduction and General Requirements

- 7.1.1. This section defines the requirements for the Heating, Ventilation, and Air Conditioning (HVAC) system. The requirements are divided into Performance, Functional, General Design, Maintainability, and Validation.
- 7.1.2. Refer to the following sections for car systems and components interfacing with the HVAC System and other applicable requirements:
- a) Design and Performance Criteria – Section 2.
 - b) Cab and Cab Controls – Section 5.
 - c) Side Door System – Section 6.
 - d) Auxiliary Electrical Equipment and Distribution – Section 9.
 - e) Carbody Equipment and Interiors – Section 15.
 - f) Monitoring and Diagnostics – Section 17.
 - g) Software Systems – Section 18.
 - h) Materials, Processes, and Workmanship – Section 19.
 - i) Reliability, Maintainability, and System Assurance - Section 21.
 - j) System Support - Section 22.
 - k) Testing Program – Section 24.
- 7.1.3. The HVAC system shall be designed for maximum energy efficiency, ease of maintenance, and maximum reliability.
- 7.1.4. The Contractor shall be responsible for providing a conditioned air delivery system that results in interior temperature variations that meet the requirements given in Section 7.2.1.4, the selection of the HVAC Controller switch point temperatures, and the proper proportioning of the cooling and heating capacities to meet the car performance requirements given in Section 7.2.
- 7.1.5. All materials used in the HVAC system shall meet the flammability and smoke emission requirements of Section 19.1.10.
- 7.1.6. The use of proprietary equipment and technologies shall be held to a minimum and shall be subject to NYCT approval.

7.2. Performance Requirements

7.2.1. General

7.2.1.1. The HVAC unit and interior heating and cooling equipment shall have the capacity to maintain the car interior conditions in compliance with the temperature requirements of Section 7.2.1.2a) under the following conditions.

a) **Summer ambient temperature.**

- i. Tunnel: 120 °F^(DB) (48.9 °C^(DB)); 80 °F^(WB) (26.7 °C^(WB)).
- ii. Surface: 105 °F^(DB) (40.6 °C^(DB)); 75 °F^(WB) (23.9 °C^(WB)).

b) **Winter ambient temperature.**

- i. Tunnel: 11 °F (-11.7 °C).
- ii. Surface: 0 °F (-17.8 °C).

c) **Passenger load:** 190 passengers at 450 Btu/hr (0.13 kW) per passenger at a Sensible Heat Ratio (SHR) of 0.55.

d) **Fresh air quantity:** 7.5 cfm per passenger at AW2 loading up to a maximum of 1055 cfm per car evenly divided between the HVAC units.

e) **Total air flow.**

- i. As required to meet the internal temperature, humidity, and car pressurization requirements of this Specification.
- ii. A minimum of 100 cfm of conditioned air shall be delivered to all cabs.

f) **Car pressurization:** Between 0.1 and 0.2 inches (2.54 and 5.08 mm) of water at all operating conditions with all doors closed.

g) **Carbody heat transmission (U Factor):** Carbody and insulation designed to meet the requirements of Section 15.2.2.

h) **Lighting load:** Total wattage of heat producing interior lights.

i) **Solar load:** In accordance with the latest edition of the Load and Energy Calculations section of ASHRAE Handbook – Fundamentals.

j) **Miscellaneous interior equipment heat rejection:** In accordance with Contractor's heat producing equipment data.

7.2.1.2. With the side doors closed, the HVAC unit and interior heating and cooling equipment performance shall conform to the following:

a) **Interior Average Temperature:** The average temperature inside the car shall, at the ambient temperature ranges in Figure 7-1, be within the ranges given in Figure 7-1.

b) **Design Conditions:** Design conditions shall be as given in Table 7-2.

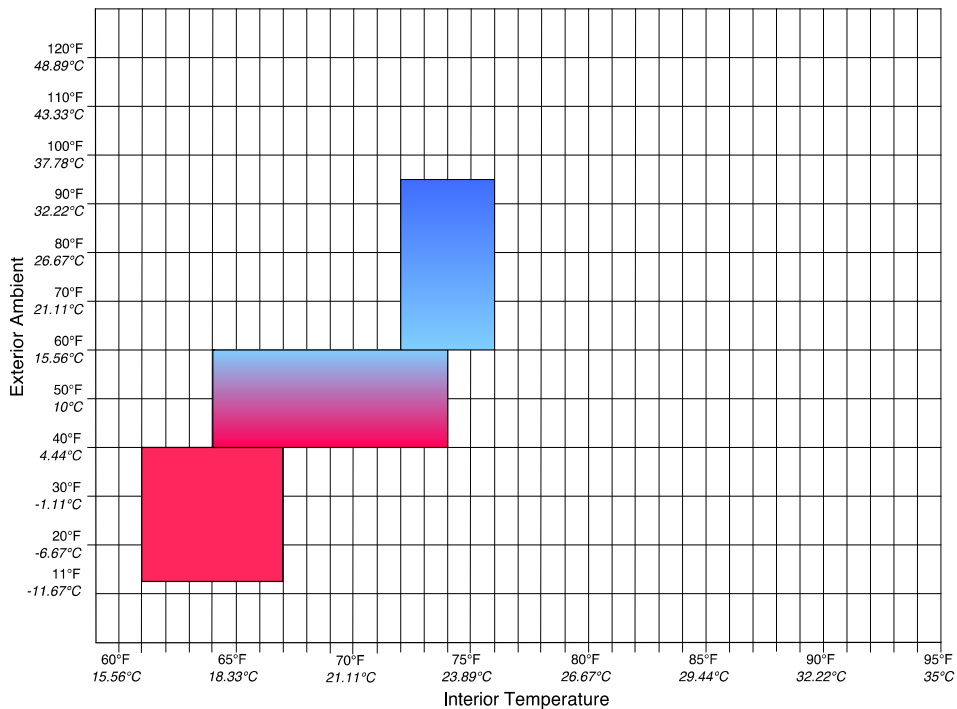


Figure 7-1 Temperature Schedule

Mode	Ambient Temperature (DB)	Interior Temperature (DB)
Heating	11 °F (-11.7 °C)	67 °F (19.4 °C)
Cooling	115 °F (46.1 °C)	85 °F (29.4 °C)

Table 7-2 Design Conditions

- 7.2.1.3. The interior relative humidity shall not exceed 55 percent with the HVAC equipment operating at design conditions. Provisions shall be included for reheat of the air stream to maintain humidity limits.
- 7.2.1.4. At steady state conditions, the following variations in temperatures in the passenger compartment shall not be exceeded:
 - a) At any given point in the car, at the entrance ways, and at least 12 inches (305 mm) from the ceiling and 6 inches (152 mm) from the floor and walls: 5 °F variation (2.8 °C variation).
 - b) At any given time among all points in the same horizontal plane from one end of the car to the other: 4 °F variation (2.2 °C variation).
 - c) At any given time between any point 48 inches (1219 mm) above the floor and the corresponding point 6 inches (152 mm) above the floor in a vertical plane: 4 °F variation (2.2 °C variation).
- Note:** Transient and temporary excursions outside these limits, or a limited number of data points not meeting these limits, may be acceptable with specific NYCT approval.
- 7.2.1.5. The level of vibration generated by the HVAC equipment shall meet the requirements of Section 2.9.5.
- 7.2.1.6. All components of the HVAC system shall be designed to withstand the shock and vibration levels specified in Section 2.9.6. Additionally, the system shall be able to withstand shock and vibration

encountered during removal or replacement from the car, or transportation by road between shops over rough surfaces.

7.2.2. Heating

- 7.2.2.1. The overhead forced air heater shall have the capacity to heat the quantity of fresh air defined in Section 7.2.1.1 d) from 11°F (from -11.7°C) to 65°F (to 18.3°C) at nominal supply power.
- 7.2.2.2. The passenger compartment and cab compartment floor heating system shall meet the following requirements:
- The floor heating system shall have the capacity to maintain the car interior temperature 54°F above (30°C above) the minimum exterior ambient design temperature at nominal supply power levels and at all car operating speeds.
 - At the minimum specified design exterior ambient temperature, the floor heating system and overhead heater shall have the capacity to raise the interior temperature from the minimum steady state layover conditions defined in Section 7.2.2.3 to 62°F (16.7°C) with a pull-up time of less than 45 minutes.
 - The heater system shall be designed to prevent interior surfaces with which passengers may come in contact from exceeding 125°F (51.7°C) under worst case conditions.
 - If required, the cab heater guards may incorporate an over-temperature thermostat to limit the surface temperature to the allowable maximum temperature.
- 7.2.2.3. In the Layover mode, per Section 7.3.5.26, and using just floor heat, the average car temperature shall be maintained at 50 ±5°F (10 ± 2.8°C).
- 7.2.2.4. All heating requirements shall be met without consideration of solar or passenger load.

7.2.3. Cooling

- 7.2.3.1. The refrigeration system shall be able to function without damage at all exterior temperatures down to 50°F (10°C).
- 7.2.3.2. With an ambient temperature at the condenser and fresh air intakes of up to 110 °F^(DB)/81 °F^(WB) (43.3 °C^(DB)/27.2°C^(WB)), the refrigeration system shall provide full design cooling.
- 7.2.3.3. The refrigeration system shall remain operational, at reduced capacity if necessary, with an ambient temperature of 125°F^(DB)/84°F^(WB) (51.7°C^(DB)/28.9°C^(WB)) at the condenser and fresh air intakes and under the design internal, solar, and passenger loads specified in Sections 7.2.1.1 and 7.2.1.2.
- 7.2.3.4. With the side doors on one side of a car operating continuously on a 1 minute open, 2 minutes closed cycle, the average car interior temperature shall remain within the temperature range required by Section 7.2.1.2a).
- 7.2.3.5. The condenser coil design shall limit the condensing temperature to less than 29°F above (16.1°C above) the condenser cooling air temperature conditions given in Section 7.2.3.2.
- 7.2.3.6. The condenser coil design shall provide a minimum of 10°F (a minimum of 5.6°C) subcooling.
- 7.2.3.7. Condenser fan noise shall be in accordance with Section 2.9.4.2.

7.2.4. Ventilation

- 7.2.4.1. The ventilation system shall maintain a positive internal static pressure at all car speeds. See Section 7.2.1.1 for details.

- 7.2.4.2. When combined with the roof insulation value, the top of the air distribution duct insulation shall provide a thermal resistance value of at least R-11.
- 7.2.4.3. The sides of the air distribution ducts shall be insulated to a thermal resistance value of R-4.5 or as needed to prevent the formation of condensation. The duct side insulation shall include an approved vapor barrier or vapor barrier coating.
- 7.2.4.4. Insulation spikes or other NYCT-approved supplementary mechanical fastening methods shall be used on vertical and inverted horizontal duct surfaces.
- 7.2.4.5. Thermal breaks shall be used where ducts are fastened to the car structure.
- 7.2.4.6. Air shall be ducted to the cab using insulated branch ducts.
- 7.2.4.7. To minimize noise, air turbulence, and eddies, and to provide uniform air flow from the HVAC unit into the air distribution air ducts, noise-attenuating air turning vanes and straighteners shall be incorporated and be designed in accordance with the recommendations of the Air Movement and Control Association (AMCA) Fan Application Manual.
- 7.2.4.8. 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 (152 mm) below the face of the diffusers.
- 7.2.4.9. The average velocity of discharged air shall not be greater than 100 fpm (0.51 m/s) with maximum velocity not to exceed 200 fpm (1.02 m/s) at 6 inches (152 mm) below the diffusers.
- 7.2.4.10. The air velocity anywhere below 48 inches (1219 mm) above the floor throughout the car interior shall not exceed 50 fpm (0.25 m/s).
- 7.2.4.11. The air temperature differential between the car interior and the air leaving the linear diffusers shall not be greater than 8°F differential (4.4°C differential) in heating mode (except during warm up) and 25°F differential (14°C differential) in cooling mode (except during pull-down) with the average car interior temperatures within the ranges specified in Section 7.2.1.2a).
- 7.2.4.12. Air flow across the fresh and return air filter faces shall be uniform and the velocity shall not exceed the filter manufacturer's recommendation.
- 7.2.4.13. Fresh and return air filter performance shall be in accordance with ASHRAE Standard 52.2-2012.
- 7.2.4.14. The Contractor shall design the filter system for maximum system running time between required filter changes. As a minimum, filters shall meet the construction and performance requirements within Appendix C-10 (Air Conditioning Filters for NYCT Subway Cars, 2061-PROD-89, rev. E).

7.3. Functional Requirements

7.3.1. HVAC Unit

- 7.3.1.1. Each end of the car shall have an independent, vapor cycle, direct expansion, unitized sealed roof-mounted HVAC unit. The HVAC unit shall use R-407C or other NYCT approved refrigerant. The refrigerant shall be listed in the U.S. Environmental Protective Agency's (EPA) Significant New Alternatives Policy (SNAP) for Motor Vehicle Air Conditioners (MVAC): Passenger Air Conditioning in Buses and Trains.
- 7.3.1.2. All HVAC units shall be identical and interchangeable on the same car and between any other R211 class cars, per Section 1.1.3, without any modification or adjustment.
- 7.3.1.3. The HVAC unit design and installation shall allow full accessibility for on-car maintenance, troubleshooting, and minor repairs without the need to remove other systems or components.

- 7.3.1.4. The HVAC units shall be removable from the car without the need to disconnect anything other than the HVAC unit mounting hardware, electrical connectors, and drain pipe connections.
- 7.3.1.5. Air duct connections between the HVAC unit and the carbody supply and return air openings shall not require maintainer intervention when the HVAC unit is installed on or removed from the car roof. The connections shall be sealed using a soft silicone rubber or approved equal compression gasket.
- 7.3.1.6. To prevent water entry into the carbody, the supply and return air interface openings shall be raised above the surface of the car roof sheet located under the HVAC unit. Alternatively, an HVAC unit fitted with a perimeter gasket guaranteeing a watertight seal with the carbody, which eliminates the need for a car roof sheet located under the HVAC unit may be proposed for NYCT approval.
- 7.3.1.7. To prevent condensate carryover from the evaporator coil fins, the air velocity across the evaporator coil face shall be uniform and shall be limited to 450 fpm (2.29 m/s) without additional baffling devices upstream or downstream of the coil, unless otherwise approved by NYCT.
- 7.3.1.8. A condensate drain pan shall be provided beneath the evaporator coil, headers, thermal expansion valves, coil U-bends, and any other evaporator components that may produce condensate.
- 7.3.1.9. The drain pan shall be made of stainless steel with stainless steel or copper-alloy fittings.
- 7.3.1.10. The drain pan shall be baffled and arranged so that water does not spill over into the ceiling area under any operating conditions including the worst case combination of grade, superelevation, positive or negative acceleration, and car roll.
- 7.3.1.11. Condensate drain lines shall be sloped for positive drainage to the underside of the car and shall not be routed through electrical or electronic cabinets.
- 7.3.1.12. An elastomeric flapper (kazoo) shall be attached to the drain line termination underneath the car. To eliminate negative pressure conditions that could prevent condensate in the drain pan from entering the drain lines, the elastomeric flapper shall be designed so that it reverts to the closed state after the discharge of accumulated condensate.
- 7.3.1.13. The condensate drain lines, the evaporator coil housing, and the drain pan bottom and sides shall be insulated to prevent the formation of condensation unless otherwise approved by NYCT.
- 7.3.1.14. The condensate drain lines shall be routed to discharge to the underside of the car and the condensate shall be discharged clear of all underfloor equipment, the running rails, and the third rail.
- 7.3.1.15. Routing of the condensate drain lines through the carbody side sill is prohibited unless otherwise approved by NYCT. See Section 3.5.1.
- 7.3.1.16. The evaporator blower and condenser fan motors shall be totally enclosed with permanently lubricated bearings and shall be rated for wash down applications.
- 7.3.1.17. The evaporator blower and condenser fans shall be directly driven.
- 7.3.1.18. The evaporator blower motor shall be powered by a 3-phase AC power supply operating from third rail power.
- 7.3.1.19. The evaporator blower assembly shall be isolated so that vibration and noise transmitted to the car structure is below the limits specified in Sections 2.9.4 and 2.9.5.
- 7.3.1.20. The condenser fan motor shall be powered by a FVFF 3-phase AC power supply operating from third rail power.
- 7.3.1.21. The compressor shall be resiliently mounted to the HVAC unit frame.

- 7.3.1.22. The refrigerant (air conditioning) compressor motor shall be powered by a Variable Voltage Variable Frequency (VVVF) 3-phase AC power supply operating from third rail power.
- 7.3.1.23. Where practical (such as with the condenser fan motor and the overhead heater that are not required to operate at the same time), some HVAC unit 3-phase AC loads may share a common inverter subject to NYCT approval. See Section 9.1.4.
- 7.3.1.24. The 3-phase inverter(s), designed in accordance with Section 9 - Auxiliary Electrical Equipment and Distribution, shall be installed within the HVAC unit, unless otherwise approved by NYCT.
- 7.3.1.25. With all HVAC unit covers installed, the condenser fan area shall meet the safety requirements of UL 1995, paragraph 11.
- 7.3.1.26. Alternate configurations, whereby controls or other elements are shared between the two HVAC units, while maintaining the performance, reliability and redundancy requirements of this Specification, may be proposed by the Contractor for NYCT approval.

7.3.2. Heating

- 7.3.2.1. The car heating system shall consist of a combination of cab and passenger compartment floor heat using convection heater enclosures and grilles at floor level, and forced-air overhead heat in the HVAC unit.
- 7.3.2.2. The passenger compartment and cab floor heaters shall consist of electric strip heaters mounted behind stainless steel heater grilles that the close heater enclosures located along the sidewalls at the floor level. Refer to Section 15.9.9 for additional details on the heater grilles.
- 7.3.2.3. The floor heater circuits shall be powered from third rail power.
- 7.3.2.4. Air shall enter the heater enclosure through slots at the bottom of the heater grille and pass over the heater strip, with the heated air exiting through perforations in the upper front face of the heater grille.
- 7.3.2.5. The floor heater circuits shall be arranged in two stages with each stage of heat energy distributed around the periphery of the passenger compartment in a manner that meets the required interior temperature distribution.
- 7.3.2.6. As an alternative to strip heaters, radiant floor heaters, subject to NYCT approval, may be used to heat the passenger and cab areas. If radiant floor heaters are used, they shall be:
 - a) To the greatest extent possible, repairable without removing radiant floor heat panels from the car.
 - b) Ground fault protected.
- 7.3.2.7. If radiant floor heaters are used, a zone heating control plan shall be submitted for NYCT approval.
- 7.3.2.8. Independent power supplies may be used for radiant floor heaters as approved by NYCT. The overhead heater shall be single stage open or tubular element located downstream from the cooling coils.
- 7.3.2.9. The overhead heat shall be powered by a VVVF 3-phase AC power supply operating from third rail power.
- 7.3.2.10. Replaceable-element protective heaters shall be provided for components such as side door threshold plates that are subject to malfunction or damage due to moisture accumulation and subsequent freezing. See Section 15.4.7.

- 7.3.2.11. The protective heat circuit shall be controlled at $40 \pm 5^{\circ}\text{F}$ ($4.4 \pm 2.8^{\circ}\text{C}$) and sensed by a protective heat temperature sensor located in position to accurately reflect the temperatures in the vicinity of the devices being protected.
- 7.3.2.12. Overhead heat and floor heat shall be automatically controlled by the HVAC Controller, in both the normal and layover modes.

7.3.3. Cooling

- 7.3.3.1. The refrigeration system shall incorporate a hermetic scroll refrigerant compressor, sized to meet the performance requirements given in Section 7.2.
- 7.3.3.2. Alternate compressor arrangements may be submitted for NYCT consideration if it can be demonstrated that the alternate configuration and control scheme will minimize HVAC unit size, cost, system weight, and maximize performance and reliability.
- 7.3.3.3. Refrigeration capacity shall be controlled by varying the refrigerant compressor motor speed. Other capacity control means may be proposed for NYCT approval.
- 7.3.3.4. High and low pressure cutout switches shall be directly wired in the refrigerant compressor power switching control circuit. The circuit shall be arranged such that condenser fan(s) operation is not interrupted by the high pressure cutoff control. When the reset pressure is reached, the compressor shall restart following a time delay period recommended by the HVAC unit supplier and approved by NYCT.
- 7.3.3.5. High and low pressure protection shall not be affected by a HVAC Controller malfunction.
- 7.3.3.6. If recommended by the refrigerant compressor manufacturer, the refrigerant system controls shall include an automatic pump-down cycle, or other NYCT approved liquid refrigerant control system.
- 7.3.3.7. Pump-down shall be initiated by closing the liquid line solenoid valve when an "OFF" signal has been received. The refrigerant shall be transferred to the condenser until the compressor suction pressure drops below the low-pressure cutoff set-point, and the low-pressure switch opens and stops the compressor.
- 7.3.3.8. Pump-down shall not be initiated if the system shutdown is initiated by a protective safety device such as excessive pressure, temperature, or current protective devices.

7.3.4. Ventilation

- 7.3.4.1. Ventilation shall be available at all times when primary power is available and the HVAC unit is activated under trainline control. A malfunction of the heating or cooling equipment or of the HVAC Controller shall not cause the loss of ventilation.
- 7.3.4.2. Fresh air quantities shall be variable and automatically adjusted for passenger load by an NYCT approved means. Refer to Section 7.2.1.1 d) for nominal cfm requirements.
- 7.3.4.3. To limit waste of heated or cooled air, the ventilation system shall have the ability to modulate airflow when the side doors are open. See Section 6.4.14.5. This demand control feature shall be capable of being adjusted or disabled via the portable test equipment (PTE) and shall be subject to NYCT approval.
- 7.3.4.4. The main air distribution ducts shall be located above the car ceiling.
- 7.3.4.5. The main air distribution ducts shall be sized so that the air velocity does not exceed 1,200 fpm (6.1 m/s).
- 7.3.4.6. The main duct shall be divided so that air from each HVAC unit supplies only the diffusers on one side of the car.

- 7.3.4.7. Air shall be discharged into the passenger compartment through two continuous rows of flush-mounted linear double-slot diffusers located in the ceiling panels and shall extend longitudinally along the bottom of the supply air distribution duct.
- 7.3.4.8. The diffusers shall be designed to provide uniform temperature distribution throughout the car in accordance with the requirements of Section 7.2.1.4.
- 7.3.4.9. The final settings of the slot diffusers in all prototype and production cars shall be identical to those approved during climate room testing. The production diffusers shall be non-adjustable.
- 7.3.4.10. If required to provide conditioned air to areas such as the ends of the car not fed by the main duct, individual supply ducts with diffusers, fed from both sides of the main center distribution duct, shall be routed to the affected areas.
- 7.3.4.11. To prevent short-circuiting of the airflow, the slot diffuser outputs adjacent to the return air grilles shall be restricted.
- 7.3.4.12. Passenger compartment and cab air shall be returned to the fresh/return air mixing plenum and the HVAC unit.
- 7.3.4.13. Recirculated air shall be drawn back to the mixing plenum and the HVAC unit through grilles in the low ceiling area located as selected by the Contractor and approved by NYCT.
- 7.3.4.14. Grilles shall be powder-coated aluminum to match the surrounding ceiling.
- 7.3.4.15. Grilles shall be hinged on one of the long sides and shall be provided with 1/4 turn, captive, tamper-proof fasteners and safety retention devices on the opposite side.
- 7.3.4.16. If safety chains are used, they shall be jacketed to prevent rattling and shall automatically stow upon closing of grilles.
- 7.3.4.17. Return air grilles shall be designed to pass the required quantity of air without turbulence and with sound levels that meet the car interior noise requirements of Section 2.9.2.
- 7.3.4.18. The return air grille design shall not allow a direct line of sight into the mixed-air plenum.
- 7.3.4.19. The return air grille shall be located at the farthest possible end of the car or as approved by NYCT.
- 7.3.4.20. The return air and fresh air grille designs shall prevent items such as cigarette butts and lit matches from being drawn or forced into the mixing plenum.
- 7.3.4.21. Air filters shall meet the combustibility and smoke generation requirements of UL Standard 900, Class 2, and the test parameters and performance characteristics contained in Appendix C-10 (Air Conditioning Filters for NYCT Subway Cars, 2061-PROD-89, rev. E). Filters shall not ignite when exposed to a lit cigarette.
- 7.3.4.22. To prevent air bypass, filter holders shall provide sealing at the return air and fresh air filter edges.
- 7.3.4.23. Support of the central filter area shall be provided to prevent the blowout of a clogged filter element.
- 7.3.4.24. Equal quantities of conditioned air shall be ducted to the cab from each HVAC unit.
- 7.3.4.25. Booster blowers shall be installed in the supply-air ducts to the cab, if required, to provide air volumes required to maintain the specified cab temperatures.
- 7.3.4.26. If throttling causes the cab diffuser to generate objectionable noise, the design shall automatically prevent operation of the booster fans when the diffuser is throttled below approximately half its fully open position.

- 7.3.4.27. The Train Operator shall be able to adjust the cab conditioned air volume from full to nearly zero, and to direct the conditioned cab air to any place in the cab area including the windshield using the ceiling diffusers described in Section 7.4.3.11. See Section 5.7.4.1.

7.3.5. Controls

HVAC Controller

- 7.3.5.1. A microprocessor-based HVAC Controller shall be provided for each HVAC unit.
- 7.3.5.2. The HVAC Controllers shall automatically maintain the car interior temperature specified in Section 7.2.1.2a) and relative humidity at the ambient conditions specified in Section 7.2.1.3, with and without variable solar loads and variable internal loads such as passengers, motors, and lights.
- 7.3.5.3. The HVAC Controller shall be powered from the Low Voltage Distribution Network (LVDN). See Section 9.4.17.
- 7.3.5.4. Each HVAC Controller shall control the HVAC unit and auxiliary power switching devices through solid-state output devices.
- 7.3.5.5. Where practical, power switching devices shall be solid-state.
- 7.3.5.6. The HVAC Controller and temperature sensor accuracy shall be integrated to control the interior temperature at the ranges that meet the requirements of Section 7.2.1.2a)a). The temperature sensors shall have an accuracy of $\pm 0.5^{\circ}\text{F}$ (accuracy of $\pm 0.3^{\circ}\text{C}$).
- 7.3.5.7. The final NYCT approved HVAC Controller design switch points shall be verified at the HVAC system qualification climate room test per Section 24.6.5.
- 7.3.5.8. The HVAC Controller shall be either integral to the HVAC unit or separately mounted adjacent to its respective HVAC unit and, if mounted separately, shall have full accessibility for on-car maintenance, troubleshooting, and minor repairs without the need to remove other systems or components.
- 7.3.5.9. The HVAC Controller electronics shall be designed in accordance with the requirements of Sections 18, Software Systems and 19, Materials, Processes, and Workmanship.
- 7.3.5.10. A communication link shall be provided between the HVAC Controllers on the same car. This may be achieved via the train network.
- 7.3.5.11. One of the HVAC Controllers shall be designated as the 'master' with the other designated as the 'slave.' The information from the fresh and return air temperature sensors associated with the master HVAC Controller shall be used to control both HVAC units. Alternate control schemes may be proposed for NYCT review and approval.
- 7.3.5.12. In the event of a master HVAC Controller or associated temperature sensor failure, the HVAC slave controller and its associated temperature sensors shall assume control of both HVAC units. Alternate control schemes may be proposed for NYCT review and approval.
- 7.3.5.13. The overhead heater shall be single stage and the output proportionally controlled.

HVAC Controller Diagnostic Functions

- 7.3.5.14. The HVAC Controller unit or the HVAC unit shall incorporate an easily accessible diagnostic test plug for the attachment of the PTE. See Section 22.8.6.
- 7.3.5.15. Using the HVAC PTE, it shall be possible to adjust the setting of each control point by $\pm 5^{\circ}\text{F}$ ($\pm 2.8^{\circ}\text{C}$) in 0.5°F (0.28°C) increments. See Section 22.8 for PTE and Section 18.6 for software adjustments.
- 7.3.5.16. A Light Emitting Diode (LED) display located externally on the HVAC Controller shall indicate Cooling Faults, Overhead Heating Faults, Control Faults, and Power Faults. As a minimum, the Control Fault

indication shall provide identification of major control circuit problems such as abnormal power input and HVAC Controller power supply voltages, and abnormal operation of the temperature and pressure sensors.

- 7.3.5.17. If radiant floor heaters are used, an LED display located in an area approved by NYCT shall indicate zone control and ground fault status. The status shall also be available for display on the MDS TOD.
- 7.3.5.18. The fault displays shall not require that fault codes be researched. Fault displays shall describe the fault in sufficient detail to provide troubleshooting direction to maintenance personnel.
- 7.3.5.19. The HVAC Controller shall include the necessary logic, memory, and interface provisions to log and store key faults and status information within the HVAC Controller and to communicate that information, via the Car Network, to the Monitoring and Diagnostic System described in Section 17.
- 7.3.5.20. The HVAC controller shall periodically synchronize its time and date settings to the master clock via the MDS. See Section 17.3.6.

Temperature Sensors

- 7.3.5.21. Each HVAC unit shall have integral return and fresh air temperature sensors.
- 7.3.5.22. Supply duct air temperature sensors shall be provided to independently control the discharge air temperature of each HVAC unit overhead heater.
- 7.3.5.23. Temperature sensors shall be located, mounted, and positioned to preclude the influence of local heat sources such as motors and resistors or by air stratification.
- 7.3.5.24. Sensors shall be accessible for maintenance and replacement, and shall be protected from damage during routine air conditioning servicing, such as replacing filters.

Controls and Interlocks

- 7.3.5.25. Activation of all HVAC systems in the train shall be controlled from the active Train Operator's console. When the HVAC trainline is de-energized, the HVAC units shall shutdown in an orderly manner.
- 7.3.5.26. The layover mode of operation shall be automatically initiated when the HVAC control trainline is de-energized and no Train Operator's console is activated.
- 7.3.5.27. The evaporator blower fan and the refrigerant compressor motor power switching devices shall be interlocked to prevent refrigerant compressor operation if the blower fans are inoperable.
- 7.3.5.28. An evaporator blower motor current sensor shall be incorporated into the temperature control system design to remove control power from the refrigerant compressor and the HVAC unit overhead heater power-switching devices whenever the air volume from the evaporator blower falls below the level needed for safe operation or where equipment damage could occur. Alternate protection schemes may be proposed for NYCT approval.
- 7.3.5.29. The temperature controls shall lockout the operation of the refrigerant compressor when the outside temperature is below 50°F (10°C).
- 7.3.5.30. An HVAC control circuit breaker in each car shall provide a means to disable HVAC operation on that car only, regardless of the status of the HVAC control trainline.

7.4. General Design Requirements

7.4.1. HVAC Unit

- 7.4.1.1. The HVAC unit shall blend into the surrounding contour of the roof and provide a streamlined appearance. It shall not, however, be a part of the carbody structure.

- 7.4.1.2. The HVAC unit structural components shall be constructed from stainless steel unless otherwise approved by NYCT.
- 7.4.1.3. Components subject to corrosion and dirt build up, such as fan shrouds, shall be stainless steel, with a bright annealed (BA) or finer finish per ASTM A480 in order to facilitate cleaning. See Section 19.2.2.4 for buffing, polishing, and surface finishing requirements.
- 7.4.1.4. HVAC units shall be secured to the car structure using a safety hung arrangement so that the HVAC unit is safely retained to the car structure should there be a failure of one or more of the mounting fasteners.
- 7.4.1.5. The HVAC unit shall be furnished with at least four connection points for shop lifting hooks, subject to NYCT approval.
- 7.4.1.6. Where practical and approved by NYCT, the HVAC unit and its sub-components shall be modularized to allow ease of removal and installation during repair and overhaul.
- 7.4.1.7. The evaporator and condenser coils shall be constructed from copper tubing and aluminum fins.
- 7.4.1.8. All components used in the refrigeration system, including seals, shall be compatible with the lubricants recommended by the refrigerant compressor manufacturer.
- 7.4.1.9. A pressure relief device, in accordance with Paragraph 33 of UL 1995, shall be installed to protect the refrigeration system against explosion or damage from excessively high pressures.
- 7.4.1.10. The refrigerant piping installation, tubing, and brazing materials shall meet the requirements of Section 19, Materials, Workmanship and Processes. All tubing shall be installed in a manner that prevents metal-to-metal rubbing caused by vibration.
- 7.4.1.11. Schrader-type access valves shall be installed in the high and low pressure refrigerant circuits, and shall be used to mount the high and low pressure transducers and switches.
- 7.4.1.12. The evaporator and condenser blower motors, refrigerant compressor motors, and overhead heater frames shall be grounded to the HVAC unit frame. The HVAC unit frame shall be grounded to the carbody structure in compliance with Section 19.25.7.
- 7.4.1.13. With the exception of grounding straps, the electrical connections between the HVAC units and the car, between subcomponents within the HVAC units, and between the HVAC unit and any associated external components shall be by means of quick disconnects in accordance with Section 19.25.5.
- 7.4.1.14. The HVAC unit shall be identified with nameplates in accordance with Section 15.14.
- 7.4.1.15. HVAC unit serial numbers shall be displayed in several places on the HVAC unit as approved by NYCT.

Evaporator Section Details

- 7.4.1.16. The evaporator coil assembly shall be housed in a rigid stainless steel frame.
- 7.4.1.17. Tube support sheets shall be constructed from stainless steel with die formed support collars for each tube. Support collars shall be free of burrs to prevent sharp edge contact with evaporator coil tubes.
- 7.4.1.18. The evaporator coil shall utilize copper tubes of sufficient wall thickness to withstand the maximum design pressure in accordance with ASME B31.5.
- 7.4.1.19. The evaporator coil shall use aluminum fins of 0.008 inch (0.20 mm) minimum thickness with a minimum fin spacing of 0.1 inch (2.54 mm).
- 7.4.1.20. Aluminum fins shall be coated to avoid potential corrosion.

- 7.4.1.21. Copper tubes shall be expanded to positively retain the fins in position and to provide maximum heat transfer.
- 7.4.1.22. The HVAC unit design shall exclude air by-pass through the drain pan and around the evaporator coil.
- 7.4.1.23. A liquid line solenoid valve shall be provided for the evaporator coil. The solenoid valve shall be of a compact design with pilot-operated disc construction.
- 7.4.1.24. A non-adjustable thermal expansion valve (TXV) shall be provided for each evaporator coil circuit. It shall have an external equalizer and replaceable working parts.
- 7.4.1.25. The TXV diaphragms shall be flat (not corrugated), stainless steel.
- 7.4.1.26. The TXV superheat shall be set at the compressor manufacturer's recommended setting and shall not vary more than 20°F (more than 11.1°C) from the design settings throughout the entire air conditioning operating range.
- 7.4.1.27. Capillary tube evaporator feeding devices will be considered, subject to NYCT approval, if it can be demonstrated that the system can operate continuously at any point in the specified operating range without damage or detriment to the HVAC unit.

Condenser Section Details

- 7.4.1.28. The condenser coil(s) shall be housed in a stainless steel frame with suitable fan shrouding and protective screening.
- 7.4.1.29. The condenser coil shall have copper tubes and aluminum fins, with minimum nominal fin thickness of 0.008 inches (0.20 mm). The minimum fin spacing shall be 0.1 inch (2.54 mm).
- 7.4.1.30. The tubes shall be expanded to positively retain the fins in position.
- 7.4.1.31. Tube support sheets shall be constructed from stainless steel with die formed support collars for each tube. Support collars shall be free of burrs to prevent sharp edge contact with condenser coil tubes.
- 7.4.1.32. The condenser coil shall utilize copper tubes of sufficient wall thickness to withstand the maximum design pressure in accordance with ASME B31.5.
- 7.4.1.33. A filter-drier assembly shall be provided in the liquid line. The filter-drier water capacity, refrigerant flow, filtering area, and acid removal ratings shall comply with ARI Standard 710.
- 7.4.1.34. Discharge line and suction line vibration eliminators shall be provided to minimize transmission of noise and vibration along the rigid piping, unless deemed unnecessary by NYCT.
- 7.4.1.35. The vibration eliminators shall be provided with an elastomeric covering over the flexible bronze wire braid to provide resistance to abrasion and to prevent condensation from freezing between the ferrules.
- 7.4.1.36. Each vibration eliminator shall consist of two straight sections joined by a rigid 90 degree bend, or other arrangement approved by NYCT, to provide equally effective isolation in all directions.

Electrical Control Compartment Details

- 7.4.1.37. An electrical compartment shall be provided and shall be an integral part of the HVAC unit. It shall be accessible for HVAC unit servicing through the return air grille.
- 7.4.1.38. The control compartment shall contain low and high pressure cutoff switches, low and high pressure transducers, any necessary relays and contactors, and the HVAC Controller and PTE connector if not remotely located.

- 7.4.1.39. All pressure switches shall be service proven and non-adjustable.
- 7.4.1.40. Pressure switch set-point tolerance shall not exceed ± 10 psig (68.9 kPa) for the discharge sensing pressure switch and ± 3 psig (20.7 kPa) for the low-pressure switch.
- 7.4.1.41. All pressure switches and transducers shall be replaceable and shall be provided with pulsation snubbers as required.

7.4.2. Heating

- 7.4.2.1. The overhead heater elements shall be mounted in a stainless steel frame.
- 7.4.2.2. In addition to the loss of evaporator blower air flow protection provided by the device described in Section 7.3.5.28, the following overhead heater over-temperature backup protection shall be provided:
 - a) An automatic resetting thermostat shall be installed on or adjacent to the heater assembly.
 - b) Upon detection of over temperature, the thermostat shall directly open the overhead heat control circuit before permanent damage to the HVAC unit or carbody occurs.
 - c) The thermostat location and setting shall be chosen to prevent temperatures that may cause nuisance activation of the next level of protection described below.
 - d) A second automatic resetting thermostat shall be installed on or adjacent to the heater unit.
 - e) Upon detection of over temperature, the thermostat shall directly activate a shunt trip (relay trip) overhead heat circuit breaker.
 - f) The thermostat location and setting shall be chosen to prevent temperatures that may cause unsafe conditions in the car.

Note: *Temperature overshoot on simultaneous shut down of the evaporator blower and overhead heater shall not cause nuisance actuation of the shunt trip overhead heat circuit breaker.*

- 7.4.2.3. The electric floor heater strips, if used, shall consist of a single nickel-chromium resistance wire embedded in a baked compressed refractory material sealed in a rust-resistant high heat transfer steel sheath. Alternate materials may be proposed for NYCT approval.
- 7.4.2.4. Heater elements shall be mounted on insulators at the carbody, not to the heater guard.
- 7.4.2.5. The heater strip mounting arrangement shall take into account the thermal expansion and contraction of the heater strip, and shall provide electrical insulation between the heater strip sheath and the mounting bracket.
- 7.4.2.6. Cab heaters shall be provided on each side of the cab compartment. One heater shall be located under the left hand side window and the other under the Train Operator's seat.

7.4.3. Ventilation

- 7.4.3.1. An evaporator motor-blower assembly shall be supplied as part of each unit. The blower shall push or draw air through the evaporator coil and overhead heater assembly, and into the supply air ducts, where it shall be discharged into the passenger and cab areas.
- 7.4.3.2. Fresh air shall be drawn into each HVAC unit through screened weather protected openings on the HVAC unit. The air shall be filtered and then delivered to a mixing plenum integral to the HVAC unit where it shall mix with the return air, be filtered, and delivered to the main supply air discharge.
- 7.4.3.3. The fresh air intake design shall include stainless steel water eliminators to preclude wind driven rain or snow from accumulating and entering the car interior under all conditions, including car

washing. The fresh air filter shall not be considered a component of the moisture exclusion design. Alternate eliminator materials may be proposed for NYCT approval.

- 7.4.3.4. The fresh air and mixed air filters shall be disposable, 2 inch (50.8-mm) thick, pleated media filters with a cardboard frame. They shall be commercial standard sizes available from at least two suppliers.
- 7.4.3.5. Alternatively, the fresh and return air may be filtered if the mixed air plenum design precludes the entrance of foreign matter into the evaporator compartment and main air ducts.
- 7.4.3.6. The top and sides of the main air distribution ducts shall be constructed of stainless steel or aluminum. Alternate materials may be proposed for NYCT approval.
- 7.4.3.7. The top and sides of the main air distribution ducts shall be thermally and acoustically insulated. Insulation shall be in accordance with Sections 7.2.4.2 and 7.2.4.3, and shall be mounted on the outside of the duct.
- 7.4.3.8. The interiors of the distribution ducts shall be treated to be non-sticky and resistant to the adhesion of dust and dirt.
- 7.4.3.9. The bottom of the duct shall be similarly constructed or the ceiling panels may serve as the duct bottom. In either case, the insulating value shall be sufficient to prevent the formation of condensation.
- 7.4.3.10. All exposed surfaces of ceiling mounted diffusers and grilles shall be finished to match the adjacent ceiling panels.
- 7.4.3.11. The cab shall be provided with conditioned air supply diffusers in the ceiling on each side of the cab.
- 7.4.3.12. The diffusers must be capable of completely restricting air flow without creating noise that exceeds the requirements of Section 2.9.2. See Section 5.7.4.1.
- 7.4.3.13. The air supply diffusers design shall prevent items such as cigarette filters and lit matches from being forced into the delivery duct.
- 7.4.3.14. To allow the return of cab air to the passenger area return air intake, the cab door shall be provided with a grille as specified in Section 15.4.6.11. The grille design shall prevent items such as cigarette butts and lit matches from being forced into the operating cab.

7.4.4. Controls

- 7.4.4.1. The temperature sensors shall be encapsulated in corrosion resistant metal tubes and positioned to prevent undue influence by nearby energy sources or stratified air flow.
- 7.4.4.2. Separate power switching devices and circuit breakers shall be provided for the cab heat, each stage of floor heat, and for the protective heaters.
- 7.4.4.3. A separate sensor mounted in a protected, but accessible, location shall be used to control the interior temperature in layover mode. The location shall be chosen to thermally represent the average car temperature when operating in the layover mode.
- 7.4.4.4. The sensor shall control the cab and passenger compartment floor heat through the same static temperature controller and contactors used for normal heating system operation.
- 7.4.4.5. The control of cab heaters (OFF-LOW-HIGH) shall be provided on MDS TOD Operating Screen. See Section 5.4.3.2.
- 7.4.4.6. The HVAC Controller shall be packaged in a single, metal enclosure and shall be protected from damage during removal and installation of the unit.

- 7.4.4.7. Any required heat dissipation from the HVAC Controller shall be accomplished by convection cooling. Cooling fins shall be arranged to avoid the collection of dirt.
- 7.4.4.8. The HVAC Controller enclosure shall be arranged for removal and replacement with no more than four captive fasteners. A method of securing the unit during installation or removal shall be submitted for NYCT review and approval.

7.5. Maintainability Requirements

- 7.5.1. The overhaul interval of the HVAC system, including all elastomers, shall be a minimum of two SMS cycles (14 years), under the normal operating conditions defined in this section.
- 7.5.2. The HVAC equipment design and installation shall provide full accessibility for maintenance, troubleshooting, and repair without interference with other systems.
- 7.5.3. All serviceable components shall be accessible through the ceiling-mounted and hinged return air grilles or from the car roof through hinged access panels or covers meeting the requirements of Section 15.15.
- 7.5.4. The condenser coil housing shall be designed to facilitate the cleaning of the coil.
- 7.5.5. Motors and blowers shall be easily removable for repair, cleaning, or replacement, either individually or as an assembly.
- 7.5.6. Routine blower assembly inspection shall be as described in the HVAC Work Manual.
- 7.5.7. Access to the overhead heater units shall be through a panel on top of the HVAC unit.
- 7.5.8. Fresh and mixed air filters shall be readily accessible from inside the car through the return air opening.
- 7.5.9. Fresh and mixed air filters shall provide at least 60 days of normal operation between required filter changes.
- 7.5.10. Equipment located within the interior of the HVAC unit, including access covers for component assemblies, shall be accessible by opening the hinged interior ceiling panels or by opening the return air grille.
- 7.5.11. All access panels and hinged covers shall be designed to be easily handled by one person.
- 7.5.12. The size, weight, and stiffness of panels and covers shall be approved by NYCT.
- 7.5.13. Each HVAC unit shall be provided with a main power disconnect switch to allow the HVAC unit to be serviced and maintained. The disconnecting device shall be readily accessible through the hinged return air grille.
- 7.5.14. HVAC PTE software, in accordance with Sections 22.8 and 18 for PTE hardware details and software requirements respectively, shall be provided by the HVAC unit manufacturer and shall, as a minimum:
 - a) Monitor and store system temperatures and pressures, power supply voltages, evaporator blower motor current, and the actuation of pressure switches, contactors, and overhead heat protection thermostats.
 - b) Be capable, for testing purposes, of overriding temperature and pressure levels inputted to the HVAC Controller.
 - c) Download HVAC system faults.

- 7.5.15. Inverter PTE software shall be provided in accordance with Sections 22.8 and 18 for PTE hardware details and software requirements respectively. Inverter PTE functions may be integrated into the HVAC PTE by the HVAC unit manufacturer.
- 7.5.16. Bench Test Equipment (BTE) shall be provided for the HVAC Controller, the HVAC unit inverters, and all other electronic components that are part of the HVAC system. See Sections 22.8 and 18, Software Systems, respectively, for BTE hardware and software details.
- 7.5.17. An HVAC unit testing frame shall be provided that shall provide a safe platform to mount the HVAC unit for troubleshooting and testing, as well as providing a convenient hook up to power supplies and the connections to a PTE or BTE to aid in troubleshooting.
- 7.5.18. Cleaning and servicing of the fresh air intake water eliminators shall not be required more often than once a year, to prevent reduction of HVAC performance below specified levels.
- 7.5.19. All motors and blowers shall be accessible for routine inspection and maintenance.
- 7.5.20. Evaporator motor-shaft-to-blower-shaft connections shall be bolted flanges, unless it can be demonstrated to NYCT's satisfaction that motors and blowers can be easily maintained, removed, and replaced individually or as an assembly using an alternate arrangement.
- 7.5.21. To facilitate removal of the condenser fan from the motor, the condenser fan motor shaft shall be made of a corrosion-resistant material or shall be treated to prevent corrosion and seizing of the fan hub on the shaft.
- 7.5.22. It shall be possible to remove and replace a refrigerant compressor without disturbing wiring other than wires directly connected to the refrigerant compressor.
- 7.5.23. The refrigerant compressor shall not be considered a line replaceable unit (LRU) for repair and maintenance. However, it shall be bar coded per Section 22.6.2 and shall include quick disconnects for all wiring.
- 7.5.24. Motor bearing lubricant shall provide a minimum of two SMS cycles (14 years) of service before scheduled bearing replacement.
- 7.5.25. The rubber kazoos installed at the end of the condensate drain line under the car shall be subject to periodic replacement (1 to 2 years) and the components readily available from multiple sources. Rubber kazoos shall be assigned a unique part number, have a defined replacement cycle, and be included as a separate item in the Illustrated Parts Catalog.
- 7.5.26. To simplify troubleshooting and minimize inventory, all passenger area floor heater strips and individual overhead heater strips shall be of one size and electrical rating, unless otherwise approved by NYCT.
- 7.5.27. The floor and overhead heater elements shall not corrode or change in conductivity during the design life of the car.
- 7.5.28. Individual floor and overhead heater elements shall be easily accessible for testing and replacement.
- 7.5.29. The HVAC unit frame and cover shall be designed to provide a walkway approximately 12 inches (305 mm) wide along the longitudinal centerline of the cover, as well as a walkway approximately 4 inches (100 mm) wide around the condenser fan opening.
- 7.5.30. The walkways shall be clearly indicated as walkways.
- 7.5.31. The walkways shall have a permanent non-slip surface.
- 7.5.32. The walkways shall support the load imposed by maintenance personnel carrying tools and equipment while working on the roof, consisting of three concentrated loads of 250 lb. (1,112 N) with a footprint of 6 square inches (3871 mm²) spaced 30 inches (762 mm) apart.

7.5.33. The screen over the HVAC condenser shall have a "NO STEP" warning.

7.6. Validation Requirements

7.6.1. Documentation Requirements

7.6.1.1. For HVAC system design approval, the following data shall be submitted: [CDRL]

- a) An engineering evaluation to show that performance requirements of this Specification can be met. This shall include a detailed technical proposal that provides a one-to-one comparison of the proposed arrangement and materials demonstrating compliance with the requirements of this Specification.
- b) Performance analysis that includes a cooling load analysis, a heating load analysis, and an analysis of air flow requirements when operating at design conditions.
- c) A predicted refrigerant compressor life analysis that shall be based on typical NYCT environmental and service conditions.
- d) The maximum allowable floor heater grille temperature shall be approved by NYCT, based on an analysis performed by the Contractor following the principles of ASTM C1055-03 and C1057-12. However, in no case shall the "Contact Skin Temperature" exceed Threshold B as shown in Figure 1 of ASTM C1055.
- e) Failure rate and maintenance intervals of the proposed HVAC system and individual components operating under environmental and design conditions given in this Specification.
- f) Service history of the proposed components used on other rail applications and identifying the application, time in revenue service, actual average time of the HVAC system operation, failure rate, mileage, and preventive maintenance requirements and interval.
- g) A complete list of the HVAC system components.
- h) Drawings of the proposed system showing all components, maintenance points, and access for maintenance.
- i) A list of all special tools including preliminary descriptions of the PTE and BTE functions to be provided. See Sections 7.5.14 and 7.5.16.
- j) Recommended list of spare parts required for routine maintenance and repairs.

7.6.1.2. Design details of the HVAC unit shall be submitted to NYCT prior to manufacturing any equipment. The required drawings and at least the following additional information, if not shown on the drawings, shall be submitted: [CDRL]

- a) Evaporator coil design criteria including:
 - i. Entering and leaving wet and dry bulb conditions at design conditions.
 - ii. Wet and dry coil pressure drops at the specified air flow rate.
 - iii. Coil circuiting.
 - iv. Number of rows and fin spacing.
- b) Make and model number of the refrigerant compressor.
- c) Refrigerant compressor capacity curves.
- d) Cooling system capacity and coefficient of performance data under nominal and extreme conditions.

- e) Condenser coil design
 - i. Coil selection curves or computer analysis illustrating air-to-refrigerant temperature differential.
 - ii. Degrees of sub-cooling.
 - iii. Pressure drop at the design conditions;
- f) Motor current, horsepower, speed/torque curves, and efficiency.
- g) Pressures and temperatures.
- h) Design saturated suction and discharge temperatures at full load activation pressures and differentials for all pressure-activated devices.
- i) Refrigerant tubing processing/cleaning procedure.
- j) Refrigerant circuit evacuation, charging, and test procedures.
- k) Electrical and control arrangement schematics.
- l) Wiring diagrams showing wire sizes and the resistance value of each resistive device.
- m) HVAC Controller arrangement.
- n) Complete descriptions of the PTE and BTE functions being provided. See Sections 7.5.14 and 7.5.16.
- o) Inverter arrangement.
- p) Refrigerant system piping diagram showing all components and pipe sizes.
- q) Refrigerant compressor vibration mount design.
- r) Evaporator blowers wheels and housing:
 - i. Type.
 - ii. Dimensions.
 - iii. Model Numbers and manufacturer.
 - iv. Head and power flow curves.
 - v. Maximum allowable blower wheel speed.
 - vi. Nominal blower motor speed.
- s) Balancing criteria for the wheels and fan-motor assembly.
- t) Predicted exterior noise levels of the HVAC unit.

7.7. Testing Requirements

7.7.1. General

Ventilation System Prototype Test

- 7.7.1.1. Prior to final acceptance of the HVAC system design, the Contractor shall construct and test a full scale and functional prototype or mockup of the ventilation system. [CDRL]
- 7.7.1.2. The mockup shall represent the ventilation system of an entire car including the HVAC unit mixing plenum and the evaporator blower assembly.
- 7.7.1.3. A test plan and procedure for the ventilation test shall be submitted for NYCT approval.

- 7.7.1.4. The tests shall verify that the ventilation system design meets the ventilation requirements.
- 7.7.1.5. As a minimum, the following information shall be recorded during the prototype ventilation system testing:
- a) Variable speed evaporator blower assembly design minimum and maximum air volumes.
 - b) Evaporator blower motor speeds.
 - c) Evaporator blower total static pressures.
 - d) Nominal electrical power requirements of the evaporator blower motor.
 - e) Evaporator blower motor current at clogged filter conditions.
 - f) Main duct static pressure.
 - g) Main duct air velocity.
 - h) Linear slot diffuser discharge velocity and mixing capability as specified in Sections 7.2.4.8, 7.2.4.9, and 7.2.4.10;
 - i) Ability of the fresh air intake system to prevent the entrance of moisture into the mixing plenum. (*Note: The worst case rain and snow condition at the air inlets may be simulated by a separate test.*)
 - j) Preliminary air baffling requirements necessary to balance the specified ratios of fresh and return air.
 - k) Accessibility of the fresh air and mixed air filters.
 - l) Absence of potential problems such as excessive noise, pure tones, air turbulence, and evaporator blower output instability.
- 7.7.1.6. Any changes and adjustments made necessary during the prototype testing shall be documented and approved by NYCT and incorporated in the final design drawings.

Other Testing Requirements

- 7.7.1.7. All pressure vessels and pressure relief devices shall conform to UL 207 and UL 1995 Standards and be tested as required by ANSI/ASHRAE Standard 15. Test reports shall be made available from the vessel manufacturer for each pressure vessel and each pressure vessel shall be marked accordingly.
- 7.7.1.8. The refrigerant compressor shall be pressure tested in accordance with the refrigerant compressor manufacturer's recommendations.
- 7.7.1.9. For refrigeration system pressure data collection purposes during the HVAC unit manufacturer's qualification testing and the Contractor's climate room testing, Schrader-type pressure tap fittings shall be provided at each suction header and at the liquid lines leading to each evaporator circuit. Both HVAC units on the climate room test car shall be so equipped.
- 7.7.1.10. The designated car climate room test HVAC units shall be pre-instrumented in accordance with Section 24.6.5.
- 7.7.1.11. HVAC system components to be used for testing shall be production items. They shall be manufactured according to the latest revision of manufacturing documentation and shall have been subjected to all prescribed quality control procedures. Deviations from these requirements shall be subject to approval by NYCT.
- 7.7.1.12. Components used for testing shall be clearly identified as test components, and disposed of in accordance with the directions of NYCT at the completion of testing.

7.7.2. HVAC Unit Qualification Testing

- 7.7.2.1. An HVAC Unit Qualification Test Plan and Procedure and Qualification Test Report shall be submitted for NYCT approval.
- 7.7.2.2. Before the car climate room testing defined in Sections 24.6.5 to 24.6.7 is performed, a production, or NYCT-approved prototype HVAC unit shall undergo qualification and dual-chamber capacity testing conducted by the HVAC unit manufacturer or an accredited laboratory. The purpose of the testing is to verify that the cooling and heating capacity and the functioning of the ventilation, refrigeration, and heating equipment conform to the approved design criteria.
- 7.7.2.3. Prior to, or as part of, the HVAC unit manufacturer's qualification testing described in this Section, two motors of each type randomly selected by NYCT shall be given a type test as required by Section 24.4.4.
- 7.7.2.4. The evaporator and condenser air flow and refrigeration capacity portions of the HVAC unit shall be tested according to ANSI/ASHRAE Standard 37, "Methods of Testing for Rating Unitary Air Conditioning and Heat Pump Equipment". The Group A, Indoor Air Enthalpy, method shall be used as the primary test method. In addition, the HVAC unit manufacturer shall select a secondary test method from Group B shown in Table 3 of the Standard.
- 7.7.2.5. Data recordings shall be conducted according to ASHRAE Standard 37, "Methods of Testing for Rating Unitary Air Conditioning and Heat Pump Equipment".

Additional HVAC Unit Qualification Testing Requirements

- 7.7.2.6. The qualification test compressor shall be provided with one oil level sight glass. Because the design may require the compressors to cycle on and off frequently when load conditions are below the capacity reduction limits of the compressor, its design must address these harsh conditions with particular attention to the lubrication system and the compressor motor and its associated starting equipment.
- 7.7.2.7. The refrigerant charge shall be determined as part of the HVAC unit qualification test. The refrigerant charge weight established at the test shall be shown on all HVAC unit nameplates.
- 7.7.2.8. Proof of all instrument calibrations shall be traceable to a master at the national standards organization of the applicable country and shall be available at the testing site at the time of testing. See Section 24.3.6 for details on test instrument calibration.
- 7.7.2.9. Testing shall be done at nominal supply and control voltage levels.
- 7.7.2.10. A condensate carry over test shall be conducted with an ambient evaporator entering air temperature at 80 °F^(DB) (26.7 °C^(DB)) 75 °F^(WB) (23.9 °C^(WB)). The unit shall be operated continuously for a period of four hours at the specified conditions. During the test, no condensate shall drip, run, or blow off the HVAC unit's casing.
- 7.7.2.11. An HVAC unit functional test shall be performed with the HVAC unit operating continuously for one hour at maximum design conditions.
- 7.7.2.12. The HVAC unit shall operate without shutting down because of high pressure cutout, a circuit breaker trip, a refrigerant compressor motor overload cutout, or the failure of any HVAC unit devices. A shutdown for any reason while operating at these conditions shall constitute a failure of the test.
- 7.7.2.13. At the end of one hour of operation, the HVAC unit shall be momentarily (less than three seconds) stopped and then restarted. The HVAC unit shall successfully restart and continue to function normally. This test shall be repeated at both the low and high power voltage levels.

- 7.7.2.14. A low temperature operation test shall be conducted at air temperatures entering evaporator coil based on the mixture of return air at 70 °F^(DB) (21.1 °C^(DB)) and 55 percent relative humidity and fresh air at 2°F (1°C) higher than the compressor lock-out temperature setpoint. The HVAC unit shall be operated continuously for a period of four hours. During the test period, the equipment shall operate without damage to itself and without the formation of ice or frost on the evaporator coil or piping.
- 7.7.2.15. Operation of the evaporator blower air flow detection device described in Section 7.3.5.28 shall be demonstrated.
- 7.7.2.16. The overhead heating system and protection controls shall be tested to verify that the heating capacity meets the approved design criteria and that the over temperature protection devices perform in accordance with the requirements of Section 7.4.2.2.
- 7.7.2.17. The HVAC unit shall be water tested and shall meet the watertightness requirements of Section 24.6.2.
- 7.7.2.18. Noise and vibrations levels of the operating HVAC unit shall be measured to assure conformance with the requirements of Section 2.9 and the recommendations of AMCA Bulletin No. 300.

7.7.3. HVAC Controller Qualification Testing

- 7.7.3.1. An HVAC Controller Qualification Test Plan and Qualification Test Report shall be submitted for NYCT approval.
- 7.7.3.2. Two production HVAC Controllers shall be subjected to a qualification test to demonstrate acceptable performance over the specified environmental temperature range given in Section 7.2.1.2 a) and the control power input voltage range defined in Section 2.5.
- 7.7.3.3. Using variable resistance devices and loop-current or voltage generators to simulate inputs from the temperature sensors and pressure transducers, the temperature and pressure switch points of the temperature control system matrix shall be verified. Switches shall be used to simulate the high and low pressure and overhead heat over temperature protection switches.
- 7.7.3.4. The HVAC system PTE shall be used to monitor sensor input values and output responses.
- 7.7.3.5. Cooling, heating, control, and power faults shall be simulated and the function of the LED fault indicators described in Section 7.3.5.16 shall be verified.
- 7.7.3.6. Communication between the HVAC Controllers shall be demonstrated and verified. The HVAC Controller master/slave interaction under failure conditions shall be demonstrated and verified. See Section 7.3.5.11.
- 7.7.3.7. Communication between the HVAC Controllers and the MDS shall be demonstrated and verified. The HVAC Controller's interaction to MDS polling and responding with status and event information synchronized to vehicle time shall be demonstrated and verified. See Section 17.4.1.

7.7.4. HVAC Inverter Qualification Testing

- 7.7.4.1. Each HVAC unit inverter type (FVFF, VVVF, etc.) shall undergo comprehensive qualification testing as required by Section 9.6.4.
- 7.7.4.2. A test plan and procedure shall be submitted for NYCT approval.
- 7.7.4.3. For each inverter type, testing shall be performed on the first production unit and one additional production unit selected at random by NYCT.
- 7.7.4.4. These tests shall include all aspects of the following under the environmental ranges in Appendix A (Fixed Facilities Description) and supply voltage variations given in Section 2.5:

- a) All output and control requirements.
- b) Performance and capacity requirements.
- c) Fault detection and annunciation requirements utilizing the inverter PTE.
- d) Insulation, isolation, and transient rejection requirements.
- e) Heat runs designed to test the inverter for the worst case heat loadings for the maximum rated output current at the lowest operational input voltage and for the lightest expected load at the highest input voltage.
- f) Shock and vibration requirements.

7.7.5. HVAC Unit Manufacturer's Production Testing

- 7.7.5.1. An HVAC unit production test procedure shall be submitted for NYCT approval.
- 7.7.5.2. Each evaporator motor-blower assembly and condenser motor-fan assembly shall be balanced in two correction planes as defined in ANSI/AMCA 204. The residual unbalance shall limit the motor-blower/fan assembly vibration to not more than 0.001 inch (0.025 mm) peak-to-peak displacement in any direction at the motor end bells when the assemblies are mounted in the HVAC unit.
- 7.7.5.3. All components in the refrigerant circuit shall be factory tested to at least 1.5 times the design working pressure for which it is rated.
- 7.7.5.4. As part of the refrigeration system manufacturing and processing procedure, the HVAC unit manufacturer shall, with a refrigeration vacuum pump, evacuate and dehydrate the refrigeration system to a vacuum of 50 microns or less. When 50 microns is reached, the vacuum pump shall be isolated from the refrigeration system and the vacuum monitored. In the following two hours, the refrigeration system vacuum shall not rise above 300 microns.
- 7.7.5.5. Six HVAC units shall be selected from the first production run and subjected to the burn-in test described in Section 7.7.5.10. Upon test completion, the filter-drier shall be removed and be visually inspected for signs of excessive contamination. If the results from the first six units are satisfactory, filter-drier replacement will be deemed unnecessary for the remainder of production HVAC units. However, the filter-drier must be replaced on all units that do not pass the refrigerant sample test described below.
- 7.7.5.6. To verify an acceptable level of system cleanliness and the adequacy of the refrigerant evacuation and system dehydration, refrigerant and oil samples shall be taken from the first six HVAC units of the first run and analyzed by an independent laboratory in accordance with Air Conditioning and Refrigeration Institute (ARI) Standard 700.
- 7.7.5.7. With the exception of the high boiling point residue test result requirement, the cleanliness test results shall comply with the requirements of the ARI Standard 700. However, the high boiling point residue tests shall be conducted to detect the presence of inorganic acids.
- 7.7.5.8. If the test results from the first six units are acceptable, a sampling plan of one unit in six shall be employed thereafter.
- 7.7.5.9. If any of the first six units' cleanliness test results are not acceptable, the HVAC unit manufacturer shall revise the relevant manufacturing procedures and the affected units shall be purged, re-cleaned, and re-sampled. A second group of six HVAC units shall then be chosen and the refrigerant and oil analysis cycle repeated.

- 7.7.5.10. All HVAC production units shall be placed in a test cell and a heat load shall be applied to both the evaporator and condenser coils. The unit shall be operated at least 5 hours with a filter drier in place without experiencing any malfunctions.
- 7.7.5.11. Each HVAC unit shall undergo insulation resistance and high potential testing in accordance with Section 24.8.3 and the results recorded on the HVAC unit production test data sheet.
- 7.7.5.12. The HVAC unit shall be given a complete functional test to demonstrate, as a minimum, the refrigerant compressor variable speed feature, functioning of the variable evaporator air flow system, proper outputs from temperature and refrigerant pressure sensors, trip and reset values of the high and low pressure switches, and proper actuation of the overhead heat over temperature thermostats.
- 7.7.5.13. The power consumption of all motors and the electric heater, evaporator and condenser fan motor speeds, system pressures and temperatures, and heat loads applied to the evaporator and condenser coils shall be recorded on an HVAC unit production test data sheet that shall be made a part of the Car History book.
- 7.7.5.14. Each HVAC unit inverter shall be given a routine test by the manufacturer in accordance with IEC 61287 to verify compliance with all aspects of the following for the nominal power input conditions defined in Section 2.5:
 - a) All output and control requirements.
 - b) Performance requirements.
 - c) Fault detection and annunciation requirements.
 - d) Insulation and isolation requirements. Insulation shall be tested as required in Section 24.8.3.
- 7.7.5.15. Each AC HVAC unit motor shall be given a "routine" test by the manufacturer in accordance with IEC Publication 349 IEEE Std. 11-2000.

7.8. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
7-01	7.6.1.1	HVAC system design and performance analyses	PDR
7-02	7.6.1.2	HVAC system design details	CDR
7-03	7.7.1.1	Full scale and functional prototype or mockup of the ventilation system	CDR*

* - This test may be performed on the car mockup if appropriate.

Section 8

Lighting Systems

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8. Lighting System

8.1. Introduction and General Requirements

- 8.1.1.1. This section defines the requirements for interior (including console and indication lights), exterior (including headlights and taillights), and emergency lighting on the cars. The requirements are divided into Performance, Functional, Design, Maintainability, and Validation categories.
- 8.1.1.2. Lighting for all applications shall be of a technology which consumes low levels of energy, and has a long useful life, such as Light Emitting Diode (LED) or NYCT approved equivalent. Fluorescent lighting systems are prohibited.
- 8.1.1.3. Except where specified, the design of the lighting system shall be guided by APTA PR-E-RP-12-99 "Recommended Practice for Normal Lighting System Design for Passenger Cars," and shall comply with 49 CFR Part 38 "Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation vehicles".

8.2. Performance Requirements

8.2.1. Interior Lighting Levels

- 8.2.1.1. The average illumination intensity within the vehicle, under normal service conditions and nominal voltage of the Low Voltage Distribution Network, shall be as defined in Table 8-1.
- 8.2.1.2. The Contractor shall, as an option, propose a method such that the intensity of the main lighting can be automatically and smoothly controlled to save energy whenever the ambient window light provides an adequate proportion of the light intensity, as defined in Table 8-1.
- 8.2.1.3. The average lighting levels throughout the vehicle shall be as stated in Table 8-1. To avoid overly bright or dark areas, the lighting intensity at any point shall be not greater than 200%, or less than 50%, of the values defined in Table 8-1.

Table 8-1 – Interior Lighting Levels, Normal Conditions

Measurement Location	Height Above Floor	Light Intensity
45 degree plane centered on front edge of any seat, any orientation	33 inches (0.838 m)	35 foot-candles (377 Lux)
45 degree plane for passengers standing anywhere within the aisles, any orientation	55 inches (1.397 m)	35 foot-candles (377 Lux)
Average intensity on floor in passenger aisles and doorway areas	0 inches (0 m)	20 foot-candles (215 Lux)
Train Operator’s console, with overhead and reading lights on	Operator’s console height	20 foot-candles (215 Lux)

- 8.2.1.4. The minimum average illumination intensity within the car, under emergency conditions during loss of primary power supply, shall be as defined in Table 8-2, and shall be available for the duration defined in Section 8.3.4. The Contractor shall ensure the emergency lighting intensity is sufficient to be compatible with the use of passenger area surveillance by the Closed Circuit Television (CCTV) cameras chosen for the R211 cars (See Section 13.9.2).

Table 8-2 – Interior Lighting Levels, Emergency Conditions

Measurement Location	Height Above Floor	Light Intensity
Average intensity on floor in passenger aisles and doorway areas	Floor level	1 foot-candle (10.8 Lux)
Train Operator’s console, with overhead and reading lights on	Operator’s console height	10 foot-candles (108 Lux)

8.2.1.5. Illumination levels, including cab indication lights, reading lights and their reflections shall be confirmed during design reviews, mock-ups, and First Article Inspections, with adjustments made as the design progresses.

8.2.2. Exterior Lighting Levels

8.2.2.1. The headlight intensity shall be sufficient to permit the visibility of a 50th percentile male (as defined in “The Measure of Man and Woman: Human Factors in Design, Revised Edition”, Wiley, 2010) standing 800 feet (244 m) in front of the coupler face.

8.2.2.2. Taillights shall emit a red light plainly visible in clear, sunlit conditions, from a distance of 1,000 feet (305 m).

8.2.3. Service Life

8.2.3.1. All lamps and driver units shall be modular and have an average useful rated life in excess of 70,000 hours of operation, the anticipated scheduled maintenance period (see Appendix C-36 Generic Passenger Car Workscope: R142 thru R160). Head/taillights are exempted from the 70,000 hour requirement, and shall be subjected to NYCT’s approval.

8.2.3.2. Service life shall be considered ended when the lighting level has fallen to below 70% of the value when new. Predictions of service life for all lamps and driver units shall be included in the Critical Design Review (CDR) submittal for Lighting Systems.

8.2.3.3. The Contractor may propose a method to adjust lighting output to compensate for any reduction of intensity over time, subject to NYCT approval.

8.3. Functional Requirements

8.3.1. Interior Lighting

8.3.1.1. Interior lighting shall be uniform throughout the car, and neutral white in color, with a correlated color temperature between 3500°K and 4200°K, and with a Color Rendering Index (CRI) greater than 80%. Any color difference between individual light emitting elements shall not be perceptible.

8.3.1.2. The main passenger area interior lighting system shall be trainline-controlled from the Train Operator’s console in any active cab.

8.3.1.3. The interior lighting system shall be separated into three circuits. Emergency lights shall occupy one circuit. The remaining interior lights shall be evenly distributed into two circuits, which shall be subject to load shedding (see Section 9.4.19).

8.3.1.4. Separate circuit breakers shall be provided for each of the main interior lighting circuits in each car.

- 8.3.1.5. The overhead lights in the cab shall be controlled separately from those in the rest of the car, from the Operator's console, and shall function as follows:
- a) Illuminated when car emergency lights are on, except in the active cab with an active Master Controller where they shall be controlled from the Train Operator's console.
 - b) Provide "night-light" functionality in all cabs in the area adjacent to the cab end door. The night-light (providing security illumination) shall function if there is an active cab anywhere in the train, regardless of presence of third rail power. The illumination level of the night-light shall be a minimum average of 1 foot-candle (10.8 Lux) at floor level.
 - c) The "night-light" function shall remain active for at least 90 minutes after loss of third rail power.
- 8.3.1.6. Cab console reading lights shall be provided, separately illuminating each side console in the cab to the level defined in Table 8-1, and controlled, via a dimmer, from the console which they illuminate.
- 8.3.1.7. In the event of a short interruption in power supply, such as would be caused by a third rail gap, the main interior lights shall remain fully illuminated, without flickering, for at least 15 seconds.
- 8.3.1.8. No lamp or indication light in the cab shall result in a reflection on the cab windshield.

8.3.2. Exterior Lighting – Headlights and Taillights

- 8.3.2.1. A separate circuit breaker shall be provided for the headlights and for the taillights.
- 8.3.2.2. Headlights and taillights on coupled car ends shall not be illuminated.
- 8.3.2.3. Two bright white LED headlights shall be provided at each cab end, with beams set parallel to the longitudinal centerline of the car, with adjustment to permit them to be aimed to strike the running rail approximately 150 feet (45.7 m) from the front of the car.
- 8.3.2.4. If LED headlights cannot meet the requirements of Section 8.3.2.3, 60 watt, 38 volt, 60PAR/1 sealed beam headlights shall be supplied.
- 8.3.2.5. Headlights shall be illuminated at the leading end of the train whenever any cab in the train is active.
- 8.3.2.6. Headlights shall be backward compatible with those on existing fleets to the maximum degree possible, whether LED or sealed beam (see Sections 8.3.2.3 and 8.3.2.4).
- 8.3.2.7. Two red taillights with an integral LED cluster arrangement shall be provided and mounted at each cab end, above the headlights.
- 8.3.2.8. Taillights shall be illuminated at each end of a train at all times, except when headlights are active on that end.
- 8.3.2.9. Heating or other means shall be employed to prevent snow and ice accumulation from blocking the headlight beam.
- 8.3.2.10. Alternate designs may be proposed for NYCT review and approval.

8.3.3. Exterior Lighting - Guard Lights

- 8.3.3.1. Two red exterior Guard Lights shall be provided on the exterior and mounted on each side of the car, in a similar configuration to that used on the R160 or R179 fleets. Interior Guard Lights, Fault

- Lights, and Master Door Controller (MDC) indication lights are covered within Section 6 – Door System.
- 8.3.3.2. Each exterior Guard Light shall have two lenses, one facing to the front of the train and one to the rear so as to be visible by the train crew looking down the side of the train.
- 8.3.3.3. Exterior Guard Lights shall indicate the status of the doors on the associated car, as described in Section 6.4.19.

8.3.4. Emergency Lighting

- 8.3.4.1. The following lights shall remain illuminated for at least 90 minutes, with the car in any orientation, supplied by an independent source of power meeting the requirement of APTA RT-VIM-S-020-10 “Emergency Lighting System Design for Rail Transit Vehicles”, following a loss of main (car) battery power:
- a) Sufficient interior lights to maintain the lighting levels defined in Section 8.2.1.4.
 - b) Cab overhead lighting.
- 8.3.4.2. The control of the emergency lighting shall distinguish between a loss of power due to the failure of the supply system and normal car load shedding function.
- 8.3.4.3. The headlights and taillights shall remain illuminated for at least 90 minutes, supplied by the main car battery system, following a loss of third rail power.

8.3.5. Special Lighting Requirements

- 8.3.5.1. Door warning lighting strips shall be mounted on each side of each doorway, as shown in Appendix E-1.
- 8.3.5.2. The door warning light strips shall illuminate in green when the doors are enabled as described in Section 6.4.15.2, or upon notification of the “next side open” functionality described in Section 13.5.3, whichever occurs first.
- 8.3.5.3. The door warning light strips shall change from green to red upon receipt of the door CLOSE command described in Section 6.4.8.7, and shall remain illuminated in red until the adjacent doors are closed and locked.

8.4. Design Requirements

- 8.4.1.1. All lights shall be protected from tampering by their design, and direct contact by passengers with lighting elements shall not be possible.
- 8.4.1.2. If lenses are used to diffuse interior or exterior lighting, the lenses shall be made from a commercially available material, easy to clean, and shall be readily replaceable by maintenance personnel.
- 8.4.1.3. Light fixtures shall not rattle or resonate while the train is in service.
- 8.4.1.4. Exterior light fixtures, and interior fixtures below ceiling level, shall be waterproof, to the IP66 rating.
- 8.4.1.5. Electrical supply and grounding arrangements for all lighting elements shall be as defined in Section 9.4.
- 8.4.1.6. All materials shall meet the flammability and smoke emission requirements of Section 19.1.10.
- 8.4.1.7. Interior light fixtures in the ceiling shall be dust and moisture proof, IP6x rated, and shall prevent accumulation of dust inside the fixture.

- 8.4.1.8. All visible portions of interior fixtures (except lens and reflector) shall be powder-coated to match the color and finish of the adjacent ceiling panels.
- 8.4.1.9. General interior lighting shall avoid point sources of light, through the use of diffusers, indirect mounting or other proven means.
- 8.4.1.10. All materials used on the exterior lighting system, including fasteners, shall be corrosion resistant.
- 8.4.1.11. Cab lighting shall be arranged to avoid glare on windshields and side windows.

8.5. Maintainability Requirements

- 8.5.1.1. All lighting fixtures shall be designed to provide ease of maintenance, including, where applicable: cleaning of lenses; lens and/or lamp change-out; adjustments; and housing removal.
- 8.5.1.2. Light fixture covers shall be retained by corrosion resistant hinges. The use of safety chains may also be required per the direction of NYCT.
- 8.5.1.3. Lamp access shall be by gasketed enclosure covers secured by tamperproof stainless steel fasteners.
- 8.5.1.4. Any exposed fasteners used in the lighting system shall be tamperproof, of the same type as used on NYCT R160 or R179 fleets.
- 8.5.1.5. Where fasteners are used for covers needed for maintenance inside the car, the fasteners shall be of quick release, captive type.
- 8.5.1.6. Adjustment and replacement of exterior lights shall be from outside the car.
- 8.5.1.7. All line replaceable lighting modules / units shall be available from at least two sources.
- 8.5.1.8. The maintenance manual shall recommend a procedure, sample size and frequency for measuring and adjusting the lighting intensity, such that adequate preparations can be arranged for partial or full replacement when the lamps are approaching the end of their service life.
- 8.5.1.9. The failure rate of the lighting connectors shall be lower than the failure rate of the lamps themselves.

8.6. Validation Requirements

- 8.6.1.1. The following documentation shall be submitted as part of the design review process: **[CDRL]**
 - a) Technical descriptions and outline drawings of all lighting elements.
 - b) The System Functional Description (SFD) of the complete lighting system, detailing control logic, schematic and calculations to demonstrate how the performance requirements of this specification will be satisfied. The SFD shall include reliability predictions for the lighting system as well as maintenance requirements and Mean Time to Repair (MTTR).
 - c) A Failure Modes Effects and Criticality Analysis (FMECA) of the lighting system, considering internal and external conditions, and both normal and emergency operation.
- 8.6.1.2. The Contractor shall make available sample fixtures, lamps of the proposed color, and indicators with lenses during the design review period for NYCT approval. **[CDRL]**
- 8.6.1.3. Lighting intensity and lighting color shall be simulated on a mock-up for NYCT approval. The mock-up shall use the same arrangements, materials and dimensions proposed for the series car so that the effect of multiple light sources, their reflection and absorption can be realized and, if necessary, corrected. The mock-up defined in Section 20.6 may be used for this purpose.

- 8.6.1.4. The following tests shall be performed on the lighting system, with reports submitted to NYCT:
 - a) Component tests that shall demonstrate the ability of the lighting components to meet the EMC requirements in Section 2.11, and operate successfully within the operating environment described in Section 2.5.
 - b) Lighting system tests on a completed car that demonstrate compliance with the lighting performance and emergency lighting duration requirements of this section.
 - c) The actual and averaged lighting values shall be reported to NYCT for each type of car, to form baseline values for future measurements of lighting intensity degradation.

- 8.6.1.5. During the First Article Inspection (FAI) of the lighting system, the Contractor shall demonstrate, for each type of lamp:
 - a) That the maintainability requirements defined in Section 8.5 are met.
 - b) The actual Mean Time to Repair (MTTR).

8.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
8-01	8.6.1.1	Lighting system design package	PDR
8-02	8.6.1.2	Sample lamps and indicators of each type	CDR

Section 9

**Auxiliary Electrical Equipment and
Distribution**

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9. Auxiliary Electric Equipment and Distribution

9.1. Introduction and General Requirements

- 9.1.1 This section specifies the collection and distribution of electrical power. The requirements are categorized into Performance, Functional, Design, Maintainability, and Validation. Refer to the following sections for car systems and components interfacing with the auxiliary electrical systems and other applicable requirements:
- Design and Performance Criteria – Section 2.
 - Coupler Systems – Section 4.
 - Cab and Cab Controls – Section 5.
 - Doors – Section 6.
 - Heating, Ventilation and Air Conditioning – Section 7.
 - Lighting Systems – Section 8.
 - Propulsion System – Section 10.
 - Trucks and Secondary Suspension Systems – Section 11.
 - Friction Braking and Air Supply Systems – Section 12.
 - Communication System – Section 13.
 - Carbody Equipment and Interiors – Section 15.
 - Trainline and Car Control Architecture – Section 16.
 - Monitoring and Diagnostics – Section 17.
 - Software Systems – Section 18.
 - Materials, Processes, and Workmanship – Section 19.
 - Reliability, Maintainability, and System Assurance - Section 21.
 - System Support - Section 22.
 - Testing Program – Section 24.
- 9.1.2 The Contractor shall be responsible for proper systems integration and functioning of the auxiliary power system.
- 9.1.3 Auxiliary power conversion equipment shall be distributed within the Unit such that auxiliary power requirements are satisfied for all allowable Unit configurations defined in Section 2.2.1.
- 9.1.4 The following types of auxiliary power converters shall be provided:
- a) Three-phase auxiliary inverters, powered from the 600 Vdc supply. Inverters shall be dedicated to a single load unless otherwise approved by NYCT.
 - b) Single-phase auxiliary inverters, powered from the 600 Vdc supply. See Section 9.4.12.
 - c) Low Voltage Power Supplies (LVPS), powered directly from the 600 Vdc supply. The outputs of all Low Voltage Power Supplies within a Unit shall be bussed through all the cars of a Unit.
 - d) All auxiliary power apparatus shall use solid-state devices for all frequency and voltage conversion.
- 9.1.5 Storage batteries shall be provided to supply uninterrupted low voltage DC power in the absence of LVPS output.
- 9.1.6 Connections between cars shall be at a maximum nominal potential of 120 V.
- 9.1.7 The Contractor may propose alternate auxiliary power distribution schemes, including sharing of 3 phase power between cars, for NYCT approval. Such schemes shall maintain the performance and in particular reliability requirements of this Specification.

9.2. Performance Requirements

9.2.1. Current Collection

- 9.2.1.1. Contact shoes shall be suitable for operation at any speed up to the maximum vehicle speed as specified in Section 2.7.3.
- 9.2.1.2. The current collector fuse shall be capable of interrupting fault conditions encountered in service at voltages specified in Section 2.5.3.

9.2.2. Auxiliary Inverters

- 9.2.2.1. The Contractor shall coordinate the design of auxiliary inverters with their input supply characteristics, such that the inverters provide full rated performance over the third rail voltage range specified in Section 2.5.3, considering an output load power factor of 0.8.
- 9.2.2.2. The nominal output voltage for three-phase inverters shall be 230 volts, except as otherwise approved by NYCT.
 - a) Output shall be regulated using a constant volts per Hertz regulator.
 - b) The ratio of voltage to frequency shall be within ± 2 percent.
 - c) Steady state frequency shall be regulated to 60 Hz ± 5 percent.
 - d) On startup, frequency shall ramp from 0 to 60 Hz.
 - e) Output regulation shall be met over all variations in input voltage and output load.
 - f) Transient voltage drops when starting any individual ac motor or motor group shall not exceed 20 percent of the nominal voltage.
- 9.2.2.3. Inverter power outputs shall be suitably conditioned to produce an output voltage waveform that can be used by standard commercially available motors or electronic components, without any adverse impacts on reliability, temperature, lifespan, or maintenance requirements.

9.2.3. Low Voltage Power Supply

- 9.2.3.1. The LVPS shall receive its power from the 600 Vdc auxiliary distribution system.
- 9.2.3.2. The LVPS shall provide full performance for third rail voltages specified in Section 2.5.3.
- 9.2.3.3. For voltages below the minimum stated in Section 2.5.3, the LVPS shall be disabled.
- 9.2.3.4. The Contractor shall coordinate the proper relationship between the LVPS capability and the load requirements, including battery charging.
- 9.2.3.5. Output efficiency shall be greater than 80 percent at 10 percent of full rated load or above.
- 9.2.3.6. The output shall be transformer-isolated from the input.
- 9.2.3.7. The nominal output shall be set to 37.5 ± 0.2 Vdc.
- 9.2.3.8. The maximum allowable ripple shall be peak-to-peak voltage of 3 percent of nominal DC voltage.
- 9.2.3.9. Output voltage regulation shall be less than ± 1 percent, except that a load-dependent voltage variation may be applied in order to promote load sharing between LVPS devices in a Unit. Such a "droop" characteristic shall not be more than 1 volt, from no load to full load.
- 9.2.3.10. The combined LVPS capacity shall be capable of supplying 120 percent of the full load requirements of the Unit, including battery charging, for all allowable Unit configurations with all LVPS devices on a Unit operable. Load shedding per Section 9.4.19 is permitted with one or more inoperable LVPS devices.
- 9.2.3.11. The output transient response shall be less than ± 10 percent for any step load change with the battery connected. In all other cases, the maximum overvoltage shall be 42 Vdc.

9.2.3.12. The LVPS shall tolerate the step application and removal of any load value up to the maximum, including maximum charging current in the case of dead batteries.

9.2.4. Battery Capacity

9.2.4.1. The service life of each battery (refer to Section 9.4.14) shall be in excess of two SMS cycles (14 years).

9.2.4.2. A capacity calculation shall be submitted based on the IEC 60623 "Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes" rating of the battery, and sized to provide the duty defined in Section 9.2.4.3 when working at either extreme of the ambient temperature range (refer to Section 2.5.1) at any time within the declared life of the battery. The calculation shall consider the scenarios described in Section 9.4.14 for any Unit formation described in Section 2.2.1. **[CDRL]**

9.2.4.3. The batteries within a Unit shall have sufficient capacity to supply all low voltage power loads on the Unit with adequate voltage (measured at the load) during the absence of output from the LVPS for a minimum period of 90 minutes. During this period, the following loads, at a minimum, shall remain energized:

- a) Emergency lights, refer to Section 8.3.4.
- b) Miscellaneous lights (at a minimum to include headlights, taillights, end route sign, interior message displays, and side destination signs).
- c) Public address intercom (30 second announcements, every 10 minutes).
- d) Radio/communications (30 second transmission, every 5 minutes).
- e) Cab and Brake controls.
- f) Door operation (one cycle after 1 hour).
- g) Door light indications.
- h) Event Recorder.
- i) Buzzer signal system.
- j) Monitoring and Diagnostics System (MDS).
- k) Communications-based Train Control (CBTC) system defined in Section 14, or Staten Island Railroad (SIR) Automatic Train Control (ATC) system defined in Section 25.14.
- l) Closed-circuit television (CCTV) system.
- m) Passenger Information System.

9.2.5. Input Filters

9.2.5.1. The inrush current due to all capacitors charging simultaneously shall be limited to 600 amperes per car.

9.2.5.2. Both the inrush current amplitude and the rate of rise, for any reason including switch-on, resetting or substation reclosing scenarios, shall be limited to assure compliance with the conductive Electromagnetic Interference (EMI) broadband transient event limits specified in Section 2.11.

9.2.5.3. For converters connected to third rail voltage, the combination or individual resonant frequency of the input filter circuit, under any condition, including extreme combinations of worst case temperature, tolerance, aging, cutout, etc., shall be such that the EMI requirements of Section 2.11 are met. **[CDRL]**

9.2.5.4. The filter design shall limit impressed substation ripple currents and converter-generated harmonics to levels below those specified in Section 2.11, as apportioned to each converter, under all converter operating conditions, including failure conditions.

9.3. Functional Requirements

9.3.1. Current Collection

9.3.1.1. The current collector shall collect electrical power from the third rail.

9.3.1.2. The fused output of each of the four current collectors on a car shall be connected together to provide the primary source of power for the car.

- 9.3.1.3. Means shall be provided to ensure the force of the current collector contact shoe on the contact rail shall be between 20 and 30 pounds (90 and 135 N).
- 9.3.1.4. The design of the current collector support shall provide for height adjustment in 0.25-inch (6.35-mm) increments by means of a bolted "washboard" arrangement for engagement of the assembly to the truck frame.
- 9.3.1.5. To minimize potential damage to the equipment and to prevent falling debris, the design shall provide sufficient movement to allow the current collector shoe to rotate beyond the protection board of the third rail system without any damage to the equipment, other than the coil spring or its equivalent. An over-travel Indicator shall be provided.
- 9.3.1.6. The current collector fuse shall include an indicator to show blown fuses.
 - a) The fuse shall be 700-ampere NYCT Commodity Number 15-42-3169 (see Appendix D-8).
 - b) The blown fuse indicator shall be NYCT Commodity Number 15-42-3070 (see Appendix D-9).
- 9.3.1.7. A cuttable ribbon connection or equivalent between the fuse box shunt and fuse assembly shall be included for the purpose of isolating the car in case of emergency.

9.3.2. General Power Conversion Requirements.

- 9.3.2.1. The power conversion equipment shall contain over and under-voltage detection on the input side for self-protection in the event third rail supply voltage should fall or rise outside the design range.
- 9.3.2.2. The power conversion equipment shall not be damaged as a consequence of any sustained abnormal input voltage. For equipment fed from the 3rd rail, IEC 60850 "Supply Voltages of Traction Systems" Annex "A" using the voltages associated with a "U_n" of 750V shall apply.
- 9.3.2.3. An automatic inhibit feature of power equipment is permissible for input voltages above the maximum and below the minimum, as defined in Section 2.5.
- 9.3.2.4. The power conversion equipment shall have sufficient protective devices on all ports to preclude damage to the power conversion equipment from both positive and negative transient voltages. The level of protection shall be justified by the Contractor and approved by NYCT for each equipment and in each application and location.
- 9.3.2.5. Power supply unit controls shall be configured such that regulator or control circuit failures reduce the power supply unit output to zero, or shall employ an overvoltage protection circuit that will detect over-voltages and interrupt the power supply system output.
- 9.3.2.6. Operation of all systems fed by high voltage, including but not limited to their filter charging functionality, shall not preempt the NYCT substation automatic DC breaker re-closing systems from energizing the third rail.
- 9.3.2.7. Activation of the substation DC breaker re-closing circuitry shall not cause improper train or train equipment operation or damage.

9.3.3. Input Filter Capacitor Discharge.

- 9.3.3.1. The capacitors shall have permanent parallel resistors which, upon disconnecting from high voltage source, will discharge the capacitors within 20 minutes, independently of controlled discharge circuitry.
- 9.3.3.2. Controlled discharge circuitry shall be provided to automatically discharge the capacitors to less than 50 volts in less than 2 minutes.
- 9.3.3.3. Operation of the controlled discharge circuitry shall be independent of low voltage power to the extent that its loss or absence shall not preclude controlled capacitor discharge.
- 9.3.3.4. Permanently connected, fast-discharge resistors that meet above timing requirements will be considered, where practical, in place of control circuitry subject to NYCT approval.

9.3.3.5. The propulsion system capacitors controlled discharge circuitry shall be activated, at a minimum, when the brake pipe is discharged or if the Main Switch (see Section 9.3.5) is in any position other than the RUN position.

9.3.4. Converter Monitoring and Diagnostics.

9.3.4.1. Each auxiliary power converter (LVPS and Auxiliary Inverters) shall contain comprehensive self-diagnostic capability and protective features.

9.3.4.2. Refer to Sections 2.14.6 and Section 17 for additional requirements related to the Monitoring and Diagnostics System (MDS) and to Section 22.8 for Diagnostic Test Equipment (DTE) requirements.

9.3.4.3. For all faults detected, the converters shall respond to the fault and then perform an automatic reset of the fault, in accordance with predefined process and limits. The process and limits for resetting faults shall be approved by NYCT.

9.3.4.4. The equipment shall provide the MDS with the fault information recorded using vehicle time, per the interfaces specified in Section 17.4.

9.3.4.5. Loss of input to and of output from any converter and the operation of any circuit protection shall be annunciated to the MDS.

9.3.5. Main Switch and Interlocks

9.3.5.1. A single-pole knife switch (hereafter referred to as "Main Switch") shall be located in an undercar position accessible from the side of the car when standing at track level.

9.3.5.2. The current collector shoes shall be electrically connected directly to the Main Switch.

9.3.5.3. No component or device shall be connected between the Main Switch and the current collectors, except as approved by NYCT.

9.3.5.4. The current from each current collector shoe shall be routed via the truck trolley cable to the Main Switch.

9.3.5.5. The Main Switch shall have four distinct positions as indicated in Table 9-1.

9.3.5.6. While the Main Switch is in the SHOP TEST position, the shop power load shall be current limited to 150 Amperes.

- a) Car controls shall use load shedding to keep the current below the 150 Ampere limit.
- b) Load shedding controls shall be designed to only shed loads as necessary for the actual operating conditions and to allow maintenance personnel to alter the load shedding arrangement in order to activate any and all loads.

Table 9-1: Main Switch Positions

Switch Position	Items Connected	Items Isolated
1. RUN	a) Collector shoes b) Auxiliaries c) Propulsion	a) Shop power stud
2. RAIL TESTS	a) Collector shoes b) Auxiliaries	a) Shop power stud b) Propulsion
3. OFF	a) None	a) Collector shoes b) Propulsion c) Auxiliaries d) Shop power stud
4. SHOP TEST	a) Shop power stud b) Auxiliaries	a) Collector shoes b) Propulsion

- 9.3.5.7. A low voltage interlock shall be provided to indicate when the Main Switch blade is fully engaged in the RUN position.
 - a) This interlock and its wiring shall be protected against high voltage, high current arcing.
 - b) Loss of RUN position indication shall cause propulsion shutdown and discharge of the propulsion system filters, as per Section 9.3.3.

9.3.6. Auxiliary Inverters

- 9.3.6.1. Output overvoltage protection shall be provided in coordination with the voltage and frequency regulation limits in Section 9.2.2.2.
- 9.3.6.2. The auxiliary inverter system shall include ground fault detection for the three-phase power output.
- 9.3.6.3. Control interlocking shall prevent the simultaneous “Direct on Line” starting of multiple ac motors or motor groups.
- 9.3.6.4. The Auxiliary Inverter circuit design shall include complete protection. Resetting Auxiliary Inverter circuitry back to a normal running condition shall be applicable to, and dependent on, the condition that caused its protection to operate. The protection proposed and resetting methodology for each Auxiliary Inverter shall be approved by NYCT.
- 9.3.6.5. The application or removal of any load at any supply voltage shall not result in the nuisance activation of protective devices.
- 9.3.6.6. Ground fault protection shall be provided in cases where single-phase power is supplied (such as cab heaters in Section 9.4.12.4).
- 9.3.6.7. Faults and the operation of the protection for each Auxiliary Inverter shall be communicated to the MDS as described in Section 17, Monitoring and Diagnostic System.

9.3.7. Low Voltage Power Supply Control and Annunciation

- 9.3.7.1. The LVPS shall supply control power to all car systems, power all lights, charge batteries, and power other loads as may be defined in the course of the vehicle design.
- 9.3.7.2. The LVPS shall have a dead battery start feature inasmuch as the converter shall start whenever the input voltage is proper, regardless of whether the vehicle low voltage system is supplying control power.
- 9.3.7.3. Faults shall be uniquely identified on a display within the converter and shall be communicated to the MDS as described in Section 17, Monitoring and Diagnostic System.

- 9.3.7.4. Protective features shall include a limited number of automatic resets. The exact implementation methodology shall be approved by NYCT.
- 9.3.7.5. The LVPS shall automatically stop when outside of its operational input supply voltage range and automatically restart when the voltage returns within range. Hysteresis and timing of the automatic stop and restart shall be approved by NYCT.
- 9.3.7.6. The LVPS shall detect internal failures.
- 9.3.7.7. The converter shall shut down if the LVPS output voltage is as follows:
- Above the upper limit of 42 Vdc.
 - Below the lower limit of 23 Vdc, except for low input voltage and brief periods of current limited operation subject to NYCT approval.
 - The converter shall restart automatically after a shutdown and a brief delay. The length of the delay shall be justified and subject to NYCT approval.
 - Repetitive restarts in a short period of time shall cause the converter to be locked out, requiring manual reset. The number of automatic restarts and the period shall be subject to NYCT approval.
- 9.3.7.8. If the current demand exceeds the current limit setting, the output current shall be held at the set limit.
- The current limit shall be adjustable up to the converter rating.
 - The rating shall consider all load and degraded mode scenarios.
 - A separate port for battery charging shall have its current limit set for dead battery charging.
- 9.3.7.9. The converter shall be self-protected against internal over-temperature.

9.3.8. Battery Protection

- 9.3.8.1. A sensor to prevent overheating shall be located within the center of the battery box to disconnect the battery from the low voltage system whenever the battery temperature exceeds the temperature specified by the battery supplier, but in no case greater than 160°F (71°C). The preferred sensor is NYCT Commodity Number 13-43-6597 (see Appendix D-10). However:
- The sensor shall not interfere with maintenance access to the battery cells.
 - The sensor accuracy shall be within 9°F (5°C) of a selected cell case at the over-temperature set point.
 - The sensor technology, location, assembly, and cell selected for sensor installation shall be approved by NYCT.
- 9.3.8.2. The protection system shall disconnect the battery in the event of battery over-temperature and shall require manual reset.
- 9.3.8.3. The battery over-temperature condition shall be reported to the car MDS.
- 9.3.8.4. A double pole battery circuit breaker of adequate capacity and approved design shall be mounted in an environmentally protected enclosure under the car and as close to the battery as possible, and made accessible for maintainers and first responders to isolate the battery.
- 9.3.8.5. The battery circuit breaker shall incorporate a shunt trip device and shall disconnect the battery from car wiring when the battery temperature is excessive.
- 9.3.8.6. The battery circuit breaker shall incorporate a series trip to protect against fault currents.

9.4. Design Requirements

9.4.1. General Power Collection Requirements

- 9.4.1.1. A current collector assembly shall be mounted to the truck frame on each side of each truck, providing four assemblies per car. Each assembly shall consist of:
- a) Current collector and associated hardware.
 - b) Fuse box and fuse.
- 9.4.1.2. All current carrying components, including cabling, shall be sized for continuous power collection to a car by a single current collector shoe.
- 9.4.1.3. All circuits and equipment shall be designed and protected so that the sustained presence of any voltage from zero to maximum line voltage will not cause damage to any part of the car or cause unsafe operation.

9.4.2. Third Rail Collector Shoe Assembly

- 9.4.2.1. Contact shoes shall not incorporate a breakaway feature.
- 9.4.2.2. Current collector fuses shall be of the current limiting cartridge type with current rating and time constant properly selected to reflect the operating currents, the third rail power supply, and third rail electrical characteristics. (See NYCT Maintenance of Way MW-1 Standard, Appendix C-5)
- 9.4.2.3. The current collector shoe design shall be such that no electrical current shall pass through any bearing or movable connection.
- 9.4.2.4. The electrical current path shall be from the contact shoe through the contact shoe shunt to the fuse box mounted on the current collector assembly.
- 9.4.2.5. The current collector shoe shunt shall be arranged so as not to interfere with the third rail protection board.
- 9.4.2.6. Each shunt shall contain no less than 80,400 circular mils (40.7 mm²) of copper.
- 9.4.2.7. An arc shield of non-conducting material shall be provided between the current collector shoe assembly and the truck frame.
- 9.4.2.8. Conductors shall be encased in thick, durable, non-conductive silicone boots wherever possible to preclude arcing to ground during rain, snow, ice conditions, and car washing operation.

9.4.3. Main Switch

- 9.4.3.1. The Main Switch and vehicle shop power stud shall be fully compatible with existing shop power connectors in NYCT's maintenance facilities.
- 9.4.3.2. The shop power stud shall be replaceable without the necessity to remove the Main Switch from the car and shall be as per NYCT Commodity Number 08-68-2515 (see Appendix D-14) unless otherwise directed by NYCT.
- 9.4.3.3. The Main Switch shall include a mechanical interlock that prevents closing of the cover unless the switch is in the RUN position.
- 9.4.3.4. The outside cover of the Main Switch enclosure shall contain a high voltage warning and a permanent nameplate with the words "MAIN SWITCH" and the device designation used for the Main Switch on the electrical schematic.
- 9.4.3.5. The Main Switch insulated handle shall be a minimum of 4.25 inches (108 mm) in length.

- 9.4.3.6. The Main Switch shall be mounted on a base of approved fire retardant material and shall be housed in a box with a captive hinged cover constructed of insulating material.
- a) All screw and bolt heads, fasteners of all types, and metal supports or brackets shall be insulated with attached, but removable, dielectric barriers on the interior of the box.
 - b) Use of RTV or similar formless sealants shall not be acceptable as the sole insulating agent. See Section 19.20.
 - c) The cover of the box shall have stenciled, in an appropriate manner, the words:
"BEFORE OPENING MAIN SWITCH, OPEN ALL SWITCHES ON PANEL BOARDS."

9.4.4. Propulsion Input Protection

- 9.4.4.1. Protection of the propulsion input power downstream of the Main Switch shall be provided by the High Speed Circuit Breaker described in Section 10.4.5.
- 9.4.4.2. Design of the cable connection between the Main Switch and this breaker shall minimize the possibility of ground faults.

9.4.5. Auxiliary Fuse

- 9.4.5.1. A DC auxiliary fuse shall be installed in the Main Switch enclosure in a location that permits its easy exchange.
- 9.4.5.2. The DC auxiliary fuse shall be coordinated with load-side protection devices such that it provides protection for faults occurring between the fuse and the load protection devices.
- 9.4.5.3. Fuses on 600 Vdc (nominal) circuits shall be sized to successfully interrupt current flow under all conditions typically encountered in the NYCT environment. The fuses shall be rated at a minimum of 1,000 Vdc and shall act (blow) without rupture, excessive heat or distortion of the fuse cartridge, and shall not damage the surrounding equipment, including the fuse holder.

9.4.6. Distribution of Auxiliary Power

- 9.4.6.1. Power shall be routed from the Auxiliary Fuse to an undercar equipment enclosure:
- a) All auxiliary power shall be distributed from the undercar equipment enclosure.
 - b) The enclosure shall contain circuit breakers or fuses as specified in Section 19.31.5.
- 9.4.6.2. All distribution circuits shall be individually protected by circuit breakers or fuses:
- a) Unless otherwise approved, no device shall protect more than one circuit.
 - b) Devices shall be accessible from the side of the car.
 - c) Device terminals shall not be used as junction points.
 - d) The circuit protection shall be sized to protect the minimum wire size used for its power distribution.
 - e) Circuit breakers shall have a frame size suitable for the continuous current interrupting duty.
 - f) Circuit breaker poles may be connected in series if required to achieve the required voltage.
 - g) Circuit breaker handles shall indicate ON, OFF, and tripped positions.
 - h) Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.
 - i) Device continuous current rating shall be selected for the load and type of service specified.
 - j) Device type and current rating shall be clearly and permanently visible after installation.
 - k) Electrically operated circuit breakers shall operate at low voltage (nominal 37.5Vdc).

- 9.4.6.3. All fuses and circuit breakers shall be clearly identified and located on enclosure labels.
- 9.4.6.4. Activation (operation) of a protective device shall be communicated to the car MDS (see Section 17, Monitoring and Diagnostic System).
- 9.4.7. Car Body Grounding**
- 9.4.7.1. All equipment on the vehicle shall be grounded to the vehicle structure.
- 9.4.7.2. Equipment boxes and enclosures, with the exception of the battery box, shall be grounded as specified in Section 19.25.7.
- 9.4.7.3. Equipment boxes and enclosures grounding shall be distinct from power return grounding.
- 9.4.7.4. With the exception of primary power circuits, each system or circuit fed from a circuit breaker or fuse shall have its own return wiring.
- 9.4.7.5. Each circuit's return wire shall be connected, via its own separate terminal, to a return bus located near the circuit breaker or fuse that supplies the circuit.
- 9.4.7.6. Circuit breakers or fuses shall not be installed in the return wiring, unless the source and the return path are broken by the same device.
- 9.4.8. Primary Power Return Circuits**
- 9.4.8.1. Primary power returns shall be connected to a single ground pad fixed to the car body unless otherwise approved by NYCT.
- 9.4.8.2. The vehicle structure and truck frames shall be grounded to the axles.
- 9.4.8.3. The car body shall be grounded to all four axles in a car through axle-mounted ground brushes.
- 9.4.8.4. The general cabling and grounding configuration shall be as on existing NYCT R160 and R179 cars.
- 9.4.8.5. Each ground brush and its cable and connections shall be sized such that any two ground brushes on a car are capable of continuously carrying the total primary return current, without damage.
- 9.4.8.6. The car body ground circuits, including wires, brushes, and wheels, shall be sized so that each brush circuit can independently carry the maximum fault current without damage and while limiting the voltage difference between the car body and the running rail to 50 volts.
- 9.4.9. Ground Brush Assemblies**
- 9.4.9.1. Axle-mounted ground brushes shall be of the radially-mounted type and shall be of a proven design in wide use in the rail transit industry.
- 9.4.9.2. Ground brushes shall bear on a bronze or steel ground ring pressed onto the axle. For unpowered axles, alternative designs may be proposed.
- 9.4.9.3. Brushes shall be made from metal graphite and shall be readily accessible from under the car for maintenance purposes.
- 9.4.9.4. Interconnection jumpers between the individual ground brush boxes, if used, shall be of flexible copper braid type tolerant of the high vibration levels experienced by the axle-mounted equipment. See Section 19.25.7.
- 9.4.10. Inverter/Converter Input Filters**
- 9.4.10.1. Inverters supplied directly from primary 600 Vdc power shall have sufficient input filtering and protection to provide reliable operation in the presence of third-rail voltage variations and transients as experienced on the NYCT system.

- 9.4.10.2. Input filtering shall meet the requirements of Section 9.2.5. Inverter outputs shall be galvanically isolated from the input supply except where the output can only be accessed by authorized personnel performing prescribed maintenance tasks.
- 9.4.10.3. Independent line filters shall be provided for each propulsion inverter and each auxiliary power converter.
- 9.4.10.4. Input filters shall be inductor-capacitor (LC) circuits.
- 9.4.10.5. Filter capacitors shall be selected in accordance with Section 19.31.7.
- 9.4.10.6. The Contractor shall conduct a Failure Mode, Effects, and Criticality Analysis (FMECA) on the filter design in accordance with Section 9.6.1.8. [CDRL]
- 9.4.10.7. In the event that the filter design FMECA indicates a failure mode with interference levels exceeding those specified in Section 2.11, fail-safe circuitry shall be provided to disconnect the faulty converter from third rail power in the event that allowable ripple thresholds are exceeded.
- 9.4.10.8. The design of the circuit characteristics shall be coordinated with the EMI design of the converter.

9.4.11. Inverter Cooling

- 9.4.11.1. Auxiliary power inverters shall be designed to use externally grounded or electrically insulated, non-energized heat sink fins.
- 9.4.11.2. Forced ventilation of the inverter enclosure interior is not permitted.
- 9.4.11.3. Sealed heat pipes that do not require opening during maintenance are acceptable.

9.4.12. Auxiliary Inverters

- 9.4.12.1. Auxiliary Inverters and their loads shall conform to the requirements of IEC61287, IEEE Std. 1476 and the requirements of this Specification.
- 9.4.12.2. Each Auxiliary Inverter shall be powered from 600 Vdc primary power via an adequately rated power diode and shall provide either three-phase power according to Section 9.2.2, or 120 volts single-phase, 60 Hz, ac voltage as required by the supplied load for use within the car.
- 9.4.12.3. The Contractor shall ensure that loads connected to non-isolated inverter outputs are designed to withstand the maximum voltages (including transients) that may be impressed on output phases with respect to ground.
- 9.4.12.4. Cab heater circuits shall be supplied from a single-phase power distribution network inverter compliant with IEEE Std. 1476 Section 4.3.2 or from the Low Voltage Distribution Network (LVDN) described in Section 9.4.17.
- 9.4.12.5. Heater circuits powered by an AC source shall be galvanically isolated from the 600 Vdc supply.

9.4.13. Low Voltage Power Supply

- 9.4.13.1. The LVPS shall be a DC-DC converter in conformance with the requirements of IEC61287 and IEEE Std. 1476 including its approved loading calculation for all Units formations permitted by Section 2.2.1 and the requirements of this Specification.
- 9.4.13.2. The LVPS shall be naturally convection cooled, not dependent upon car motion.
- 9.4.13.3. The LVPS enclosure shall be isolated from both the input and output circuits.
- 9.4.13.4. For maintenance purposes the circuit breaker that supplies High Voltage (input power) to the LVPS shall be located within 5 feet (1.5 m) of, and on the same side of the car as the LVPS enclosure, and when opened shall remove all of its HV derived input power. Alternative locations of the LVPS circuit breaker may be proposed for NYCT approval. This requirement need not apply to the other auxiliary inverters/converters.

- 9.4.13.5. NYCT approved signage shall be installed on the LVPS that instructs the maintainer to open the main high voltage circuit breaker and wait 5 minutes prior to servicing the equipment. The sign shall also advise the maintainer that low voltage / battery power is present with the high voltage circuit breaker open.
- 9.4.13.6. Not used.
- 9.4.13.7. The high voltage input to the LVPS shall include a diode to prevent capacitor discharge into third rails and to protect the Unit from negative transients.
- 9.4.13.8. An output fuse or circuit breaker shall be provided in the LVPS converter and sized to protect the car wiring.
- 9.4.13.9. An output short circuit shall not damage the converter and shall not result in the need to manually reset any protective device.

9.4.14. Storage Battery

- 9.4.14.1. Each B Car shall have an identical nickel cadmium alkaline storage battery consisting of 25 standard size cells in polymer cases, rated according to Section 9.2.4.
- 9.4.14.2. Alternative battery technologies and arrangements may be proposed subject to NYCT approval.
- 9.4.14.3. The car battery and battery tray shall conform to NYCT Specification 2039-PROD-84 (see Appendix C-11).
- 9.4.14.4. Each battery shall be charged using an LVPS dedicated output.
- 9.4.14.5. Low rate cells shall not be used without prior approval by NYCT.

9.4.15. Battery Box

- 9.4.15.1. The battery box shall accommodate standard size nickel cadmium cells in compliance with all requirements of this specification.
- 9.4.15.2. The batteries shall be mounted on a single pull out, drawer type roller tray in an enclosure located below the car floor to permit ease of installation and servicing accessibility from the side of the car.
- 9.4.15.3. The enclosure shall be a structural frame of welded stainless steel construction.
- 9.4.15.4. The battery box shall be electrically insulated from the car body.
- 9.4.15.5. The battery box interior shall be covered with an approved electrolyte resistant, glass fiber reinforced polyester resin. Alternate coating(s) may be proposed for approval by NYCT.
- 9.4.15.6. No flammable or hygroscopic materials shall be used for any part within the battery enclosure.
- 9.4.15.7. Ventilation openings shall be provided to prevent the buildup of gases, such as hydrogen.
 - a) The location of the openings shall ensure air circulation throughout the box with the vehicle in motion or stationary.
 - b) At a minimum, ventilation shall be provided on the top and in the back of the box.
- 9.4.15.8. The pull-out force required to move the drawer roller tray shall be 25 lb. (110 N) maximum, measured after reaching the initial peak force required to overcome the inherent inertia.
 - a) The maximum peak force shall be 40 lb. (180 N).
 - b) The roll-out tray shall have a positive lock that, when properly secured, shall absolutely prevent the tray from moving.
 - c) The roll-out tray lock shall be arranged so that it must be in the "tray locked" position before the battery box cover can be closed.
- 9.4.15.9. The enclosure shall have a drain plug accessible from the outside.
 - a) The drain plug shall be held captive to the enclosure by means of a cotter pin or a chain.
 - b) If a chain is used, removal of the plug without disengagement of the chain shall be possible.

- 9.4.15.10. The enclosure cover shall be captive to the enclosure sides through a mechanical linkage arrangement.
- The cover retaining mechanism shall not interfere with access to, or normal maintenance of, the batteries nor shall it, under any circumstances, contact any part of the battery.
 - The cover shall open so as to permit full access to the battery compartment without cover removal.
 - The cover shall be designed to be easily opened and closed by one person, and it shall not be necessary to hold the cover in place while operating latching or fastening devices.
 - The cover shall not swing open or fall off if the car is moved with the cover unlocked.

9.4.16. Circuit Breaker Panels

- 9.4.16.1. Circuit breaker panels for all low voltage and auxiliary AC power distribution circuits shall be provided in each car.
- 9.4.16.2. Separate panels shall be provided for low voltage and auxiliary powered circuits.
- 9.4.16.3. Circuit breaker panels, labels, and markers shall conform to the requirements of Section 19.31.4.
- 9.4.16.4. Each circuit breaker shall be identified to indicate the circuit it protects.
- 9.4.16.5. A protective device or cover shall be provided to secure the event recorder circuit breaker from accidental manual tripping. See Section 5.5.6.3 for details on the protective cover.
- 9.4.16.6. In A Cars, the circuit breaker panels shall be conveniently located within the cab.
- 9.4.16.7. In B Cars, the circuit breaker panels shall be located in the No. 1 end locker.
- 9.4.16.8. Each circuit breaker panel shall be equipped with a substantial, self-latching door that shall be opened using the standard Master Door Controller Key or alternative approved by NYCT.
- 9.4.16.9. The High Voltage distribution described in Section 9.4.6 shall be located underfloor as approved by NYCT.

9.4.17. Low Voltage Distribution Network

- 9.4.17.1. The LVPS units and batteries shall supply low voltage power to the Low Voltage Distribution Network (LVDN), which shall connect all cars in a Unit.
- 9.4.17.2. The LVDN shall power all of the low voltage loads of a Unit.
- 9.4.17.3. Under all operating conditions, the maximum voltage drop between a power source and every load shall be 4 volts, including both the supply and return wiring.
- 9.4.17.4. No resistors shall be installed between segments of the LVDN.

9.4.18. Low Voltage System Return Circuits

- 9.4.18.1. An independent negative return shall be provided for each system or circuit fed by a separate supply circuit breaker.
- 9.4.18.2. The negative return for each circuit or system and the negative connection from the battery and the LVPS shall be connected to a common negative bus bar.
- 9.4.18.3. The Contractor shall propose where and how the low voltage system shall be grounded, for NYCT approval. [CDRL]
- 9.4.18.4. The low voltage distribution system design of the auxiliary power within an operating Unit shall account for variations of potential at the running rails resulting from traction return current flow.
- 9.4.18.5. The supplier shall take appropriate measures to ensure correct operation of all trainlined low voltage circuitry under the worst case differences of ground return potential between the cars of the train.

9.4.19. Load Shedding

- 9.4.19.1. Load shedding may be performed in response to loss of one or more LVPSs on a Unit.
- 9.4.19.2. In addition to sensing LVPS shutdown, load shedding controls shall determine whether 600 Vdc primary power has been lost as well, and shall provide load shedding appropriate for each condition.
- 9.4.19.3. For 50 percent or less loss of LVPS capacity in an operating Unit, 50 percent of the non-emergency lighting intensity in the Unit may be shed after 15 seconds.
- 9.4.19.4. For greater than 50 percent loss of LVPS capacity within an operating Unit, load shedding of non-essential loads is permitted, as approved by NYCT, together with deactivation of the non-emergency lights and the LVDCN supplied door threshold heaters in the Unit.
- The delay for lighting deactivation shall be 15 seconds; longer delays may be appropriate for other loads as approved by NYCT.
 - The Unit shall be capable of operating indefinitely with the non-essential functions disabled.
- 9.4.19.5. The identification of functions as essential or non-essential is subject to review by NYCT, but the following minimum functions, shall be considered essential to operation:
- Loads listed in Section 9.2.4.3, with duty cycles appropriate for normal operation.
 - Cab controls and indicators.
 - LVDCN supplied cab heaters, windshield heaters, and air duct booster fans.
 - Propulsion system.
 - Air compressor and controls, along with any associated power supply equipment.
- 9.4.19.6. For loss of 600 Vdc primary power on a car equipped with an LVPS, control power to loads on that car requiring 600 Vdc for operation (or three-phase AC derived from 600 Vdc) may be shed after a suitable time delay in addition to loads shed in response to the resulting LVPS shutdown. Continued Unit operation at reduced performance shall be possible in this case.
- 9.4.19.7. For loss of 600 Vdc primary power on an entire Unit, the load requirements of Section 9.2.4.3 shall apply. Non-emergency lights shall be shed after 15 seconds; other loads may be shed after a suitable time delay.
- The time delay shall be such that a two-Unit train can continue to the next station to discharge passengers if one of the Units has primary power available.
 - In addition, all exterior signs and the internal displays shall be shed after 5 minutes.
 - The ceiling interior information sign shall enter a reduced power mode and be limited to public service and emergency messages after 5 minutes.
 - All microprocessor-based systems may shut down or enter a sleep mode after 30 minutes.
 - In determining time delays for load shedding where specific times are not stated, the Contractor shall consider factors such as the reliability impact of additional shutdowns and restarts, and the degree of difficulty (e.g., restart delay, coordination with other systems) involved in system re-initialization.
- 9.4.19.8. Reconnection of loads shall be automatic in response to restoration of the power supply.
- Output sensing devices shall detect the loss of constant voltage DC output from an LVPS, due to any cause.
 - The detection devices shall also detect the restoration of constant voltage output and shall automatically reconnect the previously disconnected loads.
 - Loads shed due to loss of primary 600 Vdc power shall be automatically reconnected once primary power is restored.

- d) Re-powering shall be sequenced to avoid in-rush current overloading of the converters.
- e) Load shedding based on low input voltage (as opposed to total loss of 600 Vdc primary power) shall not be allowed without approval by NYCT.

9.4.20. Convenience Outlets

- 9.4.20.1. There shall be a 120-Vac, 60-Hz, 20-ampere, heavy-duty duplex convenience outlet in each car.
- 9.4.20.2. The convenience outlet shall be located in the cab of the A Cars and in a locker in the B Cars. The location of the locker in the B Cars shall be subject to NYCT review and approval.
- 9.4.20.3. 120 Vac shall be available at all times when 600 Vdc is present.
- 9.4.20.4. The outlet shall be grounded and shall include auto-monitoring ground fault circuit interrupter (GFCI) protection conforming to UL 943 GFCI Standard for Ground-Fault Interrupters.
- 9.4.20.5. Convenience outlets shall have stainless steel cover plates, with individual spring-hinged covers over each individual outlet.
- 9.4.20.6. The cover plate shall be attached with tamper resistant screws.
- 9.4.20.7. The duplex outlet shall be labeled as "120 Volts."
- 9.4.20.8. The source of the 120-volt, 20-ampere power shall be supplied from an auxiliary power distribution network inverter and shall conform to IEC61287 and IEEE Std. 1476 Section 4.3.2.
- 9.4.20.9. A transformer shall be used to provide galvanic isolation for the convenience outlet output.
- 9.4.20.10. The output shall be filtered to provide a low-harmonic sine wave voltage to allow standard recording or other instrumentation to be powered.
- 9.4.20.11. In no case shall the harmonic voltage distortion be greater than 5 percent.
- 9.4.20.12. The neutral of the convenience outlet shall be grounded.

9.4.21. Not Used

9.5. Maintainability Requirements

9.5.1. Current Collection

- 9.5.1.1. Current collector assembly adjustment shall not require the use of special tools.
- 9.5.1.2. The range of current collector adjustment shall compensate for the full amount of wheel wear and suspension wear.
- 9.5.1.3. The current collector fuse shall be accessible for replacement without disassembly of the current collector.

9.5.2. Inverter Input Filters

- 9.5.2.1. Each high voltage input filter discharge shall be essentially identical in timing and functionality from a maintenance perspective.
- 9.5.2.2. A measuring point shall be provided and appropriately identified for maintenance personnel to safely and conveniently measure the filter capacitor voltage.
- 9.5.2.3. Equipment Maintenance Manuals shall incorporate appropriate procedures to enable and require NYCT personnel to verify capacitor discharge prior to commencing work on high voltage equipment.

9.6. Validation Requirements

9.6.1. Auxiliary Power System

- 9.6.1.1. Details of the auxiliary power system architecture and protective coordination shall be submitted to NYCT for approval [CDRL].
- 9.6.1.2. The Contractor shall use a functional requirements definition process as described in IEEE Std. 1476, Section 4.1 in the development of the auxiliary power system.
- 9.6.1.3. The Contractor shall propose functional responsibilities, as outlined in Table A.3 of IEEE Std. 1476, and shall identify any additional information needed from NYCT beyond that already provided in this Specification.
- 9.6.1.4. The Contractor shall include the details of all of the requirements listed in Table 1 of IEEE 1476 in its design review documentation.
- 9.6.1.5. A load analysis for all auxiliary circuits shall be submitted for approval by NYCT. The analysis shall include both normal and fault scenarios. [CDRL]
- 9.6.1.6. The proposed voltage withstand and the protective means for power conversion equipment to voltage transients and spikes shall be verified by the contractor by its own comprehensive analysis of plausible transient events induced by the third rail power distribution and measurements on the NYCT system. [CDRL]
- 9.6.1.7. All equipment powered from the third rail shall be compliant with and tested to meet the transient overvoltage requirements of IEC-61287-1, and IEC 60850, Annex "A" using all the voltages associated with a "U_n" of 750V.
- 9.6.1.8. The Contractor shall perform a FMECA on all converter circuits to demonstrate that no failure modes can produce interference currents beyond allowable limits. [CDRL]
- 9.6.1.9. The controlled discharge scheme for the propulsion system and each auxiliary power converter input filter shall be submitted for NYCT approval. [CDRL]
- 9.6.1.10. The Contractor shall submit a detailed test plan for NYCT review and approval to verify that the voltage drops in a Unit are compliant with the requirements of Section 9.4.17.3. The Contractor shall conduct the test on all Unit configurations permitted by Section 2.2.1 to verify the design. [CDRL]
- 9.6.1.11. Load shedding details and the restart scheme shall be presented during Preliminary Design Review. [CDRL]

9.6.2. Battery Capacity

- 9.6.2.1. The Contractor shall provide load calculations for the LVPS and battery loads under all operating conditions, using the methodology of IEEE Std. 1476 Section 4.2. [CDRL]
- 9.6.2.2. The submittal shall include load profiles, operating conditions, derating factors, and other parameters as defined in IEEE Std. 1476 Section 4.5.1, which is used as a basis for battery sizing.

9.6.3. Electric Motor Type Tests

- 9.6.3.1. Electric Motor Type Testing shall be made according to Section 24.4.4.

9.6.4. Power Converter Type Tests

- 9.6.4.1. The Contractor shall type test each power converter type (all APS inverters and LVPS).
- 9.6.4.2. The Contractor shall test the first converter of each type, and then one additional production unit selected at random by NYCT.
- 9.6.4.3. Type testing shall be according to IEC 61287-1 with the procedure for each converter type submitted for NYCT approval, including a completed IEC 61287-1 Annex B and the response to 9.6.6.1.

- 9.6.4.4. Each procedure shall use the environmental ranges and supply voltages given in Section 2.5, and the performance and functional information from this Section.
- 9.6.4.5. Type testing shall include the interface to the MDS and the PTE ensuring the correct information is recorded and available for all the failure modes. Each failure mode shall be simulated, with the converter performance and its diagnostic information reported.
- 9.6.4.6. The Contractor shall perform a test to demonstrate converter performance while negotiating non-bridgeable 3rd rail power gaps. The power gap shall be comprised of series of tests to measure the performance of the system under a variety of load conditions and durations including those around the filters' low voltage threshold.
- 9.6.4.7. Noise measurements shall be made to demonstrate compliance with Section 2.9.
- 9.6.4.8. During all tests, the output voltage waveforms shall be monitored by an oscilloscope and documented, to validate the compliance with the specified regulation and levels of harmonics/ripple.

9.6.5. Electric Motor Routine Tests

- 9.6.5.1. Electric Motor Routine Testing shall be made according to Section 24.8.9.

9.6.6. Power Converter Routine Tests

- 9.6.6.1. The Contractor shall test each Power Converter in accordance with an approved procedure based on IEC 61287-1.
- 9.6.6.2. The system shall be operated in automatic mode under a variety of electrical loads to validate the control, output and performance requirements, operating points, fault detection, and annunciation, insulation and isolation requirements.
- 9.6.6.3. Each Converter shall be subject to 30 minute operation at nominal output voltage, rated output current and nominal input voltage.
- 9.6.6.4. The Contractor shall validate function and proper operation of safety interlocks.

9.6.7. Battery System Tests

- 9.6.7.1. A battery sample, randomly selected from the production lot by NYCT, shall be tested to validate the battery capacity in accordance with requirements of Section 9.2.4.
- 9.6.7.2. Battery testing and rating shall be in accordance with IEC 60623, Vented Nickel-Cadmium Prismatic Rechargeable Single Cell, or approved equal if different technologies are used.
- 9.6.7.3. The Contractor shall perform a series of tests in accordance with agreed upon test plan, to demonstrate operation of the battery and load shedding system.
- 9.6.7.4. Five percent of the batteries supplied, selected at random by NYCT, and shall be given a capacity test at the point of manufacture in accordance with Section 4.2.1 of IEC Publication 60623.
- 9.6.7.5. Any battery set that is not installed within one year of its manufacture and factory charging, shall be fully reconditioned as per recommended OEM procedures.

9.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
9-1	9.2.4.2, 9.6.2.1	Battery capacity and sizing calculation	PDR
9-2	9.2.5.3	Analysis of the conductive EMI from the arrangements of 600 Vdc Converters and Inverters	CDR
9-3	9.4.10.6	Inverter input filter FMECA	CDR
9-4	9.4.18.3	LV grounding scheme	PDR
9-5	9.6.1.1	Auxiliary power system architecture and protective coordination	PDR
9-6	9.6.1.5	Auxiliary load analysis	CDR
9-7	9.6.1.6	Supply transient voltage withstand	CDR
9-8	9.6.1.8	Interference current FMECA	CDR
9-9	9.6.1.9	Input filter controlled discharge scheme	CDR
9-10	9.6.1.10	Test plan to verify the voltage drops in a Unit	CDR
9-11	9.6.1.11	Load shedding and restart scheme	PDR

Section 10

Propulsion System

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10 Propulsion System

10.1 Introduction and General Requirements

- 10.1.1.1 This section defines the requirements for the propulsion system, from primary power conditioning through traction motors and gear units. The requirements are categorized into Performance, Functional, Design, Maintainability, and Validation. Refer to the following sections for car systems and components interfacing with the propulsion system and other applicable requirements:
- a) Design and Performance Criteria – Section 2.
 - b) Cab and Cab Controls – Section 5.
 - c) Doors – Section 6.
 - d) Auxiliary Electrical Equipment and Distribution– Section 9.
 - e) Trucks and Secondary Suspension Systems – Section 11.
 - f) Friction Braking and Air Supply Systems – Section 12.
 - g) Carbody Equipment and Interiors – Section 15.
 - h) Trainline and Car Control Architecture – Section 16.
 - i) Monitoring and Diagnostics – Section 17.
 - j) Software Systems – Section 18.
 - k) Materials, Processes, and Workmanship – Section 19.
 - l) Reliability, Maintainability, and System Assurance - Section 21.
 - m) System Support - Section 22.
 - n) Testing Program – Section 24.
- 10.1.1.2 Propulsion and braking of each Unit shall be provided by the coordinated action of propulsion equipment as described in this section and friction braking equipment as described in Section 12, Friction Braking and Air Supply Systems.
- 10.1.1.3 All cars shall be equipped with propulsion equipment. All axles on a Unit shall be powered except for the No. 2 truck of the A1 car, as required for implementation of CBTC (see Section 14, Train Control System).
- 10.1.1.4 The propulsion apparatus for each motor truck shall be independent of that for all other motor trucks, except as specified herein.
- 10.1.1.5 Alternate equipment configurations may be proposed by the Contractor, subject to NYCT approval. Such proposals shall maintain the performance and reliability requirements of this Specification. Proposals which include forced cooling of inverters, or which are intolerant of wheel diameter differences between trucks on the same car of up to 0.75 inch (19 mm) will not be accepted.
- 10.1.1.6 The requirements detailed in Section 9, Auxiliary Electrical Equipment and Distribution shall generally apply to this section, including conforming to IEC 61287, unless a more arduous condition is called out in this Specification.

10.1.2 System Features

- 10.1.2.1 The propulsion system shall incorporate an inverter-controlled three-phase induction motor drive system providing propulsion, and dynamic and regenerative braking. The propulsion system shall interface with the friction brake equipment.
- 10.1.2.2 The propulsion system shall incorporate a microprocessor-based spin-slide protection function that shall protect against wheel spins in propulsion mode and against wheel slides in dynamic braking modes.
- 10.1.2.3 Alternative slide control architectures for dynamic braking may be provided, subject to NYCT approval.

10.2 Performance Requirements

10.2.1 Propulsion

- 10.2.1.1 The propulsion inverter unit shall be capable of operating continuously over the current collector voltage range specified in Section 2.5.3 and shall comply with the input voltage protection requirements of Section 9.3.2.
- 10.2.1.2 The propulsion system shall comply with the transient protection requirements of, and be included in the analysis required by Section 9.6.1.6.
- 10.2.1.3 The propulsion system shall provide continuously variable propulsion as required to meet the performance requirements of Section 2.7.
- 10.2.1.4 The propulsion system shall be able to operate continuously and function properly without damage or failure of the equipment at the current collector voltages specified in Section 2.5.3.
- 10.2.1.5 Propulsion system maximum performance shall conform to the tabular data for CBTC distance versus speed shown in Appendix D-15 (NYCT Drawing 253-9013 Revision B, "New Car Acceptance (Acceleration Performance)").
- 10.2.1.6 The propulsion system control logic shall limit propulsion system performance consistent with the tabular data for Trip Stop System distance versus speed when a Unit is operating outside CBTC territory; refer to Appendix D-15.

10.2.2 Dynamic Braking

- 10.2.2.1 The propulsion system shall provide continuously variable dynamic braking as necessary to meet the requirements of Section 2.7, and shall operate in conjunction with the friction brake system.
- 10.2.2.2 Dynamic braking shall be available at all times above a speed sufficient to support motor excitation from the kinetic energy of the car, regardless of the presence or absence of third rail power.
- 10.2.2.3 Rheostatic braking shall be capable of continuous operation with a completely non-receptive line under the conditions specified in Section 2.7.
- 10.2.2.4 The dynamic brake control system shall continuously monitor line voltage and supply to the line the maximum amount of energy possible within the line voltage limits prescribed, and shall divert to the dynamic braking resistors only the generated energy in excess of that accepted by the line or used by the vehicle auxiliary systems.

- 10.2.2.5 The propulsion system shall be able to return to the line a minimum of 70 percent of the theoretically available Unit kinetic energy for a 2.0 mi/h/s (0.89 m/s²) stop from 40 mi/h to 0 mi/h (64 km/h to 0 km/h) at AW2 loading when the line is fully receptive.

10.2.3 Wheel Spin/Slide Protection

- 10.2.3.1 The spin-slide protection system shall operate on a per-truck basis.
- 10.2.3.2 The spin-slide protection system shall provide performance as specified in Section 2.7.7.

10.2.4 Energy Conservation Mode

- 10.2.4.1 The propulsion control system shall incorporate an energy conservation mode.
- 10.2.4.2 When the energy conservation mode is enabled by the Train Operator as described in Section 5.5.5, motoring performance shall be limited as follows:
- At nominal third rail voltage and above, full acceleration shall be available up to a reduced base speed of 7.5 mi/h (12 km/h);
 - Base speed shall be reduced proportionally in response to third rail voltages below the nominal voltage.
 - Above base speed, the maximum tractive effort shall, on a level tangent track, result in a maximum acceleration of 0.74 mi/h/sec (0.33 m/s²) at 10 mi/h (4.47 m/s) and 0.23 mi/h/sec (0.10 m/s²) at 15 mi/h (6.71 m/s).
 - Balance speed shall be reached at approximately 20 mi/h (8.94 m/s).

10.3 Functional Requirements

10.3.1 Propulsion System

- 10.3.1.1 The propulsion system shall be designed so that when functioning properly, it is completely self-protected against overloads and transients or damage due to all possible combinations of:
- Speed.
 - Third rail voltage.
 - Ambient temperature.
 - Train Operator's actions.
 - CBTC commands or Staten Island Railway (SIR) Cab Signaling commands as applicable.
 - Prior states of the propulsion controls.

- 10.3.1.2 The propulsion system in each car shall respond correctly to local and trainlined commands.

- 10.3.1.3 The propulsion system shall respond safely, smoothly, and predictably under all conditions.

10.3.2 Dynamic Braking

- 10.3.2.1 Regenerative and rheostatic braking shall be provided with regenerative braking having priority.

- 10.3.2.2 During partial or zero line receptivity, the excess dynamic braking energy shall be dissipated by the braking resistor grids as specified in Section 10.4.6.

- 10.3.2.3 The maximum regeneration line voltage shall be adjustable within the range of 675 Vdc to 780 Vdc by changing a single software parameter, initially set to 780 Vdc.

- 10.3.2.4 Failure of dynamic braking shall result in the Friction Brake System on the affected truck(s) automatically providing the requested braking effort.

10.3.2.5 The regeneration feature shall be configured such that it can be disabled train-wide from a single control, in which case dynamic braking shall be rheostatic (see Section 5.5.5).

10.3.3 Dead Rail and Gap Protection

10.3.3.1 A rail gap/dead third rail detector shall be provided on each car.

10.3.3.2 The detector circuit shall detect rail gaps and shall detect the sudden removal of power from the third rail at any location.

10.3.3.3 The detector shall be able to detect a non-bridgeable third-rail gap and inhibit flow of current from the car into the next section of third rail while passing through the gap at the maximum speed, regardless of the propulsion system operating mode.

10.3.3.4 The rail gap protection shall take into account the minimum length of rail gaps in the B Division. Note paragraphs 203.8, 300.2, and others in the MW-1 Track Standards and Reference Manual (see Appendix C-5).

10.3.3.5 The detector and its associated controls shall be arranged to prevent regeneration into the third rail unless the following requirements are met:

- a) Before permitting the initiation of regeneration after any interruption, the detector has determined that correct third rail voltage is present and that the third rail voltage has the characteristics of the power substation's 360 Hz or 720 Hz component(s).
- b) While regenerated energy flows into the third rail, the detector continues to determine that that third rail voltage has the characteristics of the power substation's 360 Hz or 720 Hz component(s).
- c) The detector shall detect a dead rail section and inhibit regeneration into the third rail within 3 seconds.

10.3.3.6 The detector shall incorporate an NYCT approved continuous, or regular self-test function to ensure its integrity.

10.3.3.7 Failure of the dead rail detector self-test function shall be annunciated to the Monitoring and Diagnostic System (MDS) and displayed on the Train Operator's Display (TOD) Trouble Screen (see Section 17). Propulsion and dynamic braking shall be inhibited on the affected truck until the failure is cleared.

10.3.4 Wheel Size Compensation

10.3.4.1 A wheel size compensation system shall be provided for each truck to permit adjustment of tractive effort to maintain rated positive acceleration and braking performance over the entire range of wheel wear.

10.3.4.2 The wheel size compensation system for each truck shall include a self-check and automatic calibration function.

10.3.4.3 Discrepant settings and similar anomalous conditions shall be annunciated to the MDS, if appropriate, and shall be logged for maintenance attention.

10.3.4.4 The derivation of reference speed for automatic calibration may include one manual wheel diameter setting per car.

10.3.5 Load Weigh Compensation

10.3.5.1 A load weigh signal shall be provided to adjust acceleration and braking control with changing car weight.

- 10.3.5.2 Failure of the load weigh compensation system shall result in acceleration normally provided for AW0 and braking effort normally provided for the AW3 weight.
- 10.3.5.3 Load weigh compensation shall be applied to motoring and dynamic braking as specified in Section 2.7.10.
- 10.3.5.4 The load weigh compensation for the Friction Brake System may be accomplished by the propulsion load weigh compensation system, subject to NYCT approval.
- 10.3.5.5 The load weigh compensation system shall not respond to dynamic suspension motions.
- 10.3.5.6 The load weigh compensation system in each car shall report car weight to the MDS (see Section 17.3.7).
- 10.3.5.7 Propulsion system performance in the event of load weigh compensation system failure(s) shall be simulated and validated by testing.

10.3.6 Wheel Spin and Slide Protection

- 10.3.6.1 The spin-slide protection system shall be designed so that failures do not reduce braking effort below that commanded by the brake request.
- 10.3.6.2 The spin-slide protection system shall include a self-calibration function to null out all wheel diameter errors in the relative speed sensing functions and the individual axle rate of change of speed sensing functions.

10.3.7 No-Motion Signal

- 10.3.7.1 The propulsion control logic shall provide a no-motion signal to other systems on the same car, as required by Section 5.5.12.
- 10.3.7.2 The no-motion signal shall indicate when the speed of the car is less than 1.0 mi/h (1.6 km/h).
- 10.3.7.3 The system shall provide valid no-motion information with up to two failed propulsion system speed sensors per car.

10.3.8 Interlocks

- 10.3.8.1 Propulsion system interlocks shall provide for the inhibition or removal of positive tractive effort in conformance with the safety requirements set forth in Section 2.12.
- 10.3.8.2 The propulsion mode shall be inhibited by the following:
 - a) An indication of an open side door panel through the interlock signal specified in Section 6.4.20.
 - b) Command of an emergency brake application.
 - c) Application of Friction Brake at any location in the train.
 - d) Application of a Parking brake at any location in the train.
 - e) When train direction does not correspond to the direction commands that are received as a local or trainline function.
- 10.3.8.3 A sealed Brake Release Interlock Bypass Switch shall be provided in the cab to permit movement of the train in an emergency when full brake release cannot be achieved.

10.3.9 Protection

- 10.3.9.1 The propulsion system shall be protected from damage and incorrect operation by protective functions including, but not limited to, the following:
- a) Traction inverter current overload sensing in acceleration and braking.
 - b) Traction inverter over-temperature.
 - c) Reversed connection of motor leads.
 - d) Traction motor over-temperature.
 - e) Detection of locked traction motor rotor.
 - f) Propulsion ground faults. Detection of a ground fault shall cause power removal by opening the line contactors.
 - g) Charging resistor and braking resistor open circuit protection with lockout of affected functions.
 - h) Transient voltage protection for all solid-state apparatus.
 - i) Detection of failure of line contactor to open when commanded.
 - j) Detection of excessive Electromagnetic Interference (EMI) current if required (see Section 2.11).
 - k) Braking resistor over-temperature.
- 10.3.9.2 Actuation of any protective function shall be annunciated to the MDS (Section 17, Monitoring and Diagnostic System) and also logged in the propulsion system.
- 10.3.9.3 Transient abnormal or fault conditions shall be reset automatically as provided in Section 2.14.3. Resets shall be counted as provided in Section 2.14.3. The details of allowed resets shall be decided upon during design review.

10.3.10 Over-speed Protection

- 10.3.10.1 Tractive effort shall be removed at the maximum declared service speed, to be initially set at 55 mi/h (88.5 km/h).
- 10.3.10.2 The propulsion control system shall include protection logic, which shall be configured such that no propulsion system on a train can be in power while another is in brake.

10.3.11 Friction Brake Test

- 10.3.11.1 The propulsion system shall include provisions to cutout dynamic braking to allow for conducting a running test with friction brakes only.
- 10.3.11.2 Propulsion system dynamic braking cutout shall be implemented on a per car basis via a dedicated Brake Test circuit breaker.

10.3.12 Odometer

- 10.3.12.1 The propulsion control system for each A Car shall include an odometer driven by the propulsion logic to record cumulative mileage information.
- 10.3.12.2 The odometer log shall record distance to a resolution of 1 mile (1.6 km).
- 10.3.12.3 The odometer shall be wheel-size compensated.
- 10.3.12.4 The cumulative mileage information shall be stored in non-volatile memory to prevent loss of information if battery supply is removed.
- 10.3.12.5 Each change to the cumulative mileage record shall be made available to the MDS.

10.3.13 Control Logic

- 10.3.13.1 The propulsion system shall include control logic that shall interpret commands received as trainline functions and provide necessary signals to the propulsion equipment to obtain the requested performance.
- 10.3.13.2 The control logic shall provide:
- a) Self-diagnostic routines.
 - b) Fault monitoring of internal and external devices.
 - c) User programmable operating characteristics.
- 10.3.13.3 Control programs shall be stored in non-volatile memory.
- 10.3.13.4 The propulsion control logic shall be arranged in three hierarchical control levels:
- a) One Car Control Unit (CCU) for each car, and
 - b) An Inverter Control Unit (ICU) for each motorized truck, and
 - c) A Friction Brake Electronic Control Unit (FBECU) for each truck. See Sections 12.1.11 and 12.4.1.1.
- 10.3.13.5 The control logic shall be microprocessor-based and shall comply with Sections 18, Software Systems and 19, Materials, Processes, and Workmanship.
- 10.3.13.6 Each logic unit shall have sufficient capacity to solve the relevant control equations and provide diagnostic capability while permitting expansion of computer function as specified in Section 18, Software Systems.

10.3.14 Car Control Unit

- 10.3.14.1 As a minimum, the CCU on each car shall perform the following functions:
- a) Communication with the on-board digital networks and discrete trainlines for exchange of command and status information with other car systems and functions.
 - b) Load weigh compensation.
 - c) Rail gap and dead rail protection.
 - d) Computation of tractive effort reference for propulsion and dynamic braking.
 - e) Generation of no-motion signal.
 - f) Overall communication with, and supervision of, the inverter and/or friction brake control units on the same car.
 - g) When vehicle direction does not correspond to the direction commands that are received as a local or trainline function, both propulsion Inverters shall be inhibited. No allowance shall be made for rollback. The MDS shall report and record this fault.

10.3.15 Inverter Control Unit

- 10.3.15.1 The Inverter Control Unit (ICU) shall be a single logic unit controlling the inverter for one motorized truck.
- 10.3.15.2 As a minimum, the ICU associated with each motor truck shall perform the following functions:
- a) Control and protection of the associated inverter.
 - b) Control and protection of the associated brake chopper.
 - c) Spin/slide control for the associated truck.
 - d) Coordination with the friction brake equipment, including the prevention of rollback when starting on a grade.
 - e) Communication with the associated car control unit.

10.3.15.3 The ICU shall communicate the status of the above to the MDS specified in Section 17, Monitoring and Diagnostic System.

10.3.16 Diagnostic Features

10.3.16.1 The control units shall provide diagnostic features complying with the requirements of Section 17.4.1, and using Time Clock management as required by Section 17.3.6.

10.3.16.2 The control units shall log and report each fault. A fault shall be defined as:

- a) Activation of a protective function and/or
- b) Occurrence of an abnormal condition indicative of current or incipient equipment failure.

10.3.16.3 The control units shall record time histories of critical vehicle and propulsion system parameters prior to the detection of any fault.

10.3.16.4 Sufficient memory shall be included to store all of the significant parameters that occurred over a period of at least 10 seconds before a fault occurred.

10.3.16.5 Each control logic unit shall include a monitoring panel(s) with visual displays indicating which fault(s) have occurred and other general system conditions.

Fault Data Handling

10.3.16.6 The fault data shall be recorded for a minimum of 100 fault events.

10.3.16.7 If the number of faults exceeds the fault memory storage capacity before the memory is reset, the new event shall write over the oldest of the stored fault events. Fault events resulting in restrictions upon system operation also shall be written to a separate Lockout log. The selection of fault events for this purpose shall be conducted during design review.

10.3.16.8 Fault data shall be retained in non-volatile memory until a reset command is received from the Portable Test Equipment (PTE).

10.3.16.9 Fault data shall be addressable by the PTE for troubleshooting purposes and by the built-in troubleshooting displays.

10.3.17 Inverters

10.3.17.1 Inverter units shall be installed under each car in watertight, dustproof enclosure(s). See Section 15.15 for exterior equipment enclosure watertightness requirements.

10.3.17.2 Each inverter unit shall drive two traction motors mounted on the same truck.

10.3.17.3 Each inverter unit shall be of the pulse-width-modulation (PWM) type utilizing service-proven insulated gate bi-polar transistor (IGBT) power semiconductors. Alternative inverter designs shall be subject to NYCT approval.

10.3.17.4 Each inverter unit shall have two major elements:

- a) Inverter.
- b) Braking chopper.

10.3.17.5 The inverter shall convert the dc voltage supply into a variable-voltage, variable-frequency, three-phase AC voltage, and shall provide this ac voltage to the traction motors.

10.3.17.6 The inverter shall control the torque developed by the traction motors by varying the output frequency and voltage, and shall control the direction of the torque by proper sequencing of the output phases.

10.3.17.7 The braking chopper shall modulate the electrical energy delivered to the braking resistors.

10.3.17.8 The braking chopper shall direct the excess energy to the braking resistors during partial line receptivity.

10.3.18 Input Protection

10.3.18.1 The propulsion system on each car shall be protected with a High Speed Circuit Breaker.

10.3.18.2 A line contactor shall be provided for each inverter to make and interrupt power during normal operations.

10.3.18.3 The line contactors shall be interlocked such that an emergency brake application de-energizes the contactors.

10.3.18.4 The line contactor, its control, and associated equipment shall be arranged to limit instantaneous in-rush currents under all operating conditions to a value that will not cause failure, EMI, or deterioration of any component, including fuses.

10.3.18.5 The method used to limit instantaneous in-rush current shall not affect car performance under conditions of intermittent current collector shoe contact, as with an icy contact rail condition.

10.3.19 Input Filter

10.3.19.1 The propulsion apparatus for each motor truck shall be protected by a separate input filter meeting the requirements of Section 9.5.2.

10.3.19.2 Each input filter shall be provided with a charging contactor and charging resistor(s) that shall limit charging current and input filter voltage overshoot to levels set in Section 9.2.5.

10.3.20 Traction Motors

10.3.20.1 Each motorized axle shall be individually driven by a three-phase AC traction motor of the squirrel-cage type.

10.3.20.2 Over-temperature protection shall be provided as follows:

- a) If the winding temperature rises 27°F above (15°C above) the operating class temperature limit, the control unit shall decrease the motor duty cycle by removing the dynamic braking and converting to frictional braking, until the temperature falls below the operating class temperature.
- b) If the winding temperature rises above its design class operating temperature limit, the control unit shall remove power to the affected truck, until the temperature falls below the operating class temperature. The condition shall be reported and recorded by the MDS.
- c) Motor temperature shall be calculated using a thermal model of the motor and the power that the motor is handling.
- d) The measurement of winding temperatures using embedded sensors is not permitted.

10.3.21 Gear Units

10.3.21.1 Each axle shall be driven by a parallel gear unit designed and manufactured for bi-directional service.

10.3.21.2 External bearing shaft seals shall prevent high velocity splashed water from entering the gear units.

10.3.22 Ground Brushes

10.3.22.1 A ground brush assembly shall be provided on each gear unit on motorized axles.

10.3.23 Speed Sensors

10.3.23.1 Each motorized axle shall be fitted with a pulse generating active speed sensor, which shall be installed on the traction motor. Alternative speed sensor designs or locations shall be subject to NYCT approval.

10.3.23.2 Each sensor and its associated circuitry shall provide positive indication of all motion down to 1 mi/h (1.6 km/h).

10.3.23.3 Direction sensing shall be provided as required by propulsion system logic.

10.3.23.4 The system shall incorporate provisions for mounting CBTC speed sensors in accordance with Section 14, Train Control System.

10.3.24 Friction Brake Interface

10.3.24.1 The propulsion control logic and friction brake control logic shall interface as required to provide overall system performance meeting the requirements of Section 2.7.

10.3.24.2 The interface shall include all necessary output drivers and feedback elements to accomplish continuously variable control of service friction braking on a per-truck basis.

10.3.24.3 The control system shall implement all trainline information decoding, blending, load-weight compensation, failure handling, and other required logic and axle speed calculations to produce service dynamic and friction brake effort as necessary and efficiently to meet the performance requirements of Section 2.7.

10.3.24.4 The control logic shall give priority to dynamic braking under all conditions up to the dynamic braking capacity limits specified in Section 2.7.4.

10.3.24.5 The propulsion control logic shall not initiate, propagate, or limit any emergency brake application in any way, nor shall it delay or suppress any emergency brake application other than as specified in Section 12.3.4 for Passenger Emergency Handle Unit (PEHU) activation.

10.3.24.6 Failure or incapacity of the propulsion control logic on any car shall not interfere with the normal application and release of the emergency brake, except:

- a) Brake Pipe charging time may be extended proportionally as specified in Section 12.3.3.16.
- b) Response to a PEHU activation may be modified as specified in Section 12.3.4.5.

10.3.24.7 Failure or incapacity of the propulsion control logic on any car shall not interfere with the release of the service brake, which shall attempt a normal brake release, except:

- a) Wheel slide correction can be temporarily inactive.
- b) Load weighing can temporarily default to its inactive state.

10.4 Design Requirements

10.4.1 Electrical Isolation

- 10.4.1.1 Control circuitry and control voltage sources shall be optically or transformer isolated from power circuitry and high voltage sources.
- 10.4.1.2 Electronic control equipment shall be segregated from power equipment except for power semiconductor drive circuits, which may be located where required to achieve necessary drive signal characteristics.
- 10.4.1.3 Electrical isolation of battery potential circuits from power collector potential wiring in apparatus enclosures shall be provided, by means of insulating barriers or separation between the high and low voltage circuits.
- 10.4.1.4 Protection of all current-carrying parts connected to circuits with power collector potential shall be provided by means of insulation, location, or guarding to prevent accidental contact.

10.4.2 Safety Labeling

- 10.4.2.1 All doors, cover plates, screens or frames guarding high voltage apparatus shall be marked "Danger-High Voltage."
- 10.4.2.2 Safety warning signs shall conform to the requirements of Section 15.14.4.

10.4.3 Power Semiconductors

- 10.4.3.1 Power semiconductors shall be selected and applied to operate at no more than 70 percent of their breakdown capabilities.
- 10.4.3.2 Power semiconductors shall be selected and applied in such a manner that a minimum 40-year design life shall be obtained with respect to cyclic and steady state thermal parameters.

10.4.4 Inverter Cooling

- 10.4.4.1 Inverter unit cooling shall be accomplished by passive means.
- 10.4.4.2 The heat exchangers shall be solid metal heat sinks, unless otherwise approved by NYCT.
- 10.4.4.3 There shall be no electrically live surfaces external to the inverter enclosure.
- 10.4.4.4 Airflow across the heat exchanger fins shall be accomplished by natural convection and/or by motion of the car.
- 10.4.4.5 Internal or external cooling blowers are not permitted.
- 10.4.4.6 No external air shall pass through the interior of the inverter enclosure.
- 10.4.4.7 Chlorofluorocarbon (CFC)-based cooling methods shall not be used.
- 10.4.4.8 Fluid-based cooling methods of any type shall not be used with the exception of sealed heat pipes containing non-CFC based fluids, which shall be subject to NYCT approval. Tanks containing a cooling liquid and components are not permitted.
- 10.4.4.9 The point of heat exchange with the atmosphere shall be external to the sealed inverter enclosure.

10.4.5 Input Protection

High Speed Circuit Breaker

- 10.4.5.1 The propulsion system on each car shall be protected with a High Speed Circuit Breaker (HSCB) with a 30-kA DC interrupting capacity and a total breaking time of less than 15 milliseconds for a current rise of 5 Amperes per microsecond.
- 10.4.5.2 The HSCB shall be designed for a minimum of 100,000 mechanical operations.
- 10.4.5.3 The HSCB shall be installed in its own enclosure or in an approved, isolated compartment of a multi-purpose enclosure.
- 10.4.5.4 The arc chute design shall permit the arc to be safely guided away from the opening current carrying contacts.
- 10.4.5.5 The arcing energy shall be dissipated in a controlled, proportional manner using a series of de-ionizing cavities mounted on the HSCB housing.
- 10.4.5.6 The HSCB enclosure compartment shall have atmospheric venting openings to minimize ionized gas buildup.

Line Contactors

- 10.4.5.7 Line Contactor capability shall be coordinated with input protective device capability.
- 10.4.5.8 Line contactors shall be designed for a minimum of 1,000,000 mechanical operations with a minimum contact life equivalent to 100,000 miles (160,000 km) of normal operation. Routine contact replacement shall be indicated in the propulsion system Maintenance Manuals.
- 10.4.5.9 The arc chute design shall permit the arc to be safely guided away from the operating contacts.
- 10.4.5.10 Venting shall be provided to prevent ionized gas buildup in the contactor compartments.

10.4.6 Braking Resistors

- 10.4.6.1 Braking resistor design shall conform to IEC 60322 - Railway applications - Electric equipment for rolling stock - Rules for power resistors of open construction.
- 10.4.6.2 Braking resistors shall be assembled in frames of convenient size for natural ventilation. Forced ventilation shall not be permitted.
- 10.4.6.3 All resistor frames, heat shields, screens, and hardware shall be constructed of stainless steel and meet NFPA 130 – “Standard for Fixed Guideway Transit and Passenger Rail Systems”.
- 10.4.6.4 Braking resistor capacities shall be designed to meet the AW3 braking performance in Section 2.7.4 with no regeneration into the line, and to withstand the most severe duty cycles continuously without damage.
- 10.4.6.5 The resistors shall be mounted underneath the car and shall be protected from wheel splashes.
- 10.4.6.6 Heat insulation between the resistors and the carbody or carbody wiring shall be a stainless steel sheet.
- 10.4.6.7 There shall be no high voltage present in any of the resistors of the Braking Resistor assembly when the train is at standstill.
- 10.4.6.8 The resistor grids shall be isolated from their frames, and frames from the carbody with high-temperature electrical insulators.

- 10.4.6.9 Protective screens shall be provided on the top and sides of the resistor frame(s) to minimize the possibility for papers, plastic bags, and other debris being lodged within the assembly. The bottom of the enclosure shall be left open to allow debris to fall out.
- 10.4.6.10 The maximum operating temperature of any grid shall not exceed 1200°F (660°C).
- 10.4.6.11 The braking resistor assembly shall be designed to minimize the inductive coupling of brake chopper harmonic currents into the track circuits.

10.4.7 Traction Motors

General

- 10.4.7.1 The traction motor shall be of a totally enclosed, or drip-proof, splash-proof, or open design with maximum protection against ingress of abrasive materials and water.
- 10.4.7.2 The traction motor shall be designed in accordance with IEC Standard 60349-2, Electric Traction--Rotating Electrical Machines for Rail and Road Vehicles--Part 2: Electronic Converter-Fed Alternating Current Motors, or IEEE Std. 11, IEEE Standard for Rotating Electric Machinery for Rail and Road Vehicles.
- 10.4.7.3 The motor shall have a safe speed rating that meets the corresponding requirements of Section 8.3 of IEC 60349-2 or Section 9 of IEEE 11.
- 10.4.7.4 The motor, when operated under the conditions specified in Section 2.7, shall have a temperature rise at least one class below its design class according to IEEE Std. 11 Section 5 table 1 or IEC60349-2 Section 8.1.5 Table 2. The temperature of the windings shall not adversely affect bearing lubrication or bearing life.
- 10.4.7.5 The traction motor shall be designed so that its operating temperature and characteristics are compatible with the maximum 0.25 inch (6.4 mm) wheel diameter difference between axles on the same truck.
- 10.4.7.6 The completed motor frame with insulated coils shall be vacuum-pressure impregnated with a high-temperature insulation with temperature rating class at least equal to the temperature rating class of the motor winding insulation.

Rotor

- 10.4.7.7 The traction motor rotor cage shall be of copper alloy bars with brazed or welded rings, unless otherwise approved by NYCT.
- 10.4.7.8 The rotor and cooling fan shall be dynamically balanced, so that after assembly the net dynamic imbalance measured at each bearing is less than 1.0 inch-ounces (0.72 mm-kg).
- 10.4.7.9 Balance correcting weights shall be metal and retained by one of the following methods:
 - a) Welded in place.
 - b) Secured in retention grooves.
 - c) Bolted in place.

Terminals and Leads

- 10.4.7.10 Motor leads shall be connected to the stator winding connection tabs via bolted terminations.
- 10.4.7.11 It shall be possible to replace motor leads without disturbing winding insulation.
- 10.4.7.12 Terminals and terminal blocks shall be protected from weather and the operating environment.
- 10.4.7.13 Motor leads shall be clearly marked to prevent misconnection, as required by Section 19.24.4.

- 10.4.7.14 The Contractor may propose the use of motor leads of varying length to prevent misconnection; however, the motors, inclusive of the leads, must be interchangeable between both locations on any motor truck.
- 10.4.7.15 Motor lead routing for each motor location, from terminal to quick-disconnector shall be submitted for NYCT approval.
- 10.4.7.16 Motor lead connectors shall be secured on top of the traction motor frame within a fire resistant and weather tight terminal holder that provides strain relief for the cable connections.
- 10.4.7.17 Traction motor connections to car wiring shall be through a quick-disconnector, or approved alternative, mounted to the carbody in the vicinity of the truck.
- 10.4.7.18 The current value used in determining the minimum size of motor leads shall be no less than that recommended by NFPA 130, Section 8.6.3.6.

Bearings and Lubrication

- 10.4.7.19 Traction motors shall be equipped with means to prevent winding current or voltage induced currents within the motor frame from damaging the bearings, and the components of the coupling and gear-unit.
- 10.4.7.20 Bearings shall be electrically insulated with an approved coating applied to the outer race mounting surfaces.
- 10.4.7.21 The traction motor bearing lubrication schedule shall be submitted for NYCT approval.
- 10.4.7.22 Bearings shall not require replacement more often than at every SMS cycle (see Appendix C-36, "SMS Generic Car Workscope and Time Intervals").
- 10.4.7.23 The motors shall be supplied lubricated and ready for operation.
- 10.4.7.24 The bearings shall have an ANSI/AFBMA L10 rating life of 1,000,000 miles (1,610,000 km).
- 10.4.7.25 Lubricant shall be selected from the "NYCT List of Lubricants for All Car Classes" (see Appendix C-12).

Mounting Details

- 10.4.7.26 The traction motor shall be isolated by resilient elements from equipment below the primary suspension, including the gear unit if the latter is axle-mounted. The mounting arrangement shall be submitted for review. [CDRL].
- 10.4.7.27 The motors shall be designed for coupling by means of a gear-type coupling to the gear unit.
- 10.4.7.28 Traction motor mounting bolts shall be Grade 5 bolts as a minimum and shall be tightened with a torque wrench to a repeatable torque value.
- 10.4.7.29 If Grade 8 bolts are used, they shall meet the requirements of Section 19.19.7.
- 10.4.7.30 Hardened steel flat washers shall be used under bolt heads and nuts.
- 10.4.7.31 If a WN-type drive is employed, tapped holes in the lower motor suspension mounting shall have class 2-B threads or better.
- 10.4.7.32 The traction motor shall be provided with lifting lugs or with means for attaching lifting devices such as a tapped hole for lifting eyebolts. Lifting lugs/attaching devices shall be subject to NYCT review and approval.
- 10.4.7.33 The motor configuration shall ensure stability when the motor is placed on the floor.
- 10.4.7.34 The motor mounting bracket shall be integral to the motor frame. Bolting of the bracket to the motor and then to the truck shall not be allowed.

- 10.4.7.35 The traction motor shall be prevented from falling to the roadbed in the event of failure of the primary motor mounts as specified in Section 11.4.4.13.
- 10.4.7.36 The motors shall be designed with suitable truck clearances to permit each motor and gear unit combination to be removed from the truck without interference with members of the truck frame.
- 10.4.7.37 It shall be possible to remove the traction motor from above the truck without removal of the gear unit.
- 10.4.7.38 Clearances beneath the motor and gear unit shall be as specified in Section 11.2.1.8.

Vibration Limits

- 10.4.7.39 The vibration of any traction motor shall not exceed 0.0015-inch (0.038-mm) peak to peak displacement when:
 - a) Measured at the motor bearing housing and at the motor mounting points.
 - b) The motor is detached and supported on resilient mountings providing at least 0.25-inch (6.4-mm) static deflection.
 - c) The motor is rotating at any speed between 50 percent and 100 percent of the maximum normal operating speed.
- 10.4.7.40 Each assembled motor shall meet the vibration requirements of IEEE Std. 11, Section 13.2.

Ventilation and Noise

- 10.4.7.41 Motors shall be self-ventilated with an integral low-noise type fan.
- 10.4.7.42 Traction motor design shall minimize audible noise resulting from high frequency current switching patterns when operating from the propulsion inverter. The laboratory measurement of traction motor noise shall be done with an inverter source.
- 10.4.7.43 Motor openings shall be arranged to minimize ingestion of snow and dirt from the track bed, and the possibility for objects being dropped into the motor during maintenance.

10.4.8 Gear Units

General

- 10.4.8.1 The gear ratio shall be selected to provide the performance specified in Section 2.7 and shall conform to established railcar gear design practice.
- 10.4.8.2 All gear units shall be interchangeable.
- 10.4.8.3 Gear unit noise shall meet the requirements of Section 2.9.
- 10.4.8.4 All gear unit bearings shall be tapered roller bearings selected and applied to have an ANSI/AFBMA L10 rating life of 1,000,000 miles (1,610,000 km) with no degradation of performance.
- 10.4.8.5 Gears shall be fabricated from high-quality gear steel, designed and heat-treated/hardened in accordance with American Gear Manufacturers Association (AGMA) Standards.
- 10.4.8.6 Gears shall meet AGMA Quality Standards 8 to 10, or better. An alternate quality range may be accepted if the Contractor can demonstrate that the proposed range will meet specified performance standards.

Lubrication

- 10.4.8.7 The unit shall be designed such that adequate lubrication will be provided to all bearings and gears under the most severe operating conditions and to prevent moisture infiltration into the lubricant.
- 10.4.8.8 The gear unit shall not use or lose more than 1 quart (1 L) of oil within 60,000 miles (96,000 km) and shall not require oil change more frequently than every 120,000 miles (other than one break-in type lubricant change).
- 10.4.8.9 The gear unit shall have sufficient oil capacity for adequate cooling.
- 10.4.8.10 All gear lubrication shall be in accordance with AGMA Standards and shall be selected from the NYCT List of Lubricants for All Car Classes (see Appendix C-12).
- 10.4.8.11 The gear unit shall have at least one oil drain opening located at the lowest point in the case or sump.
- 10.4.8.12 Drain plug(s) shall be installed in the drain opening(s) and properly secured.
- 10.4.8.13 A readily accessible filler plug shall be provided with the opening arranged to provide an indication of oil level and to prevent overfilling.
- 10.4.8.14 The filler plug may be magnetic or may be nonmagnetic provided that a magnet shall be included in the gear unit, located for maximum contact with the lubricating oil, and readily removable for cleaning.
- 10.4.8.15 The gear unit lubrication system shall be readily accessible without de-trucking.
- 10.4.8.16 All fill drain and inspection plugs shall be safety-wired and shall be of a type or be located to prevent damage by obstacles on the track.
- 10.4.8.17 Removable and accessible oil-tight and airtight inspection covers with elastomeric gaskets or an approved equivalent method of sealing shall be provided for visual inspection of the gears.
- 10.4.8.18 The gear case shall be provided with a readily accessible glass sight gauge protected by an NYCT approved captive cover for use by maintenance personnel.
- 10.4.8.19 The quantity and grade of lubricant shall be indicated either on the filler cap or on the gear unit housing adjacent to the caps.

Mounting

- 10.4.8.20 The gear unit shall be fully suspended from the truck frame with a flexible connection to the axle or shall be axle-mounted with a resilient mount at the end opposite the axle.
- 10.4.8.21 If axle mounted with a resilient mount at the opposite end, the resilient mount shall be the vertical bolt type using bonded rubber pads at the tongue of the gear unit and at the point of suspension from the truck.
- 10.4.8.22 Bonded rubber pads shall meet the following physical specifications:
- Tensile strength, minimum: 3,000 psi (20.7 MPa).
 - Elongation, percent minimum: 450.
 - Decrease in tensile strength and elongation, after aging (heating in air at 158°F (70°C) for 288 hours), percent maximum: 20.
- 10.4.8.23 Resilient material composition, physical and mechanical properties shall be submitted for NYCT approval.
- 10.4.8.24 The drive train design shall not increase the stiffness of the axle suspension within the truck.

Manufacturing

- 10.4.8.25 Standard commercial parts shall be used to the maximum extent.
- 10.4.8.26 Supplier and part numbers shall be identified on drawings, Bills of Material, or parts lists.
- 10.4.8.27 Particular attention shall be given to thoroughness of welding, forming, machining, and assembling of parts. Burrs and sharp edges shall be rounded (see Section 19.1.3).
- 10.4.8.28 After assembly, units shall be thoroughly cleaned of manufacturing debris and other foreign material (see Section 19.1.3).

Coupling

- 10.4.8.29 A double internal-external, self-aligning, gear-type coupling shall be provided between each gear unit and the associated traction motor.
- 10.4.8.30 The coupling shall be suitably balanced to minimize noise or vibration produced at car speeds up to 60 mi/h (97 km/h) in both directions with fully worn wheels.
- 10.4.8.31 The arrangement shall provide for lateral, vertical, longitudinal, and angular motion.
- 10.4.8.32 The coupling shall be grease-lubricated.
- 10.4.8.33 Suitable seals shall be provided.
- 10.4.8.34 Lubricant shall be selected from the "NYCT List of Lubricants for All Car Classes" (see Appendix C-12).

10.4.9 Ground Brushes

- 10.4.9.1 The ground brush assembly shall meet the requirements of Sections 9.4.8 and 9.4.9.

10.4.10 Speed Sensors

- 10.4.10.1 The active face of each speed sensor shall be smooth with no protruding elements.
- 10.4.10.2 The sensor shall be hermetically sealed in a stainless steel case.
- 10.4.10.3 The active face shall be encased in a seamless stainless steel cover.
- 10.4.10.4 All sensors shall be freely interchangeable, without shimming or other mechanical adjustment.
- 10.4.10.5 It shall be neither necessary nor possible to make any mechanical adjustments to set the gap between the sensor probe tip and the gear tooth.
- 10.4.10.6 If mounted to count drive gear teeth, the mounting plate shall be precision milled for this purpose and shall be above the normal lubricant level, so that removal will not cause lubricant loss.
- 10.4.10.7 The speed sensor and its cabling shall be located to provide the maximum protection from flying objects and other potential sources of damage.
- 10.4.10.8 All speed sensors shall be easily accessible for inspection and replacement with trucks attached to vehicles over maintenance pits.
- 10.4.10.9 Electrically shielded leads shall be used from the sensor to the carbody and shall be encased in flexible sheathing.
- 10.4.10.10 The sensor end of the electrical leads shall be fitted with an integral cable and sleeve to provide a watertight seal around the connection and to prevent fatigue of the wire.

10.4.10.11 The speed sensor leads shall be dressed and supported on the truck and carbody as necessary to prevent chafing and fatigue failure.

10.5 Maintainability Requirements

10.5.1 Control Logic Location

10.5.1.1 The control logic shall be securely mounted in environmentally protected enclosures with adequate provisions for installation, cooling, maintainability, removal, and safety.

10.5.1.2 Control electronics may be located in a single area, but controls for each truck shall be segregated within the enclosure.

10.5.2 Semiconductor Modules

10.5.2.1 Power semiconductors and the associated gate drivers shall be arranged into modular assemblies, each mounted on its own heat sink or heat transfer plate.

10.5.2.2 Replacement of semiconductor module assemblies shall be accomplished with standard hand tools and lifting devices.

10.5.2.3 Each semiconductor module assembly shall be designed and designated as Line Replaceable Units (LRUs).

10.5.3 Odometer

10.5.3.1 The cumulative mileage shall be recorded and readable by the Propulsion PTE and from inside the cab.

10.5.3.2 Whenever the electronic panel containing odometer information is replaced, means shall be provided to enter an estimated mileage into the new device using the PTE.

10.5.4 Propulsion Control Logic Monitoring

10.5.4.1 A central control logic unit shall be arranged for the connection of PTE to permit static testing, diagnostics, and monitoring of the propulsion system during car operation. Refer to Section 22.8.5 for general requirements for PTE.

10.5.4.2 Each control logic unit shall have a minimum of eight channels available as analog outputs for a high impedance chart recorder, each having the ability to address all logic signals significant to analysis and diagnosis, including signals to and from contactors, and all external inputs and outputs. Alternative methods of viewing and analyzing propulsion waveforms and signals may be proposed for NYCT approval.

10.5.4.3 Scaling of software variables shall be integral with the design. They shall be displayed using a numeric scale and formatting that requires no effort by the user to understand their meaning.

10.5.4.4 The connection to the MDS shall permit the monitoring of the propulsion status on the cab TOD. This shall include; filter voltage, each motor torque, wheel spin-slide activity, each brake cylinder pressure, each motor temperature and each braking resistor temperature.

10.5.4.5 The MDS connection shall not prevent use of a directly connected PTE.

10.5.5 Traction Motors and Gear Units

General

- 10.5.5.1 Gear unit components shall be readily accessible for repair or replacement, with a minimum amount of gear unit disassembly.
- 10.5.5.2 Parts requiring replacement or adjustment shall be individually replaceable prior to reaching the in-service design life of the system.
- 10.5.5.3 Adequately bolted and gasketed openings shall be provided for inspection and routine maintenance.
- 10.5.5.4 Disassembly, re-assembly, and service maintenance of traction motors and gear units shall require common tools and maintenance equipment to the greatest extent possible.
- 10.5.5.5 Special tools required for disassembly, re-assembly, and service maintenance of traction motors and gear units shall be subject to NYCT approval, and shall be provided by the Contractor as specified in Section 22.7.

Traction Motors

- 10.5.5.6 The traction motor insulation system shall be designed to not require scheduled re-impregnation for at least 21 years or 1,260,000 miles (2,028,000 km), whichever occurs first, when operated in NYCT revenue service.
- 10.5.5.7 For bearing maintenance requirements see sections 10.4.7.19 through 10.4.7.25.

Gear Units

- 10.5.5.8 Gears shall be designed and installed for a minimum overhaul and adjustment interval of 500,000 miles (805,000 km).
- 10.5.5.9 The gear unit lubricant shall not require changing more frequently than every 120,000 miles (192,000 km) after one initial break-in type lubricant change.
- 10.5.5.10 Gears shall have a minimum fatigue design life of 1,000,000 miles (1,610,000 km) with no degradation of performance.
- 10.5.5.11 Gear unit bearings shall have a minimum overhaul or adjustment interval of 420,000 miles (676,000 km).
- 10.5.5.12 The gear unit shall be oil-lubricated using approved lubricant specified in NYCT List of Lubricants for All Car Classes (see Appendix C-12).
- 10.5.5.13 Seasonal changes of lubricants shall not be required.

10.6 Validation Requirements

10.6.1 General

- 10.6.1.1 It shall be the responsibility of the Contractor, as the system integrator, to assure that the propulsion system is properly installed and to ensure successful functioning and proper performance of the car, in accordance with Specification requirements.
- 10.6.1.2 Validation of propulsion system performance and electromagnetic interference (EMI) characteristics compliance shall be performed at the laboratory and train level. This shall include setting regeneration voltage to any value within the range specified in Section 10.3.2.3.
- 10.6.1.3 A System Functional Description (SFD) shall be submitted for NYCT approval. This shall include details of the method and regular self-test function incorporated into the Dead Rail and Gap Detector (Section 10.3.3) [CDRL]

10.6.1.4 The propulsion system shall be compliant with, and tested to the requirements of IEC-61287-1, and the over-voltages specified in IEC 60850, Annex "A" using all the voltages associated with a "Un" of 750V.

10.6.2 Control Logic Design

10.6.2.1 The proposed control logic methodology and design details shall be submitted for NYCT approval. [CDRL]

10.6.2.2 Safety and maintainability provisions for mounting of the Control Logic (Section 10.5.1) shall be submitted for approval. [CDRL]

10.6.2.3 Details of the propulsion system energy conservation mode performance characteristic shall be submitted for approval. [CDRL]

10.6.3 Traction Motor Leads

10.6.3.1 The design of traction motor lead connection arrangement is subject to NYCT approval. [CDRL]

10.6.3.2 The submission shall include details of the method used to secure traction motor connectors to the traction motor frame required by Section 10.4.7.16.

10.6.4 Traction Motor Insulation

10.6.4.1 The vacuum pressure impregnation (VPI) process shall be submitted for review and approval. [CDRL]

10.6.4.2 Sample stator and winding assemblies shall undergo the VPI process simultaneously with production stators to verify the VPI process.

10.6.4.3 The Contractor shall section the sample stator assemblies to establish freedom from voids and to verify that there is good bonding.

10.6.4.4 This VPI verification shall be conducted with the first two stators and two others selected at random by NYCT.

10.6.4.5 If voids are found in the insulation by NYCT, the VPI process shall be modified until corrected and the quantity of samples shall be increased.

10.6.4.6 All VPI verification costs, and subsequent corrections to production motors, shall be borne by the Contractor.

10.6.4.7 Relevant life analysis and supporting rail transit revenue experience for traction motor insulation shall be submitted for NYCT approval. [CDRL]

10.6.5 Traction Motor Noise

10.6.5.1 An analysis of traction motor noise to predict pure tone noise content shall be submitted for approval.

10.6.5.2 Predicted pure tone traction motor noise levels, when operating from the propulsion inverter, shall be verified during propulsion system qualification testing.

10.6.6 Control Logic Faults and Memory

10.6.6.1 The list of faults shall be submitted for NYCT approval (see Section 10.3.16.2).

- 10.6.6.2 All faults and events shall be tested or simulated during Power Laboratory Testing (see Section 10.6.10) on a test bed to ensure they can be detected and diagnosed to provide clear and unambiguous fault, event and repair or LRU replacement information. The PTE and MDS information shall be checked and corrected as necessary.
- 10.6.6.3 Worst-case scenarios shall be used to calculate memory use and capacity and shall be submitted for NYCT approval.

10.6.7 Speed Sensors

- 10.6.7.1 Speed sensor cable routing shall be submitted to NYCT for review and approval. [CDRL]
- 10.6.7.2 Speed sensor cable routing shall be subject to a FAI maintainability demonstration.

10.6.8 Traction Motor Tests

- 10.6.8.1 The Contractor and/or its subcontractors shall perform qualification tests of Traction Motors to demonstrate conformance to the requirements of this Specification.
- 10.6.8.2 The first motor, one additional motor, and then one for every 100 motors, selected at random by NYCT, shall be given an IEC Publication 60349-2 Type test by the manufacturer.
- 10.6.8.3 The Type Testing procedure shall be submitted for NYCT approval prior to test. The completed Type Test report shall also be submitted for NYCT approval.
- 10.6.8.4 Motor balance shall be dynamically tested to meet the requirements of Section 10.4.7.8.

10.6.9 Gear Unit Tests

- 10.6.9.1 The Contractor shall perform gear unit qualification tests to demonstrate conformance to the requirements of this Specification.
- 10.6.9.2 Two gear units, selected at random by NYCT, shall be subjected to a 100-hour running test as defined below.
- 10.6.9.3 The gear units shall be tested with torque load simulating maximum service conditions plus 20 percent. To that end, the manufacturer shall include the actual duty cycle information for the worst-case service conditions relative to torque/power versus speed as part of the test procedure documentation.
- 10.6.9.4 From Section 2.7, the actual duty cycle testing diagram shall then be developed. The test shall subject the gear units to conditions that are 20 percent greater in torque and speed than the worst case torque/speed combination for both gear and bearing fatigue life.
- 10.6.9.5 Torque load shall also include the effects of dynamic braking.
- 10.6.9.6 The test shall be started with the unit at a temperature from 60°F to 90°F (15.6°C to 32.2°C). In service airflow conditions may be conservatively simulated if cooling is critical.
- 10.6.9.7 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 stated in the Contractor's maintenance manuals.
- 10.6.9.8 The direction of rotation shall be reversed at intervals not greater than every 8 hours until the 100-hour test is completed.
- 10.6.9.9 Noise and vibration tests shall also be performed to verify the requirements of Section 2.9.

- 10.6.9.10 After completion of the test, the gear units shall be disassembled and all parts examined. Each gear tooth mesh and tooth pattern shall be checked and recorded before and after the test. Any sign of deterioration of any part shall be investigated jointly with NYCT.
- 10.6.9.11 The test report shall include test records of running time, oil temperatures, leak rates, and vibration readings taken at such intervals as required to verify compliance with this Specification.

10.6.10 Power Lab Tests

- 10.6.10.1 The Contractor shall perform a combined systems laboratory test on one complete set of propulsion equipment, including motors, gear units, power conditioning, protection devices, logic, and all interfaces to the friction brake system. Motor speed shall be controlled using an active dynamometer which simulates car inertia, train resistance, and rail gradient by means of a coupled and programmed motor generator.
- 10.6.10.2 The physical layout of car components and cabling for this test shall simulate actual car conditions. This test is for the purpose of demonstrating that the propulsion equipment functions properly and meets all requirements of this Section.
- 10.6.10.3 When testing the propulsion system for compliance with this Section, thermal duty and system performance settings shall reflect the maximum usable design capabilities.
- 10.6.10.4 Comprehensive test of the propulsion system self-protection, fault detection, and fault diagnostic annunciation capabilities via the PTE and MDS shall be conducted as a part of lab qualification test program.
- 10.6.10.5 The Power Lab Test Testing procedure shall be submitted for NYCT approval prior to test. The completed Test report shall also be submitted for NYCT approval.
- 10.6.10.6 An abbreviated acoustical noise test shall be made on the traction motor while operating from the actual traction inverter intended to be supplied.
- 10.6.10.7 Noise shall be measured at a distance of 15 feet (4.6 m) from the traction motor when accelerating from 0 to 40 mi/h (0 to 64 km/h) and when decelerating from 40 to 0 mi/h (64 to 0 km/h).
- 10.6.10.8 This set of propulsion equipment shall also be tested for electromagnetic emissions, conductive and inductive, according to the methods referenced in Section 24.7.7.

10.6.11 Traction Motor Routine Tests

- 10.6.11.1 Each traction motor shall be given a "routine" test by the manufacturer in accordance with IEC Publication 60349; an alternative test standard used in the industry may be proposed for approval by NYCT.
- 10.6.11.2 All the routine test options in IEC Publication 60349-2 shall be tested, with the exception of IEC 60349-2 clauses 9.2 and 9.4.

10.6.12 Gear Unit Routine Tests

- 10.6.12.1 Each gear unit shall be given the manufacturer's "routine" test, which shall include, at a minimum, the following:
- a) Gear tooth mesh shall be checked to verify that it is within the manufacturer's tolerances before the gear unit is operated.

- b) No-load operation at 60 mi/h (96.5 km/h) equivalent car speed for 10 minutes for each speed in each direction.
- 10.6.12.2 Noise and vibration produced by each gear unit and gear sump oil temperature shall be continuously monitored.
- 10.6.12.3 All gear units which do not meet the manufacturer’s requirements for oil temperature, or the manufacturer’s requirements for noise and those of Section 2.9 relative to these speed and load conditions shall be rejected.
- 10.6.12.4 Noise shall be checked at 60 mi/h (96.5 km/h) and oil temperature and vibration shall be checked at 70 mi/h (113 km/h).

10.7 Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

<u>CDRL</u>	<u>Ref</u>	<u>Deliverable</u>	<u>Timing</u>
10-01	10.4.7.26	Traction motor mounting arrangement	PDR
10-02	10.6.1.3	Dead Rail and Gap Detector design	CDR
10-03	10.6.2.1	Proposed control logic methodology and design details	CDR
10-04	10.6.2.2	Control logic mounting arrangement	CDR
10-05	10.6.2.3	Propulsion system energy conservation mode characteristic	CDR
10-06	10.6.3.1	Traction motor lead connection arrangement	CDR
10-07	10.6.4.1	VPI process	CDR
10-08	10.6.4.7	Traction motor insulation life analysis and revenue experience	CDR
10-09	Not used	Not used	Not used
10-10	Not used	Not used	Not used
10-11	10.6.7.1	Speed sensor cable routing	CDR

Section 11

Trucks and Suspension System

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11. Trucks and Suspension System

11.1. Introduction and General Requirements

11.1.1. This section defines the requirements for the trucks and suspension system on the cars. The requirements are divided into Performance, Function, Design, Maintainability, and Validation sections. Refer to the following sections for car systems and components interfacing with the Truck and Secondary Suspension System and other applicable requirements:

- a) Design and Performance Criteria – Section 2.
- b) Carbody Structure – Section 3.
- c) Materials, Processes, and Workmanship – Section 19.
- d) Reliability, Maintainability, and System Assurance - Section 21.
- e) System Support - Section 22.
- f) Testing Program – Section 24.

11.1.2. The trucks and suspension system consists of all truck components from the rail to the body bolster, including any suspension subsystem components mounted to the carbody. Requirements for propulsion equipment and brakes are defined in Sections 10 and 12 (respectively) of the Technical Specification.

11.1.3. The truck system shall be such that the car level stability, derailment mitigation, and ride quality requirements defined in Section 2.10 are satisfied.

11.2. Performance Requirements

11.2.1. General

11.2.1.1. The trucks and suspension system shall meet all of the requirements of this section and all of the applicable system design and performance requirements within Section 2, Design and Performance Criteria.

11.2.1.2. The Contractor is responsible for selecting truck design loads and allowable design stresses. Design loads and allowable stresses shall be submitted to NYCT for approval as part of the Truck Stress Analysis Plan (TSAP) (Section 11.6.2). The design loads shall consider normal and exceptional load cases, including all combinations of these cases.

11.2.1.3. The trucks shall be free to swivel, shall remain stable, and shall exhibit acceptable hunting stability at all speeds defined in Section 2.15.1, with all track conditions not condemnable by NYCT as defined in Appendix C-5 (Track Standards and Reference Manual MW-1), and with any non-condemnable wheel profile or suspension wear condition.

11.2.1.4. The truck assembly shall maintain the axles parallel to within 0.090 inch (2.29 mm) and limit the difference between diagonally opposed bearing locations to 0.20 inch (5.1 mm) when loaded between AW0 and 130 percent of AW3.

11.2.1.5. The truck stability and stiffness characteristics shall not cause wheel wear requiring wheel truing more frequently than every 60,000 miles (96,560 km).

11.2.1.6. Wheels shall not exhibit hollow wear (false flange) patterns or flange wear below the condemning thickness (thin flange) before reaching condemnable high flange condition.

11.2.1.7. Wheels shall not exhibit thermal cracking under the specified braking duty cycles of Section 2.7.11.

Clearances

- 11.2.1.8. The assembled truck with all equipment shall not exceed clearance limits required between truck and wayside equipment with maximum wear and load, primary or secondary suspension deflection, and/or rubber creep, in accordance with the clearance requirements contained within Appendix D-1 (Memorandum of Understanding Car and Line Equipment Clearances MISC #00-01).
- 11.2.1.9. The Contractor shall provide for the clearances between the trucks and the carbody and all its parts under all operating and loading conditions, including wheel and other wear. Clearances shall be provided for operation, carbody to truck cabling and hoses, internal truck cabling, piping, and hoses, inspection, maintenance, and repair, including lifting actions.
- 11.2.1.10. All truck parts with the exception of wheels, current collector shoes, trip cocks, and axle mounted equipment, shall clear the plane of the top of the rails by not less than 2.50 inches (64mm) under all conditions.
- 11.2.1.11. The suspension system shall not permit carbody motion to exceed the dynamic outline clearance requirements contained within Appendix D-1(Memorandum of Understanding Car and Line Equipment Clearances MISC #00-01), under all operating conditions.
- 11.2.1.12. Stops required to restrict lateral carbody motions shall be provided with elastomeric cushions providing not less than 0.5 inch (13 mm) of compression, with spring characteristics appropriate to achieve the required truck performance.

Noise and Vibration

- 11.2.1.13. The trucks shall not produce amplitudes of low frequency range ground-borne vibration greater than current NYCT cars or expose persons near the right-of-way to a vibration spectrum that compares unfavorably to current NYCT cars under identical test conditions. This shall be proven by test.
- 11.2.1.14. Truck-mounted components shall meet the shock and vibration requirements of Section 2.9.6.
- 11.2.1.15. Operational noise output of the truck shall allow the interior and wayside noise requirements of Sections 2.9.2 and 2.9.3 to be met.

Design Life

- 11.2.1.16. Design life of all truck components shall be based on track and operating conditions defined in Section 2 and Appendix A (Fixed Facility Description), an annual mileage of 60,000 miles (96,560 km), with an average of two station stops per mile, and an average speed of 15 mi/h (24 km/h).
- 11.2.1.17. The design life for elastomeric components shall be at least one SMS cycle (7 years).
- 11.2.1.18. Suspension dampers shall have a design life of at least one SMS cycle (7 years).
- 11.2.1.19. All other systems and subsystems without specified design life values shall have a design life in accordance with Section 2.1.4.

11.2.2. Truck Frame and Bolster**Loads and Allowable Stresses**

- 11.2.2.1. The truck shall be capable of withstanding the maximum loads imposed by the forces acting on the frame and bolster, including forces resulting from track shocks, motor torques (including dynamic braking), friction brakes, and any combination of these forces without developing stresses that are greater than the allowable stress levels.
- 11.2.2.2. Design allowable stresses for static operational or normal load cases shall not exceed 50 percent of the yield strength of the material.

- 11.2.2.3. The design allowable stresses for exceptional overload cases shall be proposed separately for NYCT approval. In no case shall allowable stresses exceed 67 percent of the yield strength.
- 11.2.2.4. For cast components, the design allowable yield strength shall be based on the properties of as-cast full section parts, unless otherwise approved.
- 11.2.2.5. Weld allowable stresses shall not exceed the requirements of AWS D1.1:2010.
- 11.2.2.6. Fatigue allowable stresses shall not exceed the requirements of AWS D1.1:2010 or AAR C-11, Section 7.4 for 10E6 cycles. Whichever criterion is selected shall be applied to all areas of the truck. Alternative published standards may be proposed for joint geometries not covered by these standards, as approved by NYCT.
- 11.2.2.7. A positive Margin of Safety (MS) for all fatigue calculations shall be provided.
- 11.2.2.8. The application of shot peening or Gas Tungsten Arc Welding (TIG) dressing of welds as a method to improve allowable stresses in production is only permitted with explicit prior approval from NYCT.

Lifting Pads, Jacking Pads, and Stops

- 11.2.2.9. Truck jacking pads per Section 11.4.4.6 shall be capable of lifting a ready to run car at AW0, supported at one end by the truck jacking pads while the other end is supported on its truck, without producing stresses in the pads and truck frame exceeding 80 percent of the material allowable yield stress.
- 11.2.2.10. Truck lifting provisions per Section 11.4.4.7 shall provide a total lifting capacity of 50,000 lb. without exceeding the yield stress of the materials utilized in the pads and truck frame.
- 11.2.2.11. The strength of rotational stops shall be proposed by the Contractor but shall not be less than the value shown in APTA SS-C&S-034-99, revision 2 Paragraph 5.6.4.

Emergency Supports

- 11.2.2.12. Emergency supports shall be designed to sustain the service loading of the item they are design to support, with positive margin, in the failed state of the primary mounting for a period of service equal to at least the periodic inspection interval. See Section 11.4.4.13 for a list of components requiring emergency supports.

11.2.3. Wheel Sets

- 11.2.3.1. Bearings shall be designed for ANSI/AFBMLA L10 of 1,000,000 miles (1,609,000 km) at AW3 passenger load and average train speed of 15 mi/h (24 km/h).
- 11.2.3.2. Wheels shall be pressed on axles at a load from 68 to 105 tons (605 to 934 kN).

11.2.4. Carbody Connection

- 11.2.4.1. Truck to carbody connections for the purpose of raising the truck with the carbody shall consider a vertical load of 50,000 lb. (22,680 kg) without exceeding the yield strength of the material.
- 11.2.4.2. The vertical connection of the truck to the carbody shall be maintained regardless of truck rotation angle, including failure of required rotational stops.
- 11.2.4.3. Mechanical connections between the truck assembly and the carbody shall resist, independent of external vertical load and without separation, an ultimate load of 150,000 lb. applied in any horizontal direction radial to the carbody center pin, and an elevation equal to the lowest point on the truck frame. Bolster anchor rods, if used, shall not be considered to contribute to the strength of the connection.

11.2.5. Truck Connection

- 11.2.5.1. Each bolster anchor rod (if used) shall be capable of carrying a longitudinal load between 100 percent and 135 percent of the required design load of two times the ready to run weight of the fully assembled truck, excluding the truck bolster assembly.

- 11.2.5.2. All bolster anchor rod connecting brackets and connection elements shall be capable of carrying 150 percent of the design load specified in 11.2.5.1 in the longitudinal direction without permanent deformation.
- 11.2.5.3. Anchor rods shall fail (deform permanently or break) before the connecting brackets and connection elements to which they are attached.

11.2.6. Primary Suspension

- 11.2.6.1. The Contractor shall propose appropriate spring rates for each of the three axes in order to meet vehicle performance requirements of Section 2, Design and Performance Criteria.
- 11.2.6.2. The resonant frequency of the truck frame on axle-wheel assembly (primary suspension) shall not exceed 7.5 Hz.
- 11.2.6.3. Raising or lowering any wheel of a truck by 2 inches shall not change the load on any wheel of that truck by more than 50 percent at AW0 under new conditions for all suspension elements with secondary suspension inflated.
- 11.2.6.4. Raising or lowering any wheel by 2.50 inches (64 mm) shall not cause loss of contact between any other wheels and the rail under AW0 loading and with inflated and deflated secondary suspension air bags.
- 11.2.6.5. The primary suspension longitudinal stiffness shall permit the axles to align in curves of 1,000 feet (305 m) radius or greater. The Contractor shall demonstrate compliance to the requirements of Section 2.10.1.
- 11.2.6.6. The primary suspension shall have a design life of at least one SMS cycle.

11.2.7. Secondary Suspension

- 11.2.7.1. The secondary suspension subsystem shall have a natural frequency in the vertical direction not to exceed 1.5 Hz under any load condition as defined in Section 2, Design and Performance Criteria.
- 11.2.7.2. Safe operation of the car shall be assured at all speeds, all car-loading conditions, and on all track conditions not condemnable by NYCT Contained in Appendix C-5 (Track Standards and Reference Manual MW-1), when any or all of the air springs are inoperative.
- 11.2.7.3. The secondary suspension shall have a design life of at least one SMS cycle.

11.2.8. Carbody Height Control

- 11.2.8.1. Floor height shall be maintained, with the equipment as specified in Section 11.4.13, within a vertical tolerance necessary to maintain level boarding as required in Section 2.3.2.
- 11.2.8.2. Secondary suspension failures shall not influence swiveling, stability, or derailment characteristics such that normal operation can be maintained, but at reduced ride quality level.
- 11.2.8.3. The suspension system shall limit the roll of the car just prior to, and during unloading, so that the car floor on the side adjacent to the station platform shall not be lower than the station platform, in accordance with the car and line equipment clearance requirements contained within Appendix D-1 (Memorandum of Understanding Car and Line Equipment Clearances MISC #00-01).

11.3. Functional Requirements

11.3.1. General

- 11.3.1.1. This section describes the functional requirements of the truck frame, truck bolster, primary suspension, secondary suspension, leveling valves, trip cocks, current collectors, wheelset assemblies, and all cabling and piping.

- 11.3.1.2. The assembled truck shall be capable of rotating about a vertical axis with respect to the carbody and shall operate freely over all curves and turnouts contained within Appendix C-5 (Track Standards and Reference Manual MW-1).
- 11.3.1.3. All motorized trucks shall be interchangeable between ends of cars without modifications to the truck except for configuring the leveling valve connections, drawbar stops, and CBTC or ATC equipment. Non-motorized trucks shall be manufactured so as to accept all equipment necessary for conversion to a motorized truck. No structural changes shall be necessary.
- 11.3.1.4. The primary and secondary suspension elements and carbody to truck hoses and cables shall not disengage or be displaced during lifting of the truck.
- 11.3.1.5. Damping, if required external to the suspension elements, shall be provided by hydraulic dampers.
- 11.3.1.6. Roll shall be controlled via torsion bars or other service proven method approved by NYCT.

11.3.2. Truck Frame and Bolster

- 11.3.2.1. The truck frame and bolster shall provide the attachment points for brake system components, motors, gear units, primary and secondary suspension elements, dampers, and other sub-components of the truck system.
- 11.3.2.2. The truck bolster provides the attachment element between the truck frame and carbody, provides side bearing pads for carbody lateral movement control, and may also function as the air reservoir for the secondary suspension.

11.3.3. Carbody Connection

- 11.3.3.1. The trucks shall be able to be raised with the carbody without performing any securement steps prior to the lifting action.
- 11.3.3.2. The retention elements shall provide protection against unintended vertical separation of the truck and carbody.
- 11.3.3.3. The truck to carbody connection shall resist horizontal loading from traction, braking, buff and draft, shunting, and other potential horizontal forces. See Section 11.2.4.
- 11.3.3.4. The carbody connection shall provide installation provisions, minimize strain due to movement, and maintain acceptable clearances for hoses and interface cabling between the carbody and truck under all conditions of relative movement between the truck and carbody.

11.3.4. Truck Connection

- 11.3.4.1. Truck connections shall incorporate a retention system as specified in Section 11.3.3.2.
- 11.3.4.2. The truck connection shall minimize weight transfer between axles of a truck, maximizing adhesion and minimizing stress levels, wear, and displacements in the truck due to transmitted traction and braking forces.

11.3.5. Primary Suspension

- 11.3.5.1. The primary suspension elements, together with the truck configuration, shall allow movement of each wheel for load equalization.
- 11.3.5.2. The primary suspension shall permit the axles to align in curves per Section 11.2.6.5.
- 11.3.5.3. The primary suspension shall preclude rotation of the journal housing with changes in vertical loading.
- 11.3.5.4. Primary suspension elements shall, by physical design features, not be interchangeable with applications on NYCT fleets that do not utilize the same stiffness values and tolerances.

11.3.6. Secondary Suspension

- 11.3.6.1. The air spring travel from AW0 load to the solid air spring height shall prevent contact with the safety secondary suspension element during operation under all passenger load conditions defined in Section 2, Design and Performance Criteria.
- 11.3.6.2. Elastomeric stops shall augment the air springs and support the carbody weight in the event of an air suspension failure.

11.3.7. Carbody Height Control

- 11.3.7.1. Provisions shall be made for a total of 1.50 inches (38.1 mm) vertical height adjustment in four 0.375-inch (9.53 mm) increments of vertical height adjustment to compensate for wheel wear, suspension tolerances, and suspension creep without impacting leveling valve calibration.
- 11.3.7.2. Adjustment shall be independent of the primary suspension and without the use of loose shims.
- 11.3.7.3. Leveling valves shall regulate the inflation of the air springs to compensate for passenger load.
- 11.3.7.4. A single leveling valve on the No. 2 truck (of each car) shall sense the height on the longitudinal centerline of the car.
- 11.3.7.5. The No. 2 truck (of each car) shall provide load weigh air pressure meeting the requirements of Section 12.3.5.
- 11.3.7.6. Sudden loss of air spring pressure on either side of the truck shall initiate rapid venting of the opposite spring.

11.3.8. Current Collection

- 11.3.8.1. The current collector assembly shall meet the requirements of Section 9.4.2.
- 11.3.8.2. The current collection equipment shall prevent truck damage due to arcing in the event of collisions with wayside debris.

11.3.9. Trip Cocks

- 11.3.9.1. Trip cock mounting shall provide adjustment provisions to maintain the required operational height above top of rail with wheel wear or after wheel truing.
- 11.3.9.2. The trip cock shall remain functional if the emergency support is engaged. See Sections 11.2.2.12 and 11.4.4.13.

11.4. Design Requirements

11.4.1. General

- 11.4.1.1. This section describes the design requirements of the truck frame, truck bolster, primary suspension, secondary suspension, leveling valves, trip cocks, current collectors, wheelset assemblies, and all cabling and piping.
- 11.4.1.2. The trucks shall be of outboard bearing design.
- 11.4.1.3. Each truck shall be equipped with a primary and secondary suspension.
- 11.4.1.4. Truck axle spacing shall be 6 feet 10 inches (2,083 mm).

- 11.4.1.5. The trucks shall have provisions for mounting, without interference, brake equipment, leveling valve(s), trip cocks, current collectors, traction motors, gear units, CBTC or ATC equipment, and all associated wiring and piping.
- 11.4.1.6. All truck surfaces shall be painted per Section 19.22.9, except those listed in Section 19.22.5.3.
- 11.4.1.7. All machined ferrous surfaces shall be free of surface defects and coated with a strippable rust preventive coating to prevent corrosion during shipment and storage. Coatings are to be removed prior to truck assembly in accordance with truck assembly procedures. Reference Section 19.22 for painting and coating requirements and Section 19.1.7.1 for restricted chemicals.
- 11.4.1.8. The lifting hooks and/or members used to attach the truck to the carbody shall be designed and located in a manner that shall minimize the possibility of damage during derailments.
- 11.4.1.9. The trucks shall be equipped with stops to limit lateral carbody motion. The stops shall be provided with elastomeric elements and stainless steel wear surfaces as specified in Section 19.6 of the Technical Specification.
- 11.4.1.10. Elastomeric elements utilized on stops shall have their spring characteristics selected to meet the ride quality requirements of Section 2.10.3.
- 11.4.1.11. Attachment of elastomeric elements shall allow use of standard tools for removal.
- 11.4.1.12. Truck parts contacted by elastomeric cushions shall be provided with stainless steel wearing surfaces.
- 11.4.1.13. Elastomeric cushions shall be provided with a wear resistant contact surface.
- 11.4.1.14. Hard stops shall be attached to the truck structures by welding in accordance with Section 11.4.2.
- 11.4.1.15. Moving contact surfaces, if utilized, shall be approved by NYCT.

11.4.2. Welded Connections

- 11.4.2.1. All welding shall be in accordance with welding and brazing requirements specified in Section 19.21.
- 11.4.2.2. Steel plate welds shall be inspected to AWS D1.1:2010, Section IX requirements.
- 11.4.2.3. Welding on the truck including application of brackets, pads, and other attachments shall be entirely completed prior to stress relieving (if required).
- 11.4.2.4. Non-destructive inspection sampling provisions of Section 19.21.4 shall be applied to plate steel weldments.
- 11.4.2.5. Welded truck fabrications or castings shall not be straightened by cold-pressing unless:
 - a) Cold-pressing is implemented using the same procedures as used on the fatigue test samples.
 - b) The maximum limit of cold-pressing used is equivalent to that used on the fatigue test sample.
 - c) Stress relief is implemented in the same manner as on the fatigue test sample (prior to fatigue test validation).

11.4.3. Mechanical Connections

- 11.4.3.1. Mechanical connections to the truck frame and bolster shall be implemented with tapping plates. No direct tapping into the truck frame or bolster shall be permitted.
- 11.4.3.2. All drilled and tapped holes shall have de-burred edges.
- 11.4.3.3. All threaded fasteners shall be SAE Grade 5 minimum.
- 11.4.3.4. Critical fasteners as defined in Section 19.19.7 shall be Grade 8, free from hydrogen embrittlement per Section 19.19.13.
- 11.4.3.5. Mechanically fastened connections shall be designed as follows:

- a) A factor of safety of 2.0 and the minimum proof strength for threaded fasteners shall be used to determine the allowable yield load criteria.
- b) A factor of safety of 1.25 and the minimum tensile strength for threaded fasteners shall be used to determine the allowable ultimate load criteria.
- c) Clamping force friction shall be ignored in the static load design and analysis.

11.4.3.6. All nuts and cap screws shall be retained by locking devices as specified in Section 19.19.10.

11.4.3.7. Drilling, tapping, and machining of finished surfaces shall be accomplished only after stress relief (if required).

11.4.3.8. Unused or provisional threaded holes shall be protected from corrosion and debris build up, as approved by NYCT.

11.4.4. Truck Frame and Bolster

11.4.4.1. The truck frames and bolsters shall be fabricated from welded plates and steel castings, or a combination thereof.

11.4.4.2. Plate steel materials shall conform to Section 19.3.

11.4.4.3. Cast materials shall conform to Section 19.4.

11.4.4.4. Elastomeric elements shall be utilized to transmit longitudinal forces between the truck frame and bolster. See Section 11.4.10.

11.4.4.5. Serial numbers shall be applied to both sides of the truck near the center of the frame. The frames shall be permanently marked as approved by NYCT with designations assigned by NYCT.

11.4.4.6. Each truck side frame shall be fitted with two slip resistant jacking surfaces approximately 6 inches long by 4 inches wide to support the truck during propulsion system functional validation and axle rotation.

11.4.4.7. Each truck shall have four lifting provisions (one at each corner). Lifting provision design shall be approved by NYCT. See Section 11.5.1.1.

11.4.4.8. Each truck frame shall have supports for the mounting of a Tread Brake Unit (TBU) for each wheel (a total of four). See Section 12.1.11.

11.4.4.9. Truck frames shall have tram marks above and below each journal bearing location located within 0.005 inch (0.13 mm) of their true position.

11.4.4.10. Pedestal tie bars, if used, shall be attached to the truck frame pedestals with threaded fasteners in a positive, metal-in-bearing path for loads. Designs relying on clamping friction to transmit loads shall not be accepted.

11.4.4.11. Truck bolsters shall be painted, with the interior of the bolster painted if accessible. Paint and painting procedures shall be approved by NYCT.

11.4.4.12. Positive stops shall be provided on the truck bolsters mating to carbody stops to limit the vertical and transverse movement of suspended trucks.

11.4.4.13. Emergency supports shall be provided for traction motors, gear units, trip cocks, current collectors, and CBTC or ATC antennas to ensure they remain clear of the track in the event of primary mount failure. Emergency support shall not support any weight until a failure has occurred.

11.4.4.14. Drainage provision shall be incorporated so that no condensation accumulates anywhere within the truck frame or bolster.

- 11.4.4.15. Parts of the structure utilized as an air reservoir shall be designed and tested to 1.5 times the maximum main reservoir pressure. Stresses associated with the pressure-vessel function shall be combined with service stresses for calculations and testing. See Sections 11.2.2, 11.6.3, 11.6.10, and 11.6.11.
- 11.4.4.16. If separate pressure vessels are used for air suspension system reservoirs, they shall meet the requirements of Section 19.15 and shall incorporate manual drain cocks.

11.4.5. Wheel Sets

- 11.4.5.1. Wheel sets shall consist of wheels, axles, gears (if applicable), journal (roller) bearings, and journal housings.
- 11.4.5.2. Requirements for gears are covered in Section 10, Propulsion System.
- 11.4.5.3. Wheel-axle sets shall be mounted in pairs matched in diameter within one-half tape size.
- 11.4.5.4. Mounted wheel set, back-to-back distance shall be 53.375 inches (1355.7 mm) with a tolerance of +0, -0.125 inch (+0, -3.2 mm).
- 11.4.5.5. Wheel sets shall be concentric within 0.005 inch (0.127 mm) total indicated run out when rotated on their bearings.
- 11.4.5.6. Mounted wheels shall not exceed 0.015 inch (0.38 mm) out of parallel to a plane perpendicular to the centerline of the axle.
- 11.4.5.7. Mounted wheels shall not exceed 0.030 inch (0.76 mm) out of parallel with each other.

11.4.6. Wheels

- 11.4.6.1. Wheels shall be ring-damped, wrought steel, per the NYCT Specification contained within Appendix C-13 (Furnishing and Delivering Heat Treated Wrought Steel Car Wheels for Rapid Transit Service Document 2091-PROD-97 Rev. C), and within Appendix D-17 (Drawing 704-3035, Rev I).
- 11.4.6.2. Wheel diameter, fully worn (condemning limit) shall be 31.0 inches (787 mm).
- 11.4.6.3. Wheels shall be interchangeable in all positions with all axles used on all trucks.
- 11.4.6.4. Wheels shall be supplied by manufacturer(s) whose wheels have been tested and approved by NYCT.
- 11.4.6.5. Wheels shall be stamped in conformance with the documents defined in this section.
- 11.4.6.6. Wheels shall be compatible with the existing wayside wheel detector system.

11.4.7. Axles

- 11.4.7.1. Motor axles shall be manufactured per the NYCT Specification contained within Appendix C-14 (Heat Treated Alloy Steel Axles 2092-PROD-97), and NYCT drawing within Appendix D-18 (Motor Axle 704-3001).
- 11.4.7.2. Axle material shall be ASTM A729 (2006/2009) Grade C, 65 ksi yield strength, 100 ksi ultimate strength.
- 11.4.7.3. Axle design shall be in accordance with all applicable AAR requirements, except as otherwise required in this Specification.
- 11.4.7.4. Axle finish shall be in accordance with AAR M-101 as a minimum.
- 11.4.7.5. Each axle shall be assigned a unique serial number which shall be legibly and permanently stamped on the gear seat end of each axle with characters at least 0.25 inch (6.3 mm) high. Serial numbers shall be as directed by NYCT.
- 11.4.7.6. Trailer axles shall follow the motor axle general manufacturing practices and shall be identical to the motor axles in the areas of axle ends, wheel seats, journal, and any such areas that are relevant to the trailer axle.

11.4.8. Journal Housings

- 11.4.8.1. Journal housings shall be mounted outboard of the wheels and guided in the truck frame by the primary suspension. Each journal housing shall contain a journal (roller) bearing and provide sufficient clearance to avoid bearing seizure.
- 11.4.8.2. A lip or hooks shall be provided on the top or side of the journal housing for support of the axle tie-down cables of the wheel truing machine as approved by NYCT. Alternative designs may be submitted for NYCT approval.
- 11.4.8.3. Each journal box shall have provision for support of the trip cock on the portion of the journal housing that is directly supported on the bearings.
- 11.4.8.4. Jacking pads incorporating a slip resistant surface shall be provided beneath the journal housings.

11.4.9. Journal Bearings

- 11.4.9.1. Journal (roller) bearings shall be of an NYCT approved design and manufacturer.
- 11.4.9.2. Bearings shall be outboard mounted, roller-type with 5-inch bore.
- 11.4.9.3. Bearings shall be sealed by contact seals.
- 11.4.9.4. Bearing grease shall be AAR M-942 (NYCT Commodity # 69-10-3161). Each assembly shall have a maximum capacity of 2 lb. (0.9 kg) of grease. The bearing supplier shall clearly define grease loss or migration limits for all journal bearings over their service life.
- 11.4.9.5. Bearings shall be interchangeable in all positions with all axles used on all trucks.
- 11.4.9.6. Bearings shall be protected from damage due to the passage of electric current.
- 11.4.9.7. There shall be no sliding surfaces involved in the method of retaining the journal bearings in their proper positions.

11.4.10. Truck Connection

- 11.4.10.1. Bolster anchor rods, if used, shall be positioned as low as possible on the truck near to the axle centerline, as permitted by allowed clearance.
- 11.4.10.2. Bolster anchor rods internal to the truck assembly shall have elastomeric cushions at each end.

11.4.11. Primary Suspension

- 11.4.11.1. The primary suspension shall be of elastomeric elements or combination of coil springs and elastomeric elements.
- 11.4.11.2. Elastomeric elements shall be stenciled with the car contract information, manufacturer's identifying mark, and year of manufacture. The manner of stenciling shall not be detrimental to the service life of the elastomeric element and shall be visible as installed in the truck.
- 11.4.11.3. The design of the truck shall allow compensation for normal creep or settlement of the primary suspension springs. See Section 11.2.6.

11.4.12. Secondary Suspension

- 11.4.12.1. The secondary suspension shall be air springs.
- 11.4.12.2. The secondary suspension shall be between the truck bolster and carbody or between the truck bolster and truck frame.
- 11.4.12.3. Shielding shall be provided to protect the air springs from damage by electrical arcing.

11.4.12.4. The air spring material shall comply with smoke, flame and toxicity requirements of Section 19.1.10 or shall be enclosed in a compliant material.

11.4.13. Carbody Height Control

11.4.13.1. The connection between the leveling valve control lever and the truck shall utilize a threaded design that is rotated for adjustment and locked in place with a jam nut.

11.4.13.2. The leveling valves shall be service proven in heavy rail transit service.

11.4.14. Current Collection

11.4.14.1. Current collection equipment shall be mounted on each side of each truck to be compatible with the third rail as described within Appendix C-5 (Track Standards and Reference Manual MW-1). See Sections 9.3.1, 9.4.1, 9.4.2, and 9.5.1.

11.4.14.2. Provisions shall be provided to allow current collection equipment to be adjustable within the range of with A and B Division third rail heights.

11.4.14.3. Truck parts in proximity to current collector equipment and conductive electric elements such as bus bars, cable lugs, and connections carrying third rail voltage shall be shielded against arc damage by dielectric, non-combustible barriers and protective shielding as approved by NYCT.

11.4.15. Trip Cocks

11.4.15.1. A trip cock, as specified in Section 12.4.11, shall be mounted on one journal housing of each truck at diagonally opposite corners of each car. Reference drawing within Appendix D-19 (R42-MK-1177 "D1 Trip Cock").

11.4.15.2. If the assembly is partially suspended by the primary springs, the trip cock shall function as intended under all conditions of primary suspension deflections.

11.4.15.3. The trip cock attachments shall use elastic stop nuts and cotter pins. The drilled through holes for the cotter pins shall be made at the end of the bolt with a reduced diameter (stepped) to allow the installation of cotter pins while preventing damage to the elastic nut insert. Alternate attachment designs may be proposed for NYCT review and approval.

11.4.15.4. The trip cock shall not be mounted on a component that is attached only by fasteners to the journal housing unless otherwise approved by NYCT.

11.4.16. Piping

11.4.16.1. For piping and hose design requirements reference Section 12.4.9.

11.4.16.2. Secondary suspension piping and pipe connections shall be sized to prevent damping of the air flow.

11.4.16.3. For piping materials and workmanship requirements reference Sections 19.14.1 and 19.14.2.

11.4.17. Wiring

11.4.17.1. All cables and conduits shall be supported to withstand shock and vibration in accordance with Section 2.9.6.

11.4.17.2. Clamps for cabling and conduits shall be attached to tapping plates or raised bosses.

11.4.17.3. Truck ground connections shall be through axle ground ring assemblies as specified in Section 10, Propulsion System.

- 11.4.17.4. In the event of a tear-off of the current collector, in either running direction, cabling and bus bar design shall minimize damage to the truck. Designs shall be subject to NYCT approval.

11.5. Maintainability Requirements

11.5.1. General Maintainability Requirements

- 11.5.1.1. The truck frame shall be capable of being "lifted" with standard lift chains in use by NYCT.
- 11.5.1.2. The trucks shall be free from sharp corners, sharp edges, or burrs which may cause injury to maintenance personnel.
- 11.5.1.3. The Contractor shall provide calibrated gauges and templates to NYCT, or approved equal, for dimensionally inspecting assemblies of wheels and axles. See Section 22.7.
- 11.5.1.4. The Contractor shall provide NYCT those items required for the long-term maintenance and overhaul of the truck frames, including, but not limited to lifting tables, truck presses, and special stands for NYCT overhaul shops that are unique to the R211 truck frames.
- 11.5.1.5. The carbody connection shall be separable without special tools.
- 11.5.1.6. The journal housing shall be removable and shall allow access to the axle centers for (centering) spindles of wheel truing machines.

11.5.2. Bearings

- 11.5.2.1. Journal boxes and bearings shall be able to be removed from axles without causing damage to any components.
- 11.5.2.2. Journal bearings shall not require field lubrication.
- 11.5.2.3. Bearings shall not require inspection more than once every 500,000 miles (804,672 km).

11.5.3. Carbody Height Adjustment

- 11.5.3.1. Leveling system adjustment shall be performed using standard maintenance tools. Leveling valves shall be located to be readily accessible to maintenance personnel for adjustment.
- 11.5.3.2. Leveling system adjustment design and process shall be subject to NYCT approval.
- 11.5.3.3. Leveling valves shall provide required operational performance between overhaul activities for a period of at least one SMS cycle.

11.5.4. Wheel Truing Machine Compatibility

- 11.5.4.1. The trucks shall be compatible with NYCT wheel truing machines (manufactured by Simmons Stanray). The truck design and installation shall permit wheel truing operations to be performed without the need for de-trucking or disassembly of any parts from the truck or the carbody.
- 11.5.4.2. The truck assembly shall be capable of being wheel-trued with use of standard tie-downs in use at NYCT.
- 11.5.4.3. The truck frame shall be provided with interface pads to accommodate the progressor used in wheel truing.

11.5.5. Inspection and Maintenance

- 11.5.5.1. It shall not be required to remove any components or de-truck the car for any periodic inspections or lubrication of the truck.
- 11.5.5.2. The axle ground ring assembly visual inspection shall be made from an inspection pit within line of sight.
- 11.5.5.3. It shall not be required to de-truck the car for any scheduled NYCT periodic component maintenance.

- 11.5.5.4. Low friction elements shall not require lubrication.
- 11.5.5.5. All lubrication fittings on the truck shall be accessible for servicing from a pit or the car side. Inspection covers shall be installed to provide accessibility to components requiring lubrication.
- 11.5.5.6. All threaded fasteners, adjustment points, and structurally critical areas of the truck shall be visible for inspection and work from a pit or car side.
- 11.5.5.7. De-trucking shall be permitted for replacement of the following:
 - a) Traction motors.
 - b) Gear units.
 - c) Air bags.
 - d) Wheels.
 - e) Axles.
 - f) Primary suspension.
 - g) Wheel bearings.
 - h) Journal boxes.
 - i) CBTC or ATC equipment.
 - j) Other items as approved by NYCT.
- 11.5.5.8. Traction motors shall be able to be removed from above the truck without interference from any part of the truck frame or any truck mounted equipment.
- 11.5.5.9. De-trucking shall not cause damage to any components and shall follow all NYCT standards and safety procedures, and the following procedure:
 - a) Disconnect all truck to carbody connections.
 - b) Release the truck to carbody locking devices.
 - c) Jack the end of the car until the engaging members clear the truck.
 - d) Roll the truck out from under the car, clearing the carbody and coupler draft gear.

11.6. Truck Stress Analysis, Test and Validation Requirements

11.6.1. General

- 11.6.1.1. The structural and mechanical components of the truck and performance of the suspension shall be validated by analysis, calculations, testing, and inspection.
- 11.6.1.2. Wheel thermal performance shall be validated per Section 12.6.4.

11.6.2. Truck Stress Analyses and Test Plan

- 11.6.2.1. The TSAP shall be submitted for NYCT approval, and discussed during the Preliminary Design Review (PDR) meeting. The Truck Structural Test Plan (TSTP) shall be submitted for NYCT review and approval. [CDRL]
- 11.6.2.2. The TSAP and TSTP shall be working documents that will be updated as the truck assembly design develops. Whenever the process for the analysis and testing of the truck assembly is revised, the plan shall be updated and resubmitted, but not more than monthly. Each revision shall include revision level indications with descriptions of each change.
- 11.6.2.3. The TSAP and TSTP shall include an outline of the procedure the Contractor will use to analyze and test the design of the truck assembly. It shall also include the following:

- a) Listing of load conditions to be used during analysis and test, with load magnitudes and points of application.
- b) Description of the analysis to be used for each load condition.
- c) Structural sketches as required.
- d) Diagrams of load applications.
- e) Table of material properties.
- f) Description of the assumptions concerning stress analysis.
- g) Description of how meshing accuracy is assessed, globally and at stress concentrations.
- h) Description of how analysis results will be correlated with test results, as required in Section 11.6.5.

11.6.2.4. The TSAP and TSTP must be approved prior to approval of the stress analysis report required by Section 11.6.6.

11.6.3. Stress Analysis

- 11.6.3.1. The stress analysis shall be used to design and validate each type of truck frame, bolster, truck equipment attachments, and secondary supports to obtain the lightest weight possible while meeting the performance requirements of this Specification. Structural tests shall be performed as required within this section to confirm the accuracy of the analysis.
- 11.6.3.2. The stress analysis shall consist, at a minimum, of a Finite Element Analysis (FEA), supplemented as necessary by manual calculations submitted for NYCT review and approval.
- 11.6.3.3. The stress analysis shall show the calculated stresses, allowable stresses and MS for all elements for all specified loading conditions consistent with the approved TSAP.
- 11.6.3.4. The stress analysis shall include calculations of stresses in all load bearing elements, in all mechanical and welded structural joints, all connection elements, fasteners, mounting brackets, and other critical areas of the truck. A listing of critical welds and critical casting areas shall be submitted for NYCT review and approval. [CDRL]
- 11.6.3.5. The approved stress analysis shall be a prerequisite for approval of the static and dynamic test procedures and shall be used as an aid in determining the strain gauge locations for use during the tests.
- 11.6.3.6. The stress analysis shall be revised and submitted for NYCT review as changes in the design, manufacture, or other changes are made at any time. The final submitted and approved stress analysis shall be for the car in the as-built configuration.
- 11.6.3.7. Aspects of the design that cannot be analyzed with the required accuracy shall be prototyped and tested to demonstrate compliance with the requirements of the design and the Specification.
- 11.6.3.8. An analysis showing the adequacy of the design with respect to axle parallelism and bearing location shall be included in the FEA deflection analysis required by Section 11.6.4.
- 11.6.3.9. Appropriate strength analyses of the axles shall be provided in the overall stress analysis as defined in Section 11.6.3.1. [CDRL]
- 11.6.3.10. For a service proven truck, the Contractor may provide relevant data from previous tests, historical data from operations, and stress analyses, as required, to satisfy the corresponding portions of these requirements, subject to NYCT approval.

11.6.4. Finite Element Analysis

- 11.6.4.1. The FEA shall be performed using a computer program such as NASTRAN or ANSYS or NYCT approved equal that generates both model and solution files compatible with post-processing programs that allow for model visualization and solution data reporting.
- 11.6.4.2. The Finite Element Model (FEM) shall be submitted and approved prior to performing the FEA. [CDRL]
- 11.6.4.3. The element mesh, all assumptions, and a complete printed copy of the input file that includes input data, such as loads, boundary conditions, area properties and material properties, shall be included as part of the FEA submittal and again as part of the complete analysis. A key to all symbols and colors shall be included. Boundary reaction forces due to gravity loading shall be included.
- 11.6.4.4. Load conditions within the model submittal shall include diagrams of areas of mesh refinement, all assumptions, all input data, reaction forces, and a table to show static equilibrium.
- 11.6.4.5. Wherever required to be submitted, the input and output shall have each page numbered, and columns of data shall be clearly labeled on each page using terms, symbols, abbreviations, and units defined in the analysis report.
- 11.6.4.6. At the discretion of NYCT, FEA models and results shall be reviewed during live interactive sessions 3 weeks after each submittal. At these sessions, NYCT shall have full access to the FEA input, output, and use of the software on the computer used for the analysis.
- 11.6.4.7. Color plots shall be prepared showing the following:
- a) Deflections in all three axes.
 - b) Von Mises, or other approved combination stresses.
 - c) Maximum and minimum principal stresses.
 - d) Direction of maximum and minimum principal stresses.
 - e) Assessment of the meshing accuracy.
- 11.6.4.8. All plots shall show the maximum and minimum values and all values that are greater than 80 percent of the specified maximum value.
- 11.6.4.9. Each drawing shall include a triad showing the direction of the global axes.
- 11.6.4.10. Plots at high magnification shall be keyed to a plot showing the truck assembly to an extent sufficient to orient the high-magnification plots.
- 11.6.4.11. The FEA input and output data shall also be submitted on electronic media as approved by NYCT. Submittal of the input file is required with the model, and at any time the file is changed, but not more often than monthly. Criteria for final approval of the analysis shall include the Contractor's submittal of the fully configured input data files as required by this paragraph. [CDRL]
- 11.6.4.12. The FEA model and analysis report shall be updated to represent the final configuration of the truck assembly upon approval of the final design.

11.6.5. FEA Validation

- 11.6.5.1. The stress results from the truck static load test required by Section 11.6.10 shall be compared with the corresponding stress analysis results. This information shall be tabulated and submitted with the truck structural test reports for each test. [CDRL]
- 11.6.5.2. The tables shall compare empirical stresses from the test with analytical stresses from the FEA.
- 11.6.5.3. Comparison shall be made for the highest-reading strain gauges in the test, which shall be at least half of the total number of strain gauges used during the test.

- 11.6.5.4. The tables shall include the test stress value, the analytical stress value, the percent difference between the two values, and a space for notes.
- 11.6.5.5. The percent difference included within the table shall be based on the strain gauge value (in the denominator).
- 11.6.5.6. A statistical regression analysis shall be performed on all strain gauges used in the execution of the test, and the corresponding analytical stresses. Correlation shall be 90 percent or greater.
- 11.6.5.7. If the analysis does not correlate with the test results, the Contractor shall revise the analysis until 90 percent correlation is achieved.
- 11.6.5.8. The analysis results shall be updated to reflect the correlation analysis taking into account correlation analysis trend and at least one standard error.
- 11.6.5.9. The revised analysis shall demonstrate compliance with the load and allowable stress requirements of Section 11.2.
- 11.6.5.10. Approval of the truck test report shall depend, in part, on the analyses of excessive variance between analytical and test stress values.

11.6.6. Stress Analysis Report

- 11.6.6.1. The stress analysis report for the most highly stressed truck type shall be submitted for NYCT review and approval. [CDRL]
- 11.6.6.2. The report shall show that all structural members satisfy the load and allowable stress requirements of Section 11.2 and practices of the rail transit industry. The report shall be organized and in sufficient detail so that the NYCT reviewer can readily follow the theory and its application to this truck.
- 11.6.6.3. The Contractor shall certify that the analysis and calculations have been reviewed and checked before the report is submitted to NYCT.
- 11.6.6.4. In addition to the body of the analysis, the stress analysis report shall include, at a minimum, all of the following:
 - a) Table of Contents.
 - b) The algebraic statement of all formulas and equations before the related calculations are performed. All terms shall be defined, and the values and units to be applied to these terms shall be stated.
 - c) Units shall be given with all quantities.
 - d) References for all formulas, calculation procedures, buckling coefficients, material strengths, fatigue strengths, and other physical and mechanical properties shall be cited where these items appear in the stress analysis.
 - e) Each page shall be numbered, dated, and initialed by the stress analyst and the checker. In the event of a revision, the revision letter shall be included with revision date and initials of the stress analyst and checker.
 - f) Truck structural drawings.
 - g) Tabulation or drawing identifying those welds deemed critical in the truck frame.
 - h) Each load case including diagrams displaying loads applied externally to the truck assembly and points of support.
 - i) Analysis showing compliance with each design load and condition, as required by Section 11.6.3.
 - j) Detailed calculations of stresses with MS in all structural framing members, with a summary of the results.

- k) Table listing locations where the MS is less than 0.20 along with the design or operating conditions (loads) which cause the stresses.
- l) Tabulation or diagram of calculated deflections of the truck assembly under full loading specified in Section 11.2.1.
- m) Analysis of all critical and highly loaded connections.
- n) Analysis of the strength of the truck frame to truck bolster and truck bolster to carbody connections, including calculated vertical and horizontal connection capacities.
- o) Tabulation of the Contractor's selection of allowable fatigue stresses, with sources, and assumed applied fatigue stress ranges for structural members which are critical in fatigue.
- p) Table listing the engineering properties of each grade and temper of each material used in the truck structure. This table shall include: material designation, yield strength, ultimate strength, elongation, Young's modulus for tension, and compression and shear elastic moduli. In each case, minimum-guaranteed values from the specifications for the corresponding grade and heat treatment of the material shall be used. Materials, grades, and tempers not used in the truck assembly construction shall not be included in the table.
- q) Table(s) showing the minimum static and fatigue strengths of all welds. Values shall be given for each material, temper, weld size, and thickness combination used in the truck assembly. The source of the data shall be provided.
- r) If tests are conducted to provide the necessary data, the entire test report shall be submitted. This report shall show the test procedure, raw data as well as reduced data, and summary.

11.6.7. General Test Requirements

- 11.6.7.1. Testing shall be performed to validate the truck design. These tests shall include all structural and mechanical components (static load and fatigue), truck dynamic, primary suspension, and equalization.
- 11.6.7.2. Qualification tests shall be performed on one of the first three truck frames built and will be selected at random by NYCT.
- 11.6.7.3. The truck test specimen shall be complete with bolster, motor and gear unit mounting provisions, and equipment attachments.
- 11.6.7.4. The Contractor is responsible for determining appropriate test loads and conditions for all tests and shall verify by measurement that actual loads incurred while operating on the existing NYCT system are not greater than those used for testing. Test loads and conditions specified herein are considered minimum values.
- 11.6.7.5. Before commencing with the application of instrumentation, the Contractor and an NYCT representative shall inspect the test specimen. The Contractor shall document the configuration of the truck and present any known deviation from the latest approved configuration for NYCT approval.
- 11.6.7.6. The truck structure shall have a minimum of 100 temperature compensated bonded resistance (SR-4) or approved equal rosette strain gauges applied. Strain gauges shall be placed where high stress is expected or in areas of interest. Drawings showing the location of each strain gauge shall be submitted to NYCT as part of the test procedure.
- 11.6.7.7. Rosettes may not be substituted by single direction strain gauges.
- 11.6.7.8. An additional five rosettes shall be available, the location of these shall be jointly determined with NYCT.
- 11.6.7.9. A load cell shall be installed at each point of load application.
- 11.6.7.10. All load cells shall be recorded simultaneously with all strain gauges.

- 11.6.7.11. Test gauges and instruments shall be in current calibration in accordance with the laboratory's national standard or the International Organization for Standardization (ISO).
- 11.6.7.12. Calibration certifications shall be maintained on file and available for review by NYCT upon request.
- 11.6.7.13. Any structural modifications made during the test or during construction and assembly shall be subject to all tests. All trucks constructed prior and subsequent to the structural tests shall incorporate these modifications. The tests and modifications shall be at the expense of the Contractor.
- 11.6.7.14. The Contractor shall make provisions to conduct data analysis at the time of the test to compare the collected data against all pass fail criteria. Testing shall not proceed until agreed upon by NYCT. Areas failing to meet any criteria shall be investigated to determine the course of action needed to bring the area in question into compliance with the specification.

11.6.8. Test Procedures

- 11.6.8.1. A test procedure shall be prepared for each test.
- 11.6.8.2. Test procedures and stress analysis shall be approved by NYCT prior to conducting any part of the tests.
- 11.6.8.3. Each procedure shall include the following:
 - a) Description and purpose of the test.
 - b) Step-by-step instruction of how the specimen is to be loaded and loading increments (if applicable).
 - c) Step-by-step procedure describing all initialization steps and instrumentation nulling.
 - d) All inspections required and measurements to be taken.
 - e) All equations for strain / strain conversion, and factors such as strain gauge factors, temperature compensation, and any other calculations.
 - f) Loading equipment.
 - g) Listing, type, numbering, and location of strain gauges via drawings with locating dimensions and a cross reference list as to location.
 - h) Strain gauge (stress) value predictions for each load case based on analysis including fatigue stress category (when appropriate).
 - i) Location of deflection and dial gauges.
 - j) Deflection gauge prediction based on analysis.
 - k) Complete description, with accuracy, of all instruments.
 - l) Details of the data acquisition system and a log of any preloaded conversion or gauge factors (by channel number), if applicable.
 - m) Drawings and sketches to clarify the text.
 - n) Drawings showing the test fixture, the specimen installed in the fixture, and location of load application points.
 - o) Typical logging sheets, print-outs, plotting forms, and examples of any other data sheets that will be used during the test or in the final report.
 - p) Tables showing the maximum allowable gauge reading for each gauge and loading condition.
 - q) Tables showing allowable criteria for all other test criteria.
 - r) Copies of the current certification for every instrument and gauge to be used during the test.
 - s) Description of when to record data.
 - t) Steps where authorization to proceed is to be obtained from NYCT.

11.6.9. Test Reports

- 11.6.9.1. The Contractor shall prepare and submit a final test report after successful completion of qualification tests.
- 11.6.9.2. Approval of the structural test report shall constitute the acceptance of the truck structural tests.
- 11.6.9.3. The calibration certifications shall be maintained on file and available for review by NYCT upon request.
- 11.6.9.4. Calibration certification for the equipment used to perform the test will be included in final test reports.
- 11.6.9.5. The Contractor shall prepare a color photographic record of the tests. This record shall include:
- Photographs of the truck in the test fixtures.
 - Installation of strain gauges.
 - Repairs or modifications.
 - Deviations from the drawings.
 - Any areas that were found non-compliant.
- 11.6.9.6. The test reports shall include:
- Table of Contents.
 - The complete test procedure.
 - Narrative describing the conduct of the test, with dates and locations of test elements.
 - Tables showing stresses and deflections which are 85 percent or more of the allowable in structural tests.
 - Description and explanation of any value that exceeded the test criteria.
 - Appendices containing all measured data for all gauges, i.e. output from each gauge for each load step. These data shall be identified with the date that they were recorded.
 - Color photographic record of the tests including photographs of the trucks in the test fixtures, installation of strain gauges, repairs or modifications, deviations from the drawings, and any areas that were found non-compliant.
 - Video recording of the testing that includes audio narration.
 - Stress (or strain) vs. load curves for the 10 greatest tension stresses and the 10 greatest compressive stresses for each structural test series.
 - Correlation analysis between the predicted strain gauge data and actual strain gauge data.

11.6.10. Static Load Test

- 11.6.10.1. The static load test shall verify that the maximum allowable static stresses selected by the Contractor, and approved by NYCT, are not exceeded under maximum expected loads.

Test Setup and Approach

- 11.6.10.2. The complete, ready-to-run truck and bolster (including primary suspension, journal boxes, and equipment attachments) shall be the test specimen.
- 11.6.10.3. The test specimen shall be tested for the maximum static load as described in Section 11.6.7.4 and the fatigue load stress range. All required data will be taken during both load application cases.
- 11.6.10.4. Instrumentation shall be as denoted in Sections 11.6.7.
- 11.6.10.5. Loads shall be applied twice for each load case, with complete release of the load between applications.

- 11.6.10.6. Strain gauges shall be re-zeroed after each load application and the offset from zero recorded and reported.
- 11.6.10.7. The methods and points of test load application and reaction shall simulate as closely as possible the actual loading conditions to which the truck will be subjected in service, including worst case derailment conditions, and produce the worst case combined stress in each quadrant of the truck.

Maximum Static Load

- 11.6.10.8. The vertical load shall be one-half of the total weight of the complete, ready-to-run car, loaded to AW3, minus the weight of the truck.
- 11.6.10.9. The lateral load shall be the maximum resulting from the operating conditions defined in Section 2, Design and Performance Criteria.
- 11.6.10.10. The longitudinal load shall be equal to the maximum possible instantaneous braking effort with no adhesion limitation at the wheels at AW3 load.
- 11.6.10.11. The lateral and longitudinal loads shall act as if they were applied at the center of gravity of the completed vehicle plus an AW3 passenger load (appropriate force couple loads shall be applied to simulate the resulting moments).
- 11.6.10.12. Accessory loads applied at attachment points shall represent maximum steady state conditions. Accessory loads shall be proposed by the Contractor and submitted for NYCT approval.
- 11.6.10.13. Loads shall be applied to produce the worst case combined stress in each representative quadrant of the truck.
- 11.6.10.14. Worst case stresses in each representative quadrant of the truck shall not be less than those that result from the application of the primary carbody-induced loads, such that the vertical augments from the lateral and longitudinal primary carbody-induced loads applied at the carbody center of gravity add in-phase to the primary carbody vertical journal reaction at each respective quadrant of the truck.
- 11.6.10.15. If the truck bolster is used as part of the air suspension volume, the bolster pressure during the static load test shall be 1.5 times the maximum main reservoir pressure.
- 11.6.10.16. Maximum stresses calculated from strain readings in any gauge during the second load application shall not exceed the allowable stresses as denoted in Section 11.2.2.2.
- 11.6.10.17. A criterion of two-thirds of the material's yield stress for exceptional load cases, such as main reservoir pressure in the brake cylinder or over-turning load, may be considered with NYCT's approval.

Static Fatigue Load

- 11.6.10.18. The static fatigue load case shall utilize loads equal to the approved fatigue test load ranges, combined as a worst case as approved for the truck fatigue test in Section 11.6.11.
- 11.6.10.19. For the fatigue range load case, the stresses in all areas of the truck shall not exceed the allowable fatigue stresses as specified in Section 11.2.2.
- 11.6.10.20. Both static test cases shall not cause any fractures, cracks, separations, or permanent deformation in the truck.
- 11.6.10.21. Following removal of all loads and review of all load cell and strain gauge readings for both static test cases, residual strains shall not exceed 50 microstrain.
- 11.6.10.22. If any of the above criteria are not met, the truck design shall be corrected and the truck retested at the Contractor's expense. This process shall continue until the tests per Section 11.6.10 are passed.

11.6.11. Fatigue Load Test

- 11.6.11.1. The fatigue test shall demonstrate that the fatigue strength of the truck under dynamic loading is acceptable.

- 11.6.11.2. For the fatigue test, the truck frame and bolster shall be subjected to not less than 6 million cycles.
- 11.6.11.3. The complete truck frame and bolster assembly including its internal elastomeric cushioning and springs, or NYCT approved substitutes, shall be tested.
- 11.6.11.4. The truck shall not contain any shock absorbers.
- 11.6.11.5. Instrumentation shall be as denoted in Section 11.6.7.

Pre-Test Inspection

- 11.6.11.6. Prior to the test, the test truck shall be given a wet, fluorescent magnetic-particle inspection for defects.
- 11.6.11.7. Magnetic particle inspections of castings and welds shall be performed in accordance with the guidelines documented in ASTM E709.
- 11.6.11.8. The type, size, location and repair of each defect found shall be documented by photographs and drawings, and all documentation of the defects shall be included in the truck fatigue test report.
- 11.6.11.9. Any defects that require repair shall be repaired using an approved procedure in accordance with, as a minimum, the requirements of Sections 19.4 and 19.21 for castings and welds, respectively.

Fatigue Test Loading

- 11.6.11.10. The mean vertical load shall be one-half of the total weight of the complete, ready-to-run car, loaded to AW3, minus the weight of the truck. The vertical load applied during the fatigue test shall alternate between the mean vertical load plus 25 percent and the mean vertical load minus 25 percent.
- 11.6.11.11. Track twist loading equal to the maximum allowable twist per Appendix C-5 (Track Standards and Reference Manual MW-1), phased as approved by NYCT. Twist shall constitute no less than 10 percent of the loading.
- 11.6.11.12. The lateral loading for the fatigue test shall alternate between 15 percent of the mean vertical load acting on one side of the truck and 15 percent of the mean vertical load acting on the other side.
- 11.6.11.13. The longitudinal loading for the fatigue test shall alternate between 15 percent of the mean vertical load acting on one end of the truck and 15 percent of the mean vertical load acting on the other end.
- 11.6.11.14. The lateral and longitudinal loads shall act as if they were applied at the center of gravity of the AW3 loaded carbody, with resulting vertical loading applied at the bolster.
- 11.6.11.15. If the truck bolster is used as a part of the air suspension volume, the bolster pressure during the fatigue test shall be the maximum service pressure required for a load equivalent to the truck's share of the AW3 loaded car on the suspension.
- 11.6.11.16. Approved accessory loading shall be applied to the truck during the fatigue test. Accessory loading shall alternate between 0 and 100 percent of the accessory load.
- 11.6.11.17. Accessory loads shall be the greater of the following:
 - a) Load applied by the traction motor under maximum torque and brake unit under maximum full service cylinder pressure without limit due to reduced adhesion availability.
 - b) Dynamic load range determined from a dynamic simulation of the truck in accordance with Section 2.15.1.
 - c) Loads derived from a test of prototype trucks on representative portions of the NYCT system in accordance with Section 11.6.12.
- 11.6.11.18. The phasing of the loads shall be selected by the Contractor and shall be such as to produce worst case combined stresses at critical locations in each quadrant of the truck. The phasing shall be approved by NYCT.
- 11.6.11.19. Worst case stresses shall not be less than those that occur from the maximum possible combined vertical components of the worst case loading in all three axes. The vertical component of truck pitching shall not be included.

Visual Inspections

- 11.6.11.20. The truck shall be visually inspected periodically during the fatigue test to detect crack initiation and crack progression. If evidence of crack progression or failure is detected:
- a) The test shall be stopped.
 - b) Appropriate corrective action shall be taken.
 - c) The test shall be rerun from the beginning (on another truck if required).

Post-Test Inspection and Acceptance Requirements

- 11.6.11.21. At the conclusion of the 6 million cycle fatigue test, load cell and strain gauge readings shall be reviewed.
- 11.6.11.22. Following removal of all loads and review of all load cell and strain gauge readings, residual strains shall not exceed 50 microstrain.
- 11.6.11.23. At the conclusion of the test, a magnetic particle or dye-penetrant inspection identical to the pre-test inspections shall be made for cracks.
- 11.6.11.24. If cracks that were not present before the test are found, or cracks have propagated from original recorded dimensions, the design shall be corrected, and the test rerun from the beginning with a new test specimen at the Contractor's expense.
- 11.6.11.25. The fatigue test shall not cause any fractures, cracks, separations, permanent deformation, or reservoir (if used) leakage in the truck.
- 11.6.11.26. If any of the above criteria are not met, the truck design shall be corrected and the truck retested with a new test specimen at the Contractor's expense. This process shall continue until the fatigue test is passed.
- 11.6.11.27. Upon completion of the 6 million cycle fatigue testing, the test shall continue for an additional 2 million cycles, or until failure, at an applied dynamic load factor of 1.5 to verify design margin and to identify potential crack initiation maintenance inspection points. The inspection points shall be reflected in the Work Manual and Overhaul Process Manuals for truck frames. See Sections 22.3.7 and 22.3.8.

11.6.12. Truck Dynamic Test

- 11.6.12.1. After the static load and fatigue tests, two trucks shall be installed on a car and tested on representative portions of the NYCT system.
- 11.6.12.2. The truck dynamic testing shall validate and calibrate the truck static and dynamic analyses required by Section 11.6.3, and validate the accessory dynamic load ranges utilized in Section 11.6.11.17.

Instrumentation

- 11.6.12.3. The Contractor shall provide a working procedure for the attachment of accelerometers for truck testing.
- 11.6.12.4. One of the two trucks shall be instrumented with tri-axial accelerometers at the following locations subject to NYCT approval:
- a) Two journal bearing boxes, diagonally opposite from each other.
 - b) One gear unit.
 - c) One traction motor.
 - d) One Tread Brake Unit (TBU).
 - e) The truck frame transoms, both center and end transoms as applicable.
- 11.6.12.5. Linear or rosette strain gauges, as appropriate, shall be installed on at least 15 locations subject to NYCT approval:

- a) The motor/gear unit.
- b) Motor/ gear unit mounting brackets.
- c) TBU mounting bracket.
- d) CBTC/ATC truck brackets. Separate tests shall be run if CBTC and ATC brackets are not identical.

Data Comparison

- 11.6.12.6. The accelerometer data recorded during the truck dynamic test shall show that the loads used during the truck fatigue test and truck component tests are greater than the actual measured loads.
- 11.6.12.7. Data comparison shall be made using rain flow counting of the measured data (per ASTM E1049), frequency-domain analysis of the data, or other approved method.
- 11.6.12.8. Filtering used during data analysis shall not attenuate frequencies between 1 Hz and 200 Hz.
- 11.6.12.9. Stresses calculated from the strain gauge data shall be below the allowable fatigue stresses for the design and from the truck stress analysis for each location instrumented for strain.

Dynamic Test Option

- 11.6.12.10. The truck dynamic test may be performed before the fatigue test (Section 11.6.11) if approved by NYCT and the following conditions are met:
- a) The test procedure shall be approved by NYCT.
 - b) The truck stress analysis required by Section 11.6.3 shall be completed and reviewed by NYCT.
 - c) NYCT questions on the truck stress analysis shall have been satisfactorily resolved and accepted by NYCT.
- 11.6.12.11. A single pre-production truck frame and bolster may be used.
- 11.6.12.12. Pre-production truck frames and bolsters shall be configured in accordance with the NYCT approved Contractor drawings, but may be assembled by expedient means without serial production jigs, fixtures, and tooling.
- 11.6.12.13. In the event that fatigue and dynamic testing is conducted concurrently, any failure observed in the fatigue test shall result in the removal of the dynamic test specimen(s) from service pending successful resolution of the fatigue test failure.

11.6.13. Primary Suspension Test

- 11.6.13.1. The primary suspension test shall verify that the system performance meets design requirements.
- 11.6.13.2. The primary spring rate and material creep shall remain within the design tolerance over the course of the design life of the primary suspension.
- 11.6.13.3. Deflections of the primary suspension shall not exceed design tolerance under any service load during its design life nor shall it allow any truck element truck to infringe on the minimum clearance to the top of the rail per Section 11.2.1.10.
- 11.6.13.4. Proof of compliance shall be accomplished either by:
- a) Accelerated aging test.
 - b) Inspections of primary suspension springs done periodically over a period of five years of revenue service. These inspections will require the approval and participation of NYCT.
- 11.6.13.5. Data from previous tests and/ or inspections on the same primary suspension elements may be submitted within 90 days of NTP, and if acceptable to NYCT, Section 11.6.13 may be waived.

11.6.14. Equalization Test

- 11.6.14.1. An equalization test shall be performed on one of each type of car, in ready to run (AW0) condition, and loaded to AW3, taken from the first three cars assembled of each type.
- 11.6.14.2. The air springs shall be inflated such that the car is at ride height. All wheels on the car shall be at the same level.
- 11.6.14.3. One wheel shall be first raised 2.50 inches (63.5 mm) and then lowered 2.50 inches (63.5 mm) vertically above the other three wheels of that truck. Treads of the other three wheels shall remain in contact with the rail. This test shall be repeated with the air springs fully deflated.
- 11.6.14.4. Next, the same wheel shall be raised 2 inches (50.8 mm) and then lowered 2 inches (50.8 mm) vertically above the other three wheels of that truck. The weight on the other three wheel treads shall not decrease by more than 50 percent.
- 11.6.14.5. If the truck does not meet the test conditions, the truck suspension shall be modified, and the truck shall be retested at the expense of the Contractor.

11.6.15. Inspection Test

- 11.6.15.1. A non-destructive inspection test shall be performed on one of the first production truck frames and bolsters from each manufacturing site.
- 11.6.15.2. The inspection shall be performed on locations including all critical welds and all critical areas for castings.
- 11.6.15.3. Any weld meeting at least one of the following criteria shall be considered a critical weld:
 - a) All full penetration welds.
 - b) All welds subject to tensile stresses in excess of 50 percent of the weld's rated fatigue life.
 - c) All non-redundant load path welds whose failure could cause truck failure or derailment.
 - d) All welds whose failure could impair brake performance.
- 11.6.15.4. Any area of the casting meeting at least one of the following criteria shall be defined as a critical area of the casting:
 - a) All areas whose combined static loads and fatigue loads exceed 3,000 psi (20,685 kPa) tension.
 - b) All areas subjected to fatigue range in excess of 15,000 psi \pm 7,500 psi (103.43 kPa \pm 51.71 kPa) regardless of static load.
 - c) All areas whose failure could result in derailment or impair braking performance.
- 11.6.15.5. Phased array ultrasonic testing in accordance with AWS D1.1:2010 shall be utilized on welds or by other means as approved by NYCT.
- 11.6.15.6. Radiographic inspection tests shall be utilized on castings and shall meet the requirements of Section 19.4.3.
- 11.6.15.7. Inspection quality level shall be selected by the truck manufacturer based on truck design, but shall not be of lesser quality than required by Section 6 of AWS D1.1:2010 for welds and Section 19.4.3 for castings.
- 11.6.15.8. Critical areas may be sectioned and etched in accordance with AWS D1.1:2010 to demonstrate weld soundness. In this case, there shall not be less than three etched sections at each critical area, and the location of each shall be approved by NYCT.
- 11.6.15.9. Defects that cause a truck to fail the test shall be repaired, and the test repeated until the truck passes the test.
- 11.6.15.10. Production methods shall be modified as necessary to ensure all trucks meet the weld and casting criteria.

11.6.16. Wheel Sets

- 11.6.16.1. All wheel set assembly work shall be performed in an approved AAR certified shop. Certification shall be provided to NYCT upon request.
- 11.6.16.2. All axle-mounted components shall be mounted using the procedures and tolerances recommended by the manufacturer.
- 11.6.16.3. Wheel pressing force shall be measured and recorded by means of an approved recording gauge, which shall be checked at the beginning of each work shift with a standard gauge.
- 11.6.16.4. The pressure gauge shall be calibrated in the presence of NYCT prior to the start of pressing wheels on axles, and periodically thereafter by a schedule approved by NYCT.
- 11.6.16.5. A NYCT inspector shall witness two wheels of equal outside diameter pressed on an axle. This axle shall then be spun to verify the following:
 - a) Wheel concentricity with the axle.
 - b) Wheel diameters remain equal.
 - c) Inner faces of rims are true and parallel within tolerances.
- 11.6.16.6. Pressure diagrams shall be provided with each set of wheels and axle. Pressure diagrams shall show a uniform buildup of force with respect to displacement, or the wheel and axle set shall be rejected.
- 11.6.16.7. Axles that are galled or damaged when pressing on wheels or gear components shall be rejected.
- 11.6.16.8. Axles, wheels, and gear components subjected to pressing forces greater than the calculated maximum shall be rejected.
- 11.6.16.9. Wheel axle sets shall be mounted in the truck in pairs matched in diameter within one-half tape size.
- 11.6.16.10. The Contractor shall furnish NYCT with a record of the wheel and axle manufacturers' serial and heat numbers listed together with the serial numbers of the cars and trucks on which they have been installed.

11.6.17. Axles

- 11.6.17.1. Requirements for axle inspection shall be based on applicable requirements of Section G, Part II of the AAR manual. All axle diameters and inspection findings shall be recorded on the axle inspection report sheet.
- 11.6.17.2. Ultrasonic inspection of all axles shall be performed in accordance with ASTM A 388/A 388M, "Standard Practice for Ultrasonic Examination of Heavy Steel Forgings".
- 11.6.17.3. All axles shall be free from cracks, flaws, seams or other injurious imperfections. The interpretation of injurious imperfections shall be made in accordance with the Appendix to ASTM Specification A-21.
- 11.6.17.4. A copy of all inspection reports for all axles shall be forwarded to NYCT.

11.6.18. Other Validation

- 11.6.18.1. Refer to Section 24.8.7, Routine Tests, for truck assembly production acceptance testing requirements.
- 11.6.18.2. The Contractor shall obtain from the primary suspension spring manufacturer and furnish to NYCT a certified guarantee against failure of the springs caused by defective material and/or workmanship. [CDRL]
- 11.6.18.3. The Contractor shall furnish NYCT with a record of the wheels and the axles upon which they are mounted per Sections 11.4.6 and 11.4.7, as well as the numbers of the trucks on which they are installed. [CDRL]

11.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
11-1	Not used	Not used	Not used
11-2	11.6.2.1	Truck Stress Analysis Plan Truck Structural Test Plan	PDR CDR
11-3	11.6.3.4	Listing of critical welds and casting areas	CDR
11-4	Not used	Not used	Not used
11-5	11.6.3.9	Axle strength analysis	CDR
11-6	11.6.4.2	Finite Element Model	6 months after NTP
11-7	11.6.4.11	Electronic Finite Element Analysis (FEA) input and output data	With FEA model or at revision.
11-8	11.6.5.1	FEA validation	With final test report
11-9	11.6.6.1	Truck stress analysis report	60 calendar days before commencing frame/bolster manufacture
11-10	11.6.18.2	Primary suspension spring guarantee	Truck FAI
11-11	11.6.18.3	Record of wheel and axle numbers	Car shipment

Section 12

**Friction Braking and Air Supply
Systems**

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12. Friction Braking and Air Supply Systems

12.1. Introduction and General Requirements

- 12.1.1. This section defines the requirements for the Friction Brake and Air Supply systems on the cars. The requirements are divided into Performance, Functional, Design, Maintainability, and Validation categories. Refer to the following sections for car systems and components interfacing with the Friction Brake and Air Supply systems and other applicable requirements:
- a) Design and Performance Criteria – Section 2.
 - b) Coupler Systems – Section 4.
 - c) Cab and Cab Controls – Section 5.
 - d) Auxiliary Electrical Equipment and Distribution – Section 9.
 - e) Propulsion System – Section 10.
 - f) Trucks and Secondary Suspension Systems – Section 11.
 - g) Train Control System – Section 14.
 - h) Carbody Equipment and Interiors – Section 15.
 - i) Trainline and Car Control Architecture – Section 16.
 - j) Monitoring and Diagnostics – Section 17.
 - k) Software Systems – Section 18.
 - l) Materials, Processes, and Workmanship – Section 19.
 - m) Reliability, Maintainability, and System Assurance - Section 21.
 - n) System Support - Section 22;
 - o) Testing Program – Section 24.
- 12.1.2. The Friction Brake System shall work in full coordination with the Propulsion System to provide total braking effort for each car. See Section 10.2.2.
- 12.1.3. The Friction Brake System shall provide continuously variable control of service friction braking on a per-truck basis. Alternate friction brake control architectures shall be subject to NYCT review and approval.
- 12.1.4. The Friction Brake System shall provide electro-pneumatic controlled service braking and pneumatic controlled fail-safe emergency braking that meets the performance requirements of Section 12.2.
- 12.1.5. Dynamic braking shall provide braking effort up to the dynamic brake capacity limit; see Section 10.2.2. If dynamic braking is unable to provide the total required braking effort, friction braking shall make up the required braking effort.
- 12.1.6. Friction brake controls shall provide snow brake functions and slide control of friction braking through the same continuously variable service brake control referenced in Section 12.1.3.
- 12.1.7. The propulsion control logic interaction with emergency braking shall be as specified in Section 12.3.
- 12.1.8. The design and supply of the Friction Brake System shall be the responsibility of a single supplier.
- 12.1.9. The Propulsion and Friction Brake Systems shall be properly integrated and installed to ensure successful functioning and proper performance of the car, in accordance with Specification requirements.

- 12.1.10. The Contractor shall obtain formal concurrence from the Friction Brake System supplier that the Friction Brake System integration into the overall car propulsion and braking function is complete and validated per all applicable requirements of the Specification. This concurrence shall be submitted to NYCT as part of the Critical Design Review (CDR) for the Friction Brake System.
- 12.1.11. Each car shall be equipped with the following friction brake equipment as a minimum:
- a) Two Friction Brake Electronic Control Units (FBECU) which may be integrated into pneumatic brake operating units or integrated into propulsion control logic.
 - b) Two independent Pneumatic Brake Operating Units (one per truck).
 - c) One independent Brake Pipe Control Unit whose function may be integrated on one of the pneumatic brake operating units.
 - d) Eight Tread Brake Units (TBU) for A2 and B Cars, one per wheel, with spring brake portions integrated into one TBU per axle (four per car).
 - e) Six TBUs for A1 Cars, one per wheel except the free axle, with spring parking brake portions integrated into one TBU per axle (three per car).
 - f) One Main Reservoir.
 - g) Two Supply Reservoirs (one per truck).
 - h) One Conductor's Emergency Brake Valve (A Car cabs only).
 - i) Two Passenger Emergency Handle Units (PEHU).
 - j) Two Trip Cocks.
 - k) All other equipment required to perform the specified tasks.
- 12.1.12. Air compressor unit(s) incorporating compressor, dryer, and controls shall be applied to the operating Unit as required. See Section 12.6.1.
- 12.1.13. The system shall include a main reservoir pipe connecting air compressors and main reservoirs within each Unit.

12.2. Performance Requirements

12.2.1. General

- 12.2.1.1. This section establishes the performance criteria of the Friction Brake and Air Supply System and components. Equipment shall be designed to successfully produce the specified performance values. Car, Unit, and train level performance requirements and environmental conditions are specified in Section 2.
- 12.2.1.2. The Contractor shall demonstrate brake system component compliance to the shock and vibration requirements of Section 2.9.6.
- 12.2.1.3. The overhaul interval of the Friction Brake and Air Supply systems, including all elastomers, shall be a minimum of one SMS cycle (see SMS 89-002 Rev A, "SMS Generic Car Workscope and Time Intervals", Appendix C-36), under the normal operating conditions defined in this section.

12.2.2. Response Times

- 12.2.2.1. A step change in service brake command from 25 to 75 percent of maximum brake effort shall result in a change of brake cylinder pressure, as measured at the pneumatic operating unit, from 25 to 55 percent of maximum in 0.65 second or less (including dead time) from the time of the service brake command state change.

- 12.2.2.2. A step change in service brake command from 75 to 25 percent of maximum brake effort shall result in a change of brake cylinder pressure, as measured at the pneumatic operating unit, from 75 to 45 percent of maximum in 0.75 second or less (including dead time) from the time of the service brake command state change.
- 12.2.2.3. Dead time of the service brake response shall be less than 0.2 seconds, measured from the state change of the service brake command to the beginning of brake cylinder pressure change.
- 12.2.2.4. The propagation time for an emergency brake application shall be less than two seconds, measured from the state change of the emergency brake command at the lead car until the beginning of brake cylinder pressure rise measured at the trailing pneumatic operating unit of any train length as defined in Section 2.2.

12.2.3. Air Compressor Unit

- 12.2.3.1. Operating pressure range and maximum pressures are defined in Section 2.6.1.
- 12.2.3.2. Noise levels shall comply with Section 2.9.4.2. These requirements shall also apply to pneumatic valve exhaust.
- 12.2.3.3. The air compressor unit vibration shall meet the requirements of Section 2.9.5.
- 12.2.3.4. The performance of the air dryer system shall result in the car's air supply system meeting the requirements of APTA PR-M-S-011-99, with the exception of dew point depression requirements.
- 12.2.3.5. Dew point performance requirements of APTA PR M-S-011-99 Section 5.2.2 shall be modified to require the outlet dew point depression to be not less than 50°F (27.8°C).
- 12.2.3.6. The dryer shall have adequate capacity to meet the stated requirements at working pressure under all ambient conditions specified in Section 2.5.1, throughout the desiccant's useful life.

12.2.4. Reservoir Capacity

- 12.2.4.1. Reservoirs shall have a volumetric capacity capable of supplying all systems with sufficient air to make five consecutive full service brake applications and releases at AW3 loading without initiating an emergency application because of low air.
- 12.2.4.2. After the five consecutive full service brake applications, it shall be possible to make a normal load weighed emergency application.
- 12.2.4.3. Loss of air supply for this scenario shall occur when the main reservoir air is at the lowest operating pressure defined in Section 2.6.1.

12.2.5. System Leakage

The Contractor shall be responsible to confirm that leakage rates of the Friction Brake and Air Supply System components shall support achievement of the car leakage performance defined in Section 2.6.4.

12.2.6. Proof Pressure

Pneumatic system components shall withstand one and one half times the main reservoir safety valve opening setpoint pressure without damage and shall function without degradation after removal of the elevated pressure.

12.2.7. Horn

The horn shall provide a fundamental frequency of 400 Hz with a G4 natural tone and have a minimum sound level of 92 dBA at a distance of 100 feet (30.5 m) from the end of the car on surface or elevated track.

12.2.8. Passenger Emergency Handle Unit

The audible annunciation shall generate a sound level of 88 to 95 dBA at a distance of 6 inches (152 mm) directly in front of the PEHU sound generator with the door open 90 degrees, regardless of handle position.

12.2.9. Tread Brake Unit

- 12.2.9.1. The minimum Margin of Safety (MS) against yield for all brake components shall be 0.50, under AW3 emergency braking loads combined with maximum parking brake forces applied to the TBU.
- 12.2.9.2. The TBU shall not experience permanent deformation of any components responsible for transferring the braking and lateral load to the truck frame under loading consisting of AW3 emergency braking loads and 1.33 times the maximum lateral force due to braking and axle displacement.
- 12.2.9.3. Fatigue strength of the TBU shall provide for a MS of 0.20 from failure at six million cycles using a cumulative damage design approach under the following load cases:
 - a) AW3 service brake loads + 0.66 lateral braking force applied – Direction 1.
 - b) AW3 service brake loads + 0.66 lateral braking force applied – Direction 2.
 - c) AW3 emergency brake load + 0.66 lateral brake force applied in both directions every 60 brake applications.
- 12.2.9.4. Spring parking brake components shall provide for a MS of 0.50 from fatigue failure with 300,000 application and release cycles.
- 12.2.9.5. The TBU shall not slip in its mounting under the worst case combined loading of AW3 passenger loading emergency brake loads, 66 percent of the maximum lateral force due to braking and axle displacement, and acceleration loading. The minimum MS shall be 0.10.
- 12.2.9.6. Auxiliary parking brake release device components shall have a minimum MS from yielding of 0.50 under an application force of 338 lb. (1.5 kN).
- 12.2.9.7. Braking loads and corresponding strength calculations shall be updated as the car design progresses. Strength calculations during the design phase shall consider predicted values for the value for the brake shoe friction coefficient based on friction material supplier published data.
- 12.2.9.8. Critical components of the TBU, such as components whose failure will result in detachment of the unit, shall utilize a design MS of 0.75 for static load cases and 0.50 for fatigue load cases. A listing of components considered critical by the Contractor shall be approved by NYCT.

12.3. Functional Requirements

12.3.1. General Requirements

- 12.3.1.1. An automatic electro-pneumatically controlled Friction Brake System shall be provided on each car.
- 12.3.1.2. The Friction Brake System shall apply retarding force by means of tread brakes and shall have the primary functions of continuously variable service braking and fail-safe emergency braking.
- 12.3.1.3. The Friction Brake System shall be capable of automatically meeting the performance requirements of the braking system with dynamic braking inoperative.
- 12.3.1.4. The friction brake control shall be via logic units controlling the friction braking for each truck.
- 12.3.1.5. The FBECUs shall communicate with each other and the car control unit on the same car as required to achieve the required system functionality.
- 12.3.1.6. As a minimum, the FBECUs shall perform the following functions:
 - a) Control of the friction brake equipment on the car.
 - b) Slide control on a per-truck basis.
 - c) Coordination with the propulsion logic as required to achieve car functions and performance, i.e., blending, load weigh, and slide control coordination.
 - d) Convert trainline commands into output signals to the friction brake equipment.

- e) Provide self-diagnostic routines.
- f) Monitor for faults of internal and external devices.
- g) Contain user programmable operating characteristics.
- h) Store control programs in non-volatile memory.
- i) Provide control logic that shall provide continuous monitoring of operating parameters.
- j) The FBECU, related software, and devices shall be able to detect and annunciate errors and faults to prevent damage to the equipment.
- k) The FBECU shall include the necessary logic, memory, and interface provisions to log and store key faults and status information within the control unit and communicate that information, via the Car Network, to the Monitoring and Diagnostic System (MDS) described in Section 17.
- l) The FBECU shall periodically synchronize its time and date settings to the master clock via the MDS. See Section 17.3.6.

12.3.1.7. Alternate distribution of functions between propulsion control units and FBECUs may be proposed for NYCT approval.

12.3.1.8. FBECUs shall be microprocessor based, utilizing no more than 70 percent of the installed memory and no more than 50 percent of the available processor time. See Section 18.2.2.

12.3.1.9. FBECUs and software shall conform to the requirements of Section 18, Software Systems.

12.3.1.10. The Friction Brake System shall incorporate a switch to provide brake cylinder pressure status (e.g., brake applied, released) on each truck for indication on the cab console.

12.3.1.11. These switches shall interface with the discrete traction power interlock trainline(s) described in Section 16.1.2 without the interposition of electronic logic.

12.3.1.12. The brake cylinder pressure switches shall also interface with the propulsion control logic.

12.3.2. Service Brake

12.3.2.1. Brake cylinder pressure in service braking shall be controlled on a per-truck basis by a closed-loop proportional control with air supply from the associated supply reservoir.

12.3.2.2. The degree of brake release shall be proportional to control energization.

12.3.2.3. Loss of control energization shall result in full service brake application.

12.3.2.4. The proposed methodology and design details of the control system shall be submitted for NYCT approval.

12.3.3. Emergency Brake

12.3.3.1. Emergency braking shall be propagated by a pneumatic brake pipe running the length of the train, supplemented by discrete electric trainlines, as specified in Section 16.4.3.

12.3.3.2. Emergency braking from the pneumatic brake pipe shall be available whenever the system is charged with compressed air.

12.3.3.3. Emergency braking shall be independent of the propulsion and friction brake control logic.

12.3.3.4. All emergency brake performance requirements shall be met with electro-pneumatic propagation.

12.3.3.5. Emergency braking shall be able to be initiated by:

- a) Emergency position of Master Controller handle. See Section 5.6.2.
- b) Deadman control. See Section 5.6.3.
- c) Conductor's emergency brake valves. See Section 5.5.1.

- d) PEHUs. See Section 12.3.4. See Section 25 for Staten Island Railway (SIR) specific requirements.
- e) Trip cock activation. See Section 12.4.11.
- f) Reduction of main reservoir pressure below that needed to provide a full emergency brake application at AW3.
- g) Un-commanded uncoupling.
- h) Parting or rupture of the brake pipe or brake pipe hose.
- i) Brake pipe leakage in excess of the capacity of the maintaining valves. See Section 12.3.3.9.
- j) Energizing of the electric emergency brake trainline signal.
- k) CBTC System. See Section 14.4.6. See Section 25 for SIR specific requirements.

12.3.3.6. Emergency braking shall be developed on each truck whenever brake pipe pressure falls below an approved level regardless of the prior state of the Propulsion System or the Friction Brake System.

Brake Pipe Charging

- 12.3.3.7. The brake pipe shall be charged from main reservoir air and shall operate at main reservoir pressure.
- 12.3.3.8. Each car shall be equipped with normally closed, electrically-operated charging valves. These charging valves shall initiate development of brake pipe pressure.
- 12.3.3.9. Each car shall be equipped with pneumatic, limited-flow maintaining valves. These maintaining valves shall maintain brake pipe pressure.
- 12.3.3.10. The brake pipe shall begin charging when the Master Controller is moved from the emergency brake position to the full service position. See Section 5.6.6.
- 12.3.3.11. Brake pipe charging shall begin at the car with the controlling cab, and shall be assisted by the charging valves on other cars of the train.
- 12.3.3.12. If the Master Controller handle is moved beyond the full service brake position during the initiation of brake pipe charging, charging shall continue, providing:
 - a) The Master Controller handle remains in the brake range (not coast), and
 - b) The Master Controller handle is returned to the full service position within 3 seconds.
- 12.3.3.13. During the initiation of brake pipe charging, if the Master Controller goes into the coast or power range, or remains out of the full service position for more than 3 seconds:
 - a) The brake pipe shall vent.
 - b) The charging sequence must be reinitiated by returning the Master Controller handle to the emergency position.
- 12.3.3.14. Any discontinuity in the brake pipe anywhere in the train shall prevent the release of emergency brakes on the entire train.
- 12.3.3.15. The brake pipe shall charge to operational levels within 17 seconds of initiation for a train of maximum length.
- 12.3.3.16. The time to charge the brake pipe shall increase proportionately if the controlling logic on one or more cars in the train is inoperative.
- 12.3.3.17. The initiation or propagation of emergency braking shall not be prevented even if all charging and maintaining valves experience a failure that causes them to remain open.
- 12.3.3.18. Maintaining valves shall also provide for the main reservoir to be charged from the brake pipe.

- 12.3.3.19. The brake pipe shall be able to charge only when the reverser handle is set to the forward position and other charging conditions are satisfied.
- 12.3.3.20. The brake pipe shall be charged before the reverser handle may be moved to the reverse position, allowing the train to operate in the reverse direction.

Brake Pipe Special Charge

- 12.3.3.21. Special charge shall be initiated by the Master Controller in the active cab. See Section 5.6.4.
- 12.3.3.22. Initiation of the special charge function shall energize the electric emergency trainline.
- 12.3.3.23. Special charge of the brake pipe shall be applied, via the active A Car brake pipe charging valve 17 seconds after the special charge function is initiated.
- 12.3.3.24. Special charge shall maintain brake pipe pressure at 70 psi. The pressure range shall be approved by NYCT.

Emergency Brake Application

- 12.3.3.25. Each car shall be equipped with an Emergency Magnet Valve (EMV).
- 12.3.3.26. The EMV shall be electrically-operated and normally open.
- 12.3.3.27. When the EMV is de-energized it shall exhaust brake pipe pressure to the atmosphere, triggering a pneumatic emergency brake application.
- 12.3.3.28. The exhaust port of the EMV shall be muffled. Mufflers shall not inhibit or delay the emergency brake application and shall allow for plugging of the EMV exhaust in the instance of valve failure.
- 12.3.3.29. Energizing the electric emergency brake trainline shall cause the EMV to open in all cars, triggering a pneumatic emergency brake application. See Section 16.4.3.
- 12.3.3.30. Each car shall be equipped with a pneumatic Emergency Vent Valve (EVV).
- 12.3.3.31. The pneumatic EVV shall ensure that, once activated, an emergency brake application cannot be halted, and that the train comes to a complete stop. Alternative ways of accomplishing this function may be presented to NYCT for approval.
- 12.3.3.32. The pneumatic EVV shall respond to rapid reductions in brake pressure by exhausting brake pipe air to the atmosphere, triggering a pneumatic emergency brake application.
- 12.3.3.33. The exhaust ports of the pneumatic EVV shall be muffled. Mufflers shall not inhibit or delay the emergency brake application and shall allow for plugging of the EVV exhaust in the instance of valve failure.
- 12.3.3.34. Each car shall be equipped with at least one normally open brake pipe pressure switch.
- 12.3.3.35. The brake pipe pressure switches shall monitor brake pipe pressure and shall energize the electric emergency brake trainline if brake pipe pressure drops below a pre-set pressure. This pressure shall be approved by NYCT. See Section 16.4.3.
- 12.3.3.36. Brake pipe pressure switch activation and location shall be logged by the MDS and displayed on the Train Operator Display (TOD). See Section 17.
- 12.3.3.37. Supply of emergency brake cylinder pressure on each truck shall be from the associated truck supply reservoir.
- 12.3.3.38. The emergency brake cylinder pressure shall be sent to the TBUs by a pneumatically operated valve, piloted by brake pipe air.

12.3.4. Passenger Emergency Handle Unit

- 12.3.4.1. With PEHU activation, the emergency brake shall be applied if, and only if, the train has proceeded 600 feet (183 m) or less from its most recent station stop.

- 12.3.4.2. If the train has proceeded more than 600 feet (183 m) from its most recent station stop, the emergency brake shall be applied when the train has reached its next station stop. See Section 12.4.8.
- 12.3.4.3. A PEHU “activated” indication shall be made in each cab in which a Master Controller or Master Door Controller is activated.
- 12.3.4.4. For the purposes of the PEHU logic, a station stop shall be considered to take place whenever the no-motion signal is true and the car doors are commanded to open.
- 12.3.4.5. The PEHU circuits shall be so arranged that, in the event of failure of the logic implementing the functions described above, the response to actuation of the PEHU shall be an immediate emergency brake application.
- 12.3.4.6. PEHU activation and location shall be logged by the MDS and displayed on the TOD. See Section 17.

12.3.5. Friction Brake Load Weigh

- 12.3.5.1. A load weigh transducer shall be used to control friction service braking with changing car weight.
- 12.3.5.2. The load weigh transducer shall sense air suspension pressure from the truck equipped with the single leveling valve. See Section 11.3.7.
- 12.3.5.3. If load weigh sensing is lost, the Friction Brake System shall default as follows:
 - a) Service Brake - to a car weight of AW3.
 - b) Emergency Brake – to a car weight of AW0.
- 12.3.5.4. Emergency brake cylinder pressure shall be pneumatically limited in response to car load.
- 12.3.5.5. The load weigh system shall not respond to dynamic suspension motions.

12.3.6. Snow Brake

- 12.3.6.1. The snow brake shall be controlled by a switch on the operator’s console. Alternate methods of snow brake activation, such as a soft key, may be proposed for NYCT review and approval.
- 12.3.6.2. When activated, the snow brake shall apply whenever brake cylinder pressure would otherwise be less than the snow brake pressure.
- 12.3.6.3. The snow brake application logic shall incorporate functions to ensure TBU slack adjustment.
- 12.3.6.4. The snow brake shall keep the wheel treads and brake shoes clean and dry through a light brake force application.
- 12.3.6.5. The snow brake command shall be communicated to each car as a trainline function.

12.3.7. Slide Control

- 12.3.7.1. The friction brake slide protection system shall operate on a per-truck basis and shall provide performance as specified in Section 2.7.7.
- 12.3.7.2. The friction brake slide protection system shall be designed so that any failure of the system allows more braking effort than would otherwise be commanded.
- 12.3.7.3. A wheel size calibration system shall be provided for the purposes of friction brake slide control.
- 12.3.7.4. The wheel size calibration system for each truck shall include a self-check and automatic calibration function.
- 12.3.7.5. Discrepant settings and similar anomalous conditions shall be annunciated if appropriate and shall be logged for maintenance attention in the MDS. See Section 12.3.1.6.

12.3.8. Parking Brake

- 12.3.8.1. One TBU per braked axle shall be equipped with a spring-applied, pneumatically-released parking brake.

- 12.3.8.2. Exhaust of the control air supply to the spring parking brake cylinder shall result in the required holding power at the TBU.
- 12.3.8.3. The parking brake shall incorporate a self-resetting manual override that allows the parking brakes to be released when pneumatic pressure is not available.
- 12.3.8.4. The manual override shall be accessible from above the floor, in locations approved by NYCT.
- 12.3.8.5. If a ratchet or pump is used, it shall not require more than 30 handle cycles to override the parking brakes. As an alternate, a protected supply of compressed air may be used to override the parking brakes.
- 12.3.8.6. If a pneumatic parking brake release signal is generated, it shall cancel all manual overrides.
- 12.3.8.7. Manually released parking brakes on each A Car shall be able to be manually re-applied regardless of the pressure in the main reservoir.
- 12.3.8.8. The automatic parking brake shall apply when the main reservoir pressure is below a value approved by NYCT.
- 12.3.8.9. A manual valve shall be provided on the parking brake control unit. This valve shall isolate and vent the parking brake actuators on each car from the main reservoir. This valve shall be safety wired and sealed.
- 12.3.8.10. An anti-compounding function shall be provided to prevent the simultaneous application of parking brake force and service brake force.
- 12.3.8.11. The parking brake system shall communicate parking brake status to the propulsion control logic.

12.3.9. Air Compressor Unit

- 12.3.9.1. The air compressor unit shall maintain main reservoir pressure in accordance with Section 2.6.1 under all operating conditions.
- 12.3.9.2. Air compressor operation shall be managed on a Unit level through the means of a management system which may be integrated with the FBECU, Propulsion Controls, Train Control Network, or equivalent. The management system shall ensure air compressors operate with an acceptable duty cycle, maintain an even distribution of operating hours, and allow for distribution of operating units to maintain operation of the Unit in the event of compressor failure.
- 12.3.9.3. Details of the air compressor controls are subject to approval by NYCT.
- 12.3.9.4. The air compressor operating pressure setpoint controls shall be non-adjustable.
- 12.3.9.5. Controls shall be responsive to all rates of main reservoir depletion in the pneumatic system.
- 12.3.9.6. The number and sizing of compressors shall allow for malfunction of a single compressor on a Unit without impact to operation of the Unit. Remaining functional air compressors shall handle all operating and emergency requirements of the Unit indefinitely. See Sections 12.1.11 and 12.6.1.

12.3.10. Brake Release Bypass

- 12.3.10.1. A brake release bypass switch shall be provided which disables the brake release interlock function so that the train can move in the event of a stuck friction brake or a parking brake that is not released.
- 12.3.10.2. The BRAKE RELEASE switch shall be a two-position (NORMAL / BYPASS) toggle switch, see Sections 5.5.5.7 and 10.3.8.3.

12.4. Design Requirements

12.4.1. General

- 12.4.1.1. The Friction Brake System shall conform to the safety design principles and methods defined in Sections 2.12.2.3 b) and 2.12.2.4.

- 12.4.1.2. The Friction Brake System shall withstand the loads induced when meeting performance requirements with dynamic braking inoperative.
- 12.4.1.3. The Friction Brake System, including all valve portions and mechanical linkages, shall be designed for 6 million cycles of operating loads without failure, excluding planned replacement of expendable items.
- 12.4.1.4. The friction brake and air compressor controls shall be mounted in enclosure(s) that provide safety, protection for equipment, and access for maintenance, as approved by NYCT. Reference Section 15.15 for enclosure requirements.
- 12.4.1.5. For specific material design requirements to be applied to the system pneumatic and electronic components, see Section 19, Materials, Processes, and Workmanship.

12.4.2. Brake Operating Units and Brake Pipe Control Units

- 12.4.2.1. Pneumatic brake operating units and brake pipe control units shall be preassembled, utilizing manifold designs of laminated, cross drilled, or other design approved by NYCT.
- 12.4.2.2. Brake operating unit designs integrating the pneumatic controls with friction brake control electronics in a unitized package may be submitted for NYCT review and approval.
- 12.4.2.3. It shall be possible to remove individual operating devices without disturbing any pipes or other adjacent equipment.
- 12.4.2.4. The independent pneumatic brake operating unit and the independent brake pipe unit shall be mounted by means of a pipe bracket installed on the car underframe.
- 12.4.2.5. The units shall be equipped with a disposable-element line filter applied to the main and supply reservoir inlets. The element shall be designed to last for at least 60,000 miles (96,560 km) of car operation.
- 12.4.2.6. Filter elements shall allow for air flow to bypass in the event that the filter element becomes blocked.

12.4.3. Air Compressor Unit

- 12.4.3.1. The air compressor unit shall be designed as a single assembly incorporating motor, compressor, air dryer, controls and/or inverter, and other components necessary to realize the required air supply functions. The air compressor unit shall be housed within an underfloor mounted frame.
- 12.4.3.2. Oil-lubricated or oil-free reciprocating type air compressors shall be supplied.
- 12.4.3.3. Oil-lubricated air compressor unit designs shall incorporate provisions for minimizing oil-bypass from the compressor unit to the air dryer subject to NYCT review and approval. See Section 12.5.21.
- 12.4.3.4. The air compressor unit shall incorporate an air intake filter with particle size and efficiency performance matching the requirements of the compressor design. The filtration design shall be subject to NYCT approval.
- 12.4.3.5. The air compressor unit shall allow compressed air to bypass the after-cooler if the after-cooler becomes blocked.
- 12.4.3.6. The air compressor unit shall be equipped with safety valves which prevent the pressure in the compressor unit from exceeding the maximum operating pressures as defined by the manufacturer.
- 12.4.3.7. A safety valve shall be applied to the main reservoir system to limit pressure to a value specified in Section 2.6.1.
- 12.4.3.8. The air compressor shall be driven by an industrial-grade induction electric motor rated for 100 percent duty cycle, conforming to NEMA MG1 or other approved standard.
- 12.4.3.9. The air compressor electric motor shall be operated from an auxiliary inverter. Both shall be safety hung from the air compressor frame. See Section 9, Auxiliary Electrical Equipment and Distribution.

- 12.4.3.10. The air compressor electric motor shaft shall be supported by ball or cylindrical roller bearings. Bearings shall be double-width, pre-lubricated, and sealed.
- 12.4.3.11. Compressor controls shall include provisions for recording hours of compressor operation.
- 12.4.3.12. The air compressor unit shall be equipped with a regenerating-type, twin tower air dryer. Alternate air dryer systems may be proposed for NYCT review and approval.
- 12.4.3.13. Methods and procedures to verify proper twin-tower cycling shall be included in all Maintenance and Overhaul Manuals associated with the air supply unit.
- 12.4.3.14. The air dryer shall have a service proven automatic drain valve attached to the sump reservoir, and shall be subject to NYCT approval.
- 12.4.3.15. The automatic drain valve shall be actuated periodically when the compressor is running. The time interval between drain valve actuation shall mitigate moisture build-up in the air system; also see 12.4.3.17.
- 12.4.3.16. Every automatic drain valve shall be tested for operation under all service air pressure conditions, and to withstand the maximum pressure value specified in Section 2.6.1.
- 12.4.3.17. The automatic drain valve shall have a thermostatically-controlled heater powered by the car low voltage system.
- 12.4.3.18. The air dryer shall incorporate a replaceable moisture indication device which provides visual indication of a saturated condition (i.e. discernable change in indicator color).
- 12.4.3.19. A vented cutout cock shall be provided within the pneumatic line between the air compressor and the main reservoir tank. With the cutout cock closed, the line towards the air compressor shall be vented.
- 12.4.3.20. A check valve shall be installed between the dryer outlet and the main reservoir pneumatic circuit to protect against loss of main reservoir pressure from an air compressor unit failure.

12.4.4. Air Reservoirs

- 12.4.4.1. Each car shall have one main reservoir.
- 12.4.4.2. The main reservoir shall be equipped with a manual drain valve. The manual drain valve shall open by a remote pull lever or handle accessible from track level at the side of the car nearest the reservoir.
- 12.4.4.3. Each truck shall have one supply reservoir.
- 12.4.4.4. The supply reservoir shall supply air to the service and emergency brake cylinder pneumatic control equipment only.
- 12.4.4.5. The air supply in the supply reservoir shall be protected from loss of main reservoir pressure by a check valve.
- 12.4.4.6. The air supply reservoir shall be equipped with a manual drain plug.
- 12.4.4.7. Reservoirs shall conform to the pressure vessel requirements of Section 19.15.
- 12.4.4.8. Reservoirs shall be manufactured from low alloy steel with flange fittings.
- 12.4.4.9. Reservoirs shall be painted inside and outside. Paint and painting procedures shall be approved by NYCT.
- 12.4.4.10. All drain valves and other fittings on the bottom of reservoirs shall be provided with shrouds for protection from track debris.

12.4.5. Cutout Cocks

- 12.4.5.1. Cutout cocks shall be provided for isolation of all pneumatic components and subsystems. The cutout cocks described in this section shall be provided as a minimum. Others shall be provided as necessary for maintenance, troubleshooting, and failure recovery.

- 12.4.5.2. All cutout cocks shall have the following features:
- All cutout cock handles shall be locking type, except where multiple controls to the cutouts are applied.
 - All cutout cock handles shall be perpendicular to the flow of the air when open.
 - All cutout cock handles shall be parallel with the flow of the air when closed.
 - All cutout cocks shall indicate the direction of flow.
- 12.4.5.3. A vented cutout cock shall be provided in each brake cylinder line.
- 12.4.5.4. Each brake cylinder cutout cock shall have a control located inside the car behind a swing panel, and another control under the car at the side of the car, accessible to a person standing beside the car at track level. It shall be possible to cut out and cut in the brakes from either control.
- 12.4.5.5. One selector cutout cock shall be provided for each truck.
- 12.4.5.6. The selector cutout cock shall be used to cut out the service brakes on that truck. Emergency brakes shall not be affected.
- 12.4.5.7. Each selector cutout cock shall have a control located inside the car behind a swing panel, and another control under the car at the side of the car, accessible to a person standing beside the car at track level. It shall be possible to cut in and cut out the selector cock from either control.
- 12.4.5.8. Manually operated self-locking, non-vented cutout cocks shall be provided at each car body end of each pneumatic pipe that is trainlined. See Section 4.3.5.
- 12.4.5.9. Air Suspension Cutout (ASC) cocks, one per truck, shall be provided in the air supply line to the air springs to vent both springs and close the air supply to the springs. Cutout cocks shall be lock wired in their normal operating position.
- 12.4.5.10. The cutout cocks shall be located adjacent to each truck and shall be accessible from both sides of the car (without going under the car). Their location shall be identified by the letters "ASC" applied to the side sill adjacent to the cutout cocks.

12.4.6. Gauges

- 12.4.6.1. A single duplex air gauge shall be installed in the cab to indicate brake cylinder pressure and brake pipe pressure. See Section 5.5.8.
- 12.4.6.2. The needle for the brake pipe pressure shall be black, and the needle for brake cylinder pressure shall be red. The background of gauge face shall be white.
- 12.4.6.3. A digital gauge may be proposed, subject to NYCT approval.

12.4.7. Horn

- 12.4.7.1. A non-adjustable pneumatic horn shall be installed beneath the floor at each cab end, controlled from the adjacent cab console.
- 12.4.7.2. Air consumption of the horn shall not exceed 20 cubic feet per minute.
- 12.4.7.3. A vented cutout cock shall be provided in the air supply line for each horn upstream of any filters or control devices.
- 12.4.7.4. Each horn shall be mounted to prevent ingress of water, snow, and ice, and shall incorporate a mesh debris guard.
- 12.4.7.5. A plate shall be installed in front of the horn trumpet to deflect track debris.
- 12.4.7.6. The horn shall be equipped with an in-line filter that allows airflow to bypass the filter element in the event it is blocked. The design shall be approved by NYCT.

12.4.8. Passenger Emergency Handle Unit

- 12.4.8.1. Each car shall be provided with two PEHUs, located near each end of the car.
- 12.4.8.2. Each PEHU shall have a recessed handle that activates the PEHU controls when pulled down.
- 12.4.8.3. The handle shall require between 15 lb. (67 N) and 20 lb. (89 N) of force to activate the PEHU. The handle shall not rattle during car movement when not in use.
- 12.4.8.4. Once the handle is pulled, it shall remain in the activated position until reset by a mechanism operated by the Master Door Controller key.
- 12.4.8.5. The handle shall be red and shall visibly indicate its activation status.
- 12.4.8.6. One PEHU shall be located in the wheelchair area, and shall be recessed and located within ADA height requirements.
- 12.4.8.7. The handle shall be located within an enclosure with a detent-retained, hinged cover.
- 12.4.8.8. The hinged cover shall be spring-loaded to close and latch from an opening of 90 degrees or greater to keep the cover, once opened, from becoming a safety hazard.
- 12.4.8.9. Opening of the hinged cover shall activate an audible alarm incorporated within the PEHU enclosure.
- 12.4.8.10. The audible alarm, powered from the car's low voltage DC system, shall sound continuously until the enclosure cover is closed.

12.4.9. Pneumatic Piping Design

- 12.4.9.1. For piping materials and workmanship requirements, reference Section 19.14.
- 12.4.9.2. All pneumatic pipes shall be sized in accordance with the function intended, and the diameter of the main reservoir pipes, brake pipes, and brake cylinder pipes shall meet the brake supplier's requirements.
- 12.4.9.3. ASTM A53 or ASTM A106 piping applications shall comply in all respects to AAR Specification No. 2518, Standard 400, latest revision. Approved copper tube or approved alternates shall also comply with relevant requirements of AAR Specification No. 2518.
- 12.4.9.4. ASTM A53 or ASTM A106 piping connections and joints, where disassembly for service may be required, shall utilize swivel type butt-welded flange fittings with an "O" ring type seal.
- 12.4.9.5. The use of threaded fittings is expressly prohibited. Use of threaded fittings may be approved only where flanged fittings are proven to be unusable.
- 12.4.9.6. Pneumatic piping shall minimize the use of fittings and bends.
- 12.4.9.7. All pipe joints shall be accessible without the need to remove surrounding operating equipment.
- 12.4.9.8. All carbody mounted components interfacing with pneumatic piping shall be mounted in proximity to minimize the amount of piping.
- 12.4.9.9. Unions shall be used to permit replacement of components and hoses.
- 12.4.9.10. All piping and fittings shall be installed to provide drainage away from devices, or branch pipes leading to devices. Low spots (traps) are strictly prohibited on the trucks.
- 12.4.9.11. Piping direction changes shall be accomplished by pipe bending to a radius of not less than specified by AAR Specification No. 2518, Standard S-400, or to an NYCT-approved radius. Direction-change fittings shall not be used in the trainlined brake pipe or in the brake cylinder piping.
- 12.4.9.12. Pipes shall be rigidly supported:
 - a) Throughout their length and at all connections.
 - b) At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member.

- c) No more than 2 inches (50 mm) from either end of flexible elements.
 - d) To prevent contact or chaffing with adjacent piping, components, or structure due to any combination of car loading and deflection, car dynamics, and thermally induced movement.
 - e) To isolate from vibration and to prevent noise.
 - f) To limit stresses throughout their length and at all connections to less than 50 percent of the pipe's fatigue endurance limit under the shock and vibration conditions defined in Section 2.9.6.
- 12.4.9.13. Pipe supports shall not be welded, brazed, or otherwise permanently fastened to any pipe or tubing.
- 12.4.9.14. Pipe supports shall be inherently rigid and shall be firmly attached to car structure. Support designs and materials shall be reviewed and approved by NYCT.
- 12.4.9.15. Pipe and tubing interfaces with supports shall be insulated with an NYCT approved material.
- 12.4.9.16. All piping, fittings, and valves shall be shielded from debris.
- 12.4.9.17. Truck piping shall not be run on the bottom of truck side frames, transoms, or bolsters, unless approved by NYCT.
- 12.4.9.18. Piping shall be insulated from high voltages in locations where piping is installed adjacent to exposed high voltage components.
- 12.4.9.19. Hose connections shall be provided for the following:
- a) On all piping between the carbody and the trucks.
 - b) On all piping between the carbody and couplers.
 - c) Between the air compressor unit and carbody unless isolation is provided within the air compressor unit.
 - d) Between truck piping and TBUs.
- 12.4.9.20. Hoses shall meet the requirements contained within Appendix C-15 (Air Brake Hose Assemblies 2086-PROD-96) while conforming to AAR Specifications M-618 and M-927 for the hose and reusable fittings, respectively. Hoses shall utilize AAR-approved reusable fittings meeting AAR Specification M-927, and are subject to NYCT approval.

12.4.10. Tread Brake Units

General

- 12.4.10.1. Each TBU shall receive service brake air pressure from the brake operating unit and apply braking effort to the wheel tread through a composition brake shoe.
- 12.4.10.2. The output brake force of the TBU shall be linearly proportional to the applied brake cylinder pressure throughout the full stroke range of the actuator.
- 12.4.10.3. The TBUs shall be designed to allow periodic lubrication. Designs that do not require periodic lubrication shall be subject to NYCT approval.

TBU Mounting

- 12.4.10.4. One TBU shall be mounted on the truck frame at each wheel.
- 12.4.10.5. Truck mounting shall be designed for loading at the AW3 emergency brake cylinder pressure, combined with the maximum parking brake forces. See Section 11.2.2.
- 12.4.10.6. Braking force shall be applied coaxial with a line intersecting the center of the brake shoe and the center of the wheel.
- 12.4.10.7. The TBU shall locate the brake shoe with respect to the wheel to ensure even pressure on the shoe and prevent the shoe from sliding off the wheel tread.

- 12.4.10.8. Components shall have the appropriate features, clearances, and tolerances to minimize lateral moments and prevent shoe slide-off to mitigate uneven brake shoe wear patterns between maintenance cycles.
- 12.4.10.9. The arrangement of the TBU components shall be approved by NYCT.

Slack Adjustment

- 12.4.10.10. The TBU shall automatically adjust to compensate for brake shoe wear.
- 12.4.10.11. The TBU slack adjuster shall be designed as a minimum to accommodate a combined radial wear of 3.25 inches (83 mm) on both wheels and shoes.
- 12.4.10.12. The design of the TBU and primary suspension system of the truck shall be coordinated to ensure that no unintended slack adjustment under braking action occurs.

Brake Shoes and Heads

- 12.4.10.13. TBU brake shoe heads shall have a 17.75 inch (451 mm) radius surface.
- 12.4.10.14. TBU brake shoes shall be composition shoes, 2 inches (51 mm) thick, approved by NYCT.
- 12.4.10.15. TBU brake shoes shall conform to design, material, quality, and delivery requirements within Appendix C-16 (Composition Brake Shoes for Subway Cars 2093-PROD-97).
- 12.4.10.16. TBU brake shoes shall fit brake heads currently in service at NYCT.
- 12.4.10.17. TBU brake shoes shall comply with the noise requirements within Appendix C-16 (Composition Brake Shoes for Subway Cars 2093-PROD-97, Section 4.2.1). See Section 12.6.11.6.
- 12.4.10.18. TBU brake shoes shall comply with the wear requirements within Appendix C-16 (Composition Brake Shoes for Subway Cars 2093-PROD-97, Section 3.3.1). See also Section 12.6.11.5.
- 12.4.10.19. TBU shoes shall not contain any hazardous materials and shall not generate harmful gases exceeding federal, state, and city codes. MSDS sheets for the brake shoes shall be provided to NYCT.
- 12.4.10.20. The final approval of the TBU brake shoe will be based upon definition of shoe composition, dynamometer testing performance results, and conformance to Unit emergency brake stopping distance requirements within Appendix D-20 (Memorandum of Understanding Emergency Stopping Distances MISC #95-01). See Sections 12.6.11, 12.6.12, and 2.7.5.2.
- 12.4.10.21. TBU brake shoe heads shall permit the brake shoe keys and brake shoes to be removed and replaced as wear items.
- 12.4.10.22. Brake shoe keys conforming to commodity number 18-42-3303 within Appendix D-21 (Key, Brake Shoe) shall mount through the top of the TBU brake shoe head, and shall secure the brake shoe to the TBU brake shoe head.

Materials

- 12.4.10.23. TBU housings, levers, rods, hangers, and brake heads shall be made from steel or cast iron that conforms to the requirements in Section 19.4. Materials shall be approved by NYCT.
- 12.4.10.24. Steel brake pins, if utilized, shall be hardened to a depth of at least 0.1 inch (2.5 mm) and a hardness of at least Rockwell C60 with a surface finish of 32 micro inches (0.81 micrometers). Alternate designs shall be subject to NYCT approval.
- 12.4.10.25. Bushings shall be cold drawn seamless steel tubing, case hardened to Rockwell C60, with a surface finish of 32 micro inches (0.81 micrometers) and shall be press fit with interference between 0.003 and 0.007 inch (76 to 178 micrometers). Alternate designs shall be subject to NYCT approval.
- 12.4.10.26. Brake levers, rods, and hangers shall use bushings for all rotating connections whether they be internal in a unitized TBU, or part of a truck hanger mounting bracket for designs utilizing a separate hanger.

12.4.10.27. The use of materials other than steel for pins and bushings shall be subject to NYCT approval.

12.4.11. Trip Cock

- 12.4.11.1. Trip cocks shall be installed on the trucks as specified in Section 11.4.15.
- 12.4.11.2. The trip cock lever shall be designed and installed so that it will engage the track trip (stop arms).
- 12.4.11.3. An emergency brake application shall be initiated when the trip cock is actuated.
- 12.4.11.4. The trip cock shall automatically reset after the emergency brake application has been completed.
- 12.4.11.5. The trip cock mechanism shall be made of corrosion-resistant materials.
- 12.4.11.6. The trip cock shall be designed to allow periodic lubrication. Designs that do not require periodic lubrication shall be subject to NYCT approval.
- 12.4.11.7. The trip cock shall send a signal to the MDS as required in Section 17.5.2. The signal shall be generated in one of the following three ways:
 - a) A switch on the trip cock assembly.
 - b) A device that senses a pressure drop.
 - c) A device that senses the flow of air in the brake pipe connected to the trip cock. The sensor shall not be mounted on the trip cock or the trip cock link support assembly.

12.5. Maintainability Requirements

- 12.5.1. The FBECUs shall integrate and provide diagnostic information in compliance with the requirements of MDS Section 17, and Section 2.14.
- 12.5.2. The FBECUs shall report each fault. A fault shall be either:
 - a) Activation of a protective function by the equipment.
 - b) The occurrence of condition(s) indicative of current or pending equipment failure.
- 12.5.3. The FBECUs shall record fault relevant car and brake system parameters. The list of faults shall be approved by NYCT. See Section 2.14.6.
 - 12.5.3.1. The FBECUs shall have sufficient non-volatile storage to save fault data for a minimum of 72 days between periodic maintenance without losing data to over-writes.
 - 12.5.3.2. The oldest stored faults shall be overwritten first, with the exception that fault events resulting in restrictions upon system operation shall not be overwritten until these faults are reset. The Contractor may propose alternate means of protecting operational restriction fault events from being overwritten.
 - 12.5.3.3. Fault data shall be retained in non-volatile memory until a reset command is received from a portable test device, or a reset command on the control logic monitoring panel is generated.
 - 12.5.3.4. Fault data shall be addressable by the Portable Test Equipment (PTE) and by the built-in visual troubleshooting displays.
 - 12.5.3.5. The FBECUs shall be able to store all recorded parameters that occurred over a period of at least 10 seconds before a fault occurred.
 - 12.5.3.6. Fault conditions with worst case parameter counts and minimum recording time resolution shall be used to determine memory storage capacity for faults and parameters. The sub-system capabilities shall be submitted to NYCT for approval.
- 12.5.4. The FBECUs shall include at least one man-machine interface with visual displays indicating the past or transient fault(s) that have occurred as well as current system faults. Alternate annunciation methods may be proposed for NYCT approval.

- 12.5.5. The FBECUs shall provide for the connection of PTE to permit static testing as well as diagnostics, and monitoring of the braking system during car operations.
- 12.5.6. Reference Section 22.8 for general PTE requirements.
- 12.5.7. The FBECUs shall have at least eight channels of analog outputs for a high impedance chart recorder. Alternate methods for providing analog outputs or PTE resident charting functions shall be proposed for NYCT review and approval.
- 12.5.7.1. Each channel shall have the ability to address all inputs to and outputs from the unit.
- 12.5.7.2. The channels shall automatically scale and shall be logically decoded.
- 12.5.7.3. There shall be an addressable Ethernet based M12 output.
- 12.5.7.4. Wiring and test connectors shall be provided to connect each channel to a remote monitoring panel located in an electric locker or in the cab.
- a) The remote monitor panel shall include connectors for the PTE that allow brake system status to be monitored statically and when the car is in operation.
- b) The remote monitor panel shall not affect the use of the PTE or monitoring panel at the underfloor location when the car is not in motion.
- 12.5.8. Verification of system functions shall be provided by the FBECUs. A separate portable analyzer may be provided if applicable to the supplied brake system. The verification functionality shall confirm the following:
- a) All electric valve functions.
- b) Brake pipe pressure.
- c) Brake cylinder pressure.
- d) Main reservoir pressure.
- 12.5.9. The brake system shall be able to be operated from the cab console and from the PTE when the portable analyzer (or equivalent) is in use.
- 12.5.10. The portable analyzer (or equivalent) shall provide a pass/fail test indication for functions being tested.
- 12.5.11. Pressure test fittings shall be provided in pneumatic lines and pipe brackets to allow for troubleshooting of the Friction Brake System and components or other pneumatic system failures.
- 12.5.11.1. Pressure test fittings shall be quick disconnect fittings to connect the portable analyzer, gauges, or transducers for testing and troubleshooting. Reference Section 22.8.7.6 for the pressure test fitting requirements.
- 12.5.11.2. The pneumatic system shall be protected from test fitting failure either by a flow-limiting orifice or isolating cock.
- 12.5.11.3. The locations of test fittings shall be clearly identified in the car pneumatic schematics and shall be subject to NYCT approval.
- 12.5.12. TBUs shall be accessible for maintenance, inspection, and replacement without having to de-truck.
- 12.5.13. All wearing components of the TBUs shall be provided with renewable and replaceable elements, which may be renewed or replaced utilizing existing NYCT maintenance equipment.
- 12.5.14. Lubrication fittings shall be applied at all points on the TBUs requiring lubrication, and these fittings shall be accessible from a shop pit with the TBUs mounted on the truck.
- 12.5.15. Brake shoes and shoe keys shall be accessible for inspection and replacement from a shop pit with the TBUs mounted on the truck.

- 12.5.16. Lubrication fittings shall be applied at all points on the trip cock requiring lubrication, and these fittings shall be accessible from a shop pit with the trip cock mounted on the truck.
- 12.5.17. The air compressor intake filter element shall be readily accessible and last at least 30,000 miles (48,270 km) before needing replacement.
- 12.5.18. Replacement desiccant for air compressor air dryers shall be available in prepackaged containers or canisters which preclude the need for hand packing of the desiccant bed. Replacement desiccant shall be available from multiple sources.
- 12.5.19. Desiccant canisters shall be readily accessible and shall meet the performance requirements of Section 12.2.3 for a minimum of 2 years before needing replacement.
- 12.5.20. Visual inspection from desiccant moisture condition shall be possible from the side of the car utilizing the moisture indicator per Section 12.4.3.18.
- 12.5.21. Provisions for removal of oil and water from the air stream, if supplied, shall have automatic drains that do not require manual operation. Filters provided for separation of particulates, aerosols, oil, and water, if supplied, shall be readily accessible and require replacement no sooner than the minimum desiccant change interval.
- 12.5.22. All air hoses shall be accessible for visual inspection.
- 12.5.23. Installation of friction brake electronic control equipment shall provide easy access for the inspection, removal, servicing, and re-installation of the units.
- 12.5.24. It shall be possible to replace, repair, lubricate, and inspect all parts of the air system without disturbing piping, conduits, or a complete assembly.

12.6. Validation Requirements

12.6.1. Air Consumption

- 12.6.1.1. The Contractor shall submit an air consumption calculation for NYCT review and approval. The calculation shall validate the following: **[CDRL]**
- Quantity of compressor units in the Unit to meet normal and failure mode operating cases. See Section 12.3.9.6.
 - Duty cycle, operating time, and number of starts per hour of the compressor unit compared to the manufacturer's operational requirements.
 - Reservoir sizing, considering all ambient conditions, based on performance requirements of Section 12.2.4.
- 12.6.1.2. The calculation shall include consideration of all pneumatic equipment on the Unit and shall include factors for anticipated leakage of the pneumatic system.
- 12.6.1.3. Results of the air consumption calculation shall be validated by design qualification testing.

12.6.2. Air Dryer Performance

- 12.6.2.1. The Contractor shall supply for NYCT review and approval a calculation validating the performance of the air dryer system under the operating conditions outlined within the air consumption calculation to ensure that the unit is designed to provide the required level of performance. See Section 12.2.3. **[CDRL]**
- 12.6.2.2. Results of the air dryer calculation shall be validated by design qualification testing.

12.6.3. Brake Performance Calculation

- 12.6.3.1. The Contractor shall submit a calculation validating the brake rate performance and parking brake performance of the Unit for NYCT review and approval. The calculation shall confirm the specified service and

parking brake output forces of the TBUs and shall define the shoe composition friction performance targets. See Sections 2.7.4, 2.7.5, and 2.7.6. [CDRL]

12.6.4. Thermal Performance Calculation

- 12.6.4.1. The Contractor shall submit a calculation validating the performance of the wheel under operational thermal loading (see Section 11.2) to verify that the wheel will not develop cracks in service and that predicted temperatures are acceptable for the proposed shoe compositions for NYCT review and approval. [CDRL]
- 12.6.4.2. The Contractor shall coordinate completion of this analysis between the friction brake supplier and the wheel supplier (see Section 11.6.1) to confirm acceptability of the system and wheel performance under the duty cycle requirements of Section 2.7.11.

12.6.5. Tread Brake Unit Calculations

- 12.6.5.1. The Contractor shall submit an installation analysis confirming the installation location of the TBU on the truck based on installation space, primary suspension characteristics, and TBU operational characteristics for NYCT review and approval. This analysis should be conducted in coordination with the TBU and truck suppliers to ensure correct application of the TBU. [CDRL]
- 12.6.5.2. The Contractor shall submit an analysis of the self-energizing forces of the TBUs for NYCT review and approval. [CDRL]
- 12.6.5.3. The Contractor shall submit strength calculations of the TBUs considering all loadings specified within Section 12.4.10 for NYCT review and approval. The analysis shall include effects of the maximum temperatures that the TBUs will be exposed to when analyzing forces, thermal stresses and component life. [CDRL]
- 12.6.5.4. The Contractor shall submit a calculation validating the slack adjuster setting values in coordination with primary suspension deflection for NYCT review and approval. [CDRL]
- 12.6.5.5. The Contractor shall submit a calculation confirming the lateral strength and stability performance of the brake shoe hanger for NYCT review and approval. The calculation shall include the following: [CDRL]
- a) Confirmation that lateral forces on the TBU imparted due to lateral wheel deflection are within manufacturer's acceptable limits.
 - b) Confirmation that components used exclusively to resist lateral loading are designed to prevent shoe ride-off for all conditions of normal wear between regular maintenance cycles.

12.6.6. Air Brake Piping Validation

- 12.6.6.1. The Contractor shall submit a report containing written approval from the air brake supplier of the Contractor's air brake piping fabrication, installation, and design concept for NYCT's approval prior to review of the undercar mockup. 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) 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 19.14.
 - d) Locations of all major air brake control and emergency venting devices, and the proposed location and volume of all reservoirs.

12.6.7. Friction Brake System Combined System Testing

- 12.6.7.1. One of the first three complete production Friction Brake Systems or system components, as appropriate, shall be tested in combination with the Propulsion System in accordance to a test plan to be submitted for NYCT review and approval. [CDRL]
- 12.6.7.2. The combined system test shall ensure the system meets the requirements for:
- Response and dead times, including service brake per Sections 12.2.2.1, 12.2.2.2, and 12.2.2.3 and emergency brake utilizing a simulated equivalent brake pipe length per Section 12.2.2.4.
 - Magnitude and linearity of TBU output force response to be used in combination with brake shoe linearity performance for validation of car brake rate performance per Sections 2.7.4 and 2.7.5. See Section 12.6.11.
 - Accuracy and stability of pneumatic system responses to pressure control commands.
 - Functional integration of the Friction Brake and Propulsion Systems.

12.6.8. Proof Pressure Test

- 12.6.8.1. All pneumatic brake system components shall be pressure tested at 150 percent of the main reservoir safety valve operating pressure. No damage shall occur and components shall function without degradation after removal of the elevated pressure.
- 12.6.8.2. Failure response shall be in accordance with Section 24.3.5.

12.6.9. Brake System Endurance Test

- 12.6.9.1. One of the first three complete production Friction Brake Systems or system components, as appropriate, including the FBECU, shall be tested for one million cycles of normal apply and release applications.
- Normal service applications shall be considered to be friction only service brake applications at AW2 loading.
 - Every 100 service applications, the emergency brake shall be applied at AW2 loading.
- 12.6.9.2. Reversing stress brake reaction forces and lateral forces shall be simulated on the TBUs per Section 12.2.9.3. TBUs may be tested separately from the friction brake control system with NYCT approval.
- 12.6.9.3. Failure response shall be in accordance with Section 24.3.5.

12.6.10. Brake System Environmental Testing

- 12.6.10.1. One of the first three complete production Friction Brake Systems or system components, as appropriate, including the electronic and pneumatic control units, shall be subjected to an environmental test without a system or component failure.
- Parts of the system may be simulated, provided at least one assembly of each type is subjected to the test conditions.
 - The pneumatic equipment may be tested separately from the electronic and pneumatic control units.
- 12.6.10.2. The environmental conditions used during the test shall be as specified in Section 2.5.1.
- 12.6.10.3. The performance of the equipment at minimum and maximum ambient conditions shall be recorded at minimum, nominal, and maximum power supply voltages for the system.
- 12.6.10.4. The test procedure shall start with a minimum of an 8 hour soak at the maximum temperature, with the power on.

- 12.6.10.5. The brake system shall then be tested at nominal voltage at all temperature and humidity ranges specified.
- The brake system shall then be subjected to eight temperature and humidity cycles between minimum and maximum.
 - Performance of the equipment at minimum and maximum ambient conditions shall be recorded.
 - Each cycle shall last 12 hours.
 - Each cycle shall hold at the minimum and maximum temperatures for at least 1 hour each.

12.6.10.6. Failure response shall be in accordance with Section 24.3.5.

12.6.11. Linearity Testing

- 12.6.11.1. Proposed brake shoe friction material shall be tested on a dynamometer for selection of materials that are in compliance with requirements for accuracy, response, noise, and wear life.
- 12.6.11.2. Materials shall be bedded in prior to commencement of testing in accordance with the following steps. Alternate procedures for brake shoe bedding may be proposed for NYCT review and approval.
- Machine the test shoes to the radius of the test wheel minus 0.5 inch (12.7 mm).
 - Conduct one 45 minute grade test at 20 mi/h (32 km/h) with a 1,450 lb. (6.45 kN) shoe force.
 - Conduct five stops from 50 mi/h (80 km/h) with a 4,000 lb. (17.8 kN) shoe force.
 - Conduct five stops from 50 mi/h (80 km/h) with a 2,000 lb. (8.9 kN) shoe force.
 - Repeat steps b) through d) until a 95% bearing on the wheel is achieved.
- 12.6.11.3. Testing shall utilize a production TBU or NYCT approved equivalent.
- 12.6.11.4. For each run, plots shall be generated plotting as a minimum instantaneous and average friction coefficient values and wheel/shoe temperature versus speed. Applied brake effort (AW load and effort percentage values) shall be recorded in the plot header.
- 12.6.11.5. The shoes shall be weighed prior to and after testing. Combined with the weight loss and the calculated test energy expended, a shoe wear value in terms of grams/100 MJ or equivalent shall be calculated for each material.
- 12.6.11.6. Noise output shall be measured to provide a comparison between the tested materials. See Section 12.4.10.17.
- 12.6.11.7. The test report shall include:
- Short summary of performance of each friction material with backup data.
 - Recommendation for original equipment friction material and alternate materials based on friction performance, wear, and noise performance. Recommended materials shall have an average coefficient of friction at minimum equal to the value utilized in the brake calculation and shall exhibit minimum variation of COF under the test conditions. See Section 12.6.3.
 - All test data/plots.
- 12.6.11.8. Dynamometer runs shall be made at wheel inertial loadings equivalent to the following car loadings:
- AW0.
 - AW2.
 - AW3.

- 12.6.11.9. At each car loading, dynamometer runs shall be made at the following speeds:
- 10 mph (16 km/h).
 - 30 mph (48 km/h).
 - 50 mph (80 km/h).
- 12.6.11.10. For each loading and speed condition, the following braking effort stops shall be made.
- 25 percent of full service braking effort.
 - 50 percent of full service braking effort.
 - 75 percent of full service braking effort.
 - 100 percent of full service braking effort.
 - Emergency rate.
- 12.6.11.11. One set of tests shall be run with brake shoes and wheels initially at a maximum of 125°F (52°C).
- 12.6.11.12. One set of tests shall be run with brake shoes and wheels initially between 200°F (93°C) and 300°F (149°C).
- 12.6.11.13. Brake shoes selected for original equipment application shall also be validated to the complete set of requirements within Appendix C-16 (Composition Brake Shoes for Subway Cars 2093-PROD-97) to confirm acceptance and to provide baseline performance values for later quality assurance validation of production brake shoes.

12.6.12. Braking Capacity

- 12.6.12.1. The friction brake elements shall be run on a dynamometer or flywheel to verify the brake system capacity.
- 12.6.12.2. Test shoes shall be bedded in prior to test commencement. See Section 12.6.11.2.
- 12.6.12.3. The tests shall be run using the friction braking duty cycles in Section 2.7.11.
- 12.6.12.4. Tests shall commence with brake shoes and wheels initially at a maximum of 125°F (52°C).
- 12.6.12.5. The temperature of the brake shoes and wheels shall be measured during the tests. At no point during the testing shall the temperature of the brake shoes or wheels exceed 752°F (400°C).
- 12.6.12.6. Friction materials validated during linearity testing shall be used for this test.
- 12.6.12.7. Testing shall utilize a production TBU or NYCT approved equivalent.
- 12.6.12.8. Testing shall utilize a production wheel.
- 12.6.12.9. Parking brake torque shall be validated under test hot/cold shoe conditions:
- New brake shoes shall be utilized for the testing.
 - TBU shall be applied with a shoe force equivalent to the minimum expected spring brake shoe force output.
 - The shoe/wheel system shall be at a maximum of 125°F (52°C).
 - Torque shall be applied to the wheel and measured until rotation of the wheel commences. Torque value at breakaway shall be recorded.
 - The test shall be repeated with a shoe/wheel system at a minimum of 350°F (177°C).

12.6.12.10. At the completion of capacity testing, the brake elements (actuator/shoes/wheel) shall remain in a fully operable condition.

- a) Shoe coefficient of friction shall be verified by repeat of a subset of the linearity testing to be proposed by the Contractor. Coefficient of friction performance shall be within typical friction material variation of ± 20 percent. Shoes shall not exhibit thermal damage.
- b) Wheels shall not exhibit thermal cracking.
- c) TBUs shall be fully functional as confirmed by successful repeat of production acceptance testing. No visible thermal damage shall be noted.

12.6.13. Other Testing

12.6.13.1. Refer to Section 24, Testing Program for production acceptance (routine), car and Unit level testing requirements.

12.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
12-1	12.6.1.1	Air consumption calculation	PDR
12-2	12.6.2.1	Air dryer performance calculation	CDR
12-3	12.6.3.1	Brake performance calculation	PDR
12-4	12.6.4.1	Thermal calculation	PDR
12-5	12.6.5.1	TBU installation analysis	PDR
12-6	12.6.5.2	TBU self-energizing calculation	PDR
12-7	12.6.5.3	TBU strength calculation	CDR
12-8	12.6.5.4	TBU slack adjuster calculation	CDR
12-9	12.6.5.5	Brake hanger lateral strength calculation	CDR
12-10	Not used	Not used	Not used
12-11	12.6.7.1	Friction Brake combined system test plan	PDR

Section 13

Communications

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13. Communications

13.1. Introduction and General Requirements

- 13.1.1. This section defines the requirements for the Communications Systems on the R211 cars. The requirements in this section have been divided by subsystem. Refer to the following sections for car systems and components interfacing with the Communications System and other applicable requirements
- a) Design and Performance Criteria – Section 2.
 - b) Cab and Cab Controls – Section 5.
 - c) Side Door System – Section 6.
 - d) Auxiliary Electrical Equipment and Distribution – Section 9.
 - e) Train Control System (CBTC) – Section 14.
 - f) Trainline and Car Control Architecture – Section 16.
 - g) Software Systems – Section 18.
 - h) Materials, Processes, and Workmanship – Section 19.
- 13.1.2. Throughout this section an active cab is defined as a cab in which the Master Controller is in the RUN position (see Section 5.6.4.10). An active Conductor's position is defined as a cab in which the Master Door Controller is Zoned-in.
- 13.1.3. Each car shall have communication apparatus installed to provide the following services:
- Public Address System**
- a) A Public Address (PA) System to allow for one-way audio communication from the Train Operator and/or Conductor to the passengers via interior and/or exterior speakers, (Section 13.4).
 - b) Automatic announcements including route, destination, door closing, next station, etc., (Section 13.6).
 - c) Recorded special announcements to the passengers via the PA system, (Section 13.6).
- Radio Communication System**
- a) One-way audio communications between the wayside radio and passengers via the PA system, (Section 13.8).
 - b) Train Radio to provide two-way communication between the wayside radio and Train Operator and/or Conductor, (Section 13.8).
- Intercom System**
- a) Two-way Passenger Emergency Intercom (PEI) for passenger-initiated communication with Train Operator/Conductor, (Section 13.4.6).
 - b) Intercom between all cabs on a train for crew communication, (Section 13.4.7).
 - c) Buzzer System, (Section 13.7).
- Passenger Information and Security Systems**
- a) Passenger Information Displays, (Section 13.5).
 - b) Onboard Closed Circuit Television (CCTV) system, (Section 13.9).
 - c) Not used.
 - d) Provisions for Platform Edge CCTV system, (Section 13.10).
 - e) Provisions for communications associated with train to wayside Platform Screen Door (PSD) system, (Section 13.11).

- 13.1.4. The Communications Systems shall be of a digital design with trainwide and intra-car communication based on the digital network described in Section 16, Trainline and Car Control Architecture.
- 13.1.5. All passenger information systems shall conform to the requirements of IEEE Std. 1477, "IEEE Standard for Passenger Information Systems for Rail Transit Vehicles".

13.2. Power Distribution

- 13.2.1. The communications equipment shall be powered from the Low Voltage Distribution Network (LVDN) unless noted otherwise in this Specification.
- 13.2.2. Electrical supply and grounding arrangements for all communications equipment shall be as defined in Section 9, Auxiliary Electrical Equipment and Distribution.
- 13.2.3. A separate circuit breaker shall be provided in the cab circuit breaker panel for each major communication subsystem.
- 13.2.4. The radio subsystem, including power supply and associated controls, shall stand-alone from other elements of the Communications System. A separate power supply with a regulated 13.8 Vdc output shall be provided.
- 13.2.5. The crew intercom and PEI shall be continuously energized by both the normal and emergency electrical systems.
- 13.2.6. Emergency power and load shedding requirements are specified in Section 9.4.19.
- 13.2.7. The On-Board Radio and the PA system shall be active only in the cabs where the Master Controller is keyed up or where the Master Door Controller is zoned in.

13.3. Crew Interface

- 13.3.1. All crew controls for the communications equipment shall be located in the cab. Refer to Section 5 for details on the Cab and Cab Controls.
- 13.3.2. The Crew Interface shall include the following elements:
- a) One Communication Control Panel (CCP).
 - b) Two Conductor Panels (one located on each side of the cab).
 - c) Three Push-to-Talk (PTT) pushbuttons as follows:
 - i. One on the cab console (see Section 5.3.2).
 - ii. One on each Conductor Panel (see Section 5.5.4.1).
 - d) Automatic Announcement and Display Controls via the Train Operator Display (TOD).

13.4. Public Address and Intercom System

13.4.1. General

- 13.4.1.1. The PA and Intercom System shall allow for manual (crew-initiated), wayside radio announcements or automatic announcements to be made to all passengers in a train and, on command, adjacent station platforms.
- 13.4.1.2. The amplifier/speaker arrangement shall be redundant, such that the loss of a car's power amplifier will not result in a complete loss of announcements in that car.

Performance Requirements

- 13.4.1.3. The overall performance of the PA and Intercom System shall meet the performance requirements of IEEE Std. 1477.

- 13.4.1.4. The PA and Intercom System shall be of a digital design with transfer of audio signals between locations in the train over the car and train network described in Section 16, Trainline and Car Control Architecture. All audio signals shall be transmitted over this network using IEEE Std. 1473, "IEEE Standard for Communications Protocol Aboard Passenger Trains, Type E" approved protocols.
- 13.4.1.5. The sound pressure level throughout the passenger compartment at a height of 5 ft. 4 in. (1.63 m) shall not vary by more than 3 dB for a pink noise signal over the octave band centered at 4 kHz.
- 13.4.1.6. The maximum variation in sound levels, prior to local ambient adjustment shall not exceed 5 dB regardless of the number of cars on the train.
- 13.4.1.7. The system shall provide maximum intelligibility under the conditions of high noise and vibration normally encountered with a train in motion under NYCT operating conditions.
- 13.4.1.8. The PA System's output level in each car shall be automatically set in accordance with the ambient noise level in the car just prior to activation of the system. The range of automatic level adjustment shall be at a minimum 10 dB.
- 13.4.1.9. Gains, line levels, compression levels and equalization shall be fixed by design and confirmed by test unless otherwise approved by NYCT.

Functional Requirements

- 13.4.1.10. The PA System shall permit announcements to be made to all passengers in a train (and adjacent platform when selected) from a cab or by the Automatic Announcement System (AAS) as described in Section 13.6.
- 13.4.1.11. The exterior speakers shall be active only on the side(s) of the car where the doors are open and/or when selected by the Train Operator/Conductor through a switch in the cab (Section 13.4.5).
- 13.4.1.12. An ambient noise sensing assembly shall be provided in each car. The assembly mounting shall be acoustically transparent to the ambient noise in the car.
- 13.4.1.13. Amplifiers shall adjust their outputs automatically according to the ambient noise level.

13.4.2. Pre-Amplifiers

Design Requirements

- 13.4.2.1. Pre-amplifiers shall be located in close proximity to the microphone plate.

Performance Requirements

- 13.4.2.2. The pre-amplifier Total Harmonic Distortion (THD) shall be no greater than 1 percent at full output, and minimum frequency response shall be within ± 3 dB from 100 Hz to 8 kHz.
- 13.4.2.3. The pre-amplifier shall contain a compressor limiter section designed to hold the output level within ± 2 dB past the threshold with a change in input of 40 dB. Suitable circuit provision shall be incorporated so that if the range is exceeded, symmetrical clipping will prevent the resumption of the normal input-output gain relationship. The attack time of the compressor shall be fixed at 10 milliseconds and the release time shall be adjustable, but shall be factory set at 800 milliseconds for a 20 dB incremental input.
- 13.4.2.4. The compressor total harmonic distortion shall not exceed 1 percent at levels more than 10 dB below the clipping level.
- 13.4.2.5. The input necessary to drive the compressor amplifier into full compression shall be 250 millivolts with a 1 kHz test tone input.

13.4.3. Amplifiers

Design Requirements

- 13.4.3.1. The PA System's amplifier(s) shall be capable of driving the external speakers in sets or groups according to zone selection.
- 13.4.3.2. The output circuit and power supply shall include short circuit protection without the use of fuses.
- 13.4.3.3. The amplifier assembly shall be located within an enclosure located in the cab behind an access cover or unless otherwise approved by NYCT.
- 13.4.3.4. The amplifier assembly shall have a dust-tight cover secured by heavy duty hardware with provisions for applying a lock.
- 13.4.3.5. The amplifier design shall eliminate the need for potentiometers.
- 13.4.3.6. The amplifier shall be of modular design.
- 13.4.3.7. A connection shall be provided for maintenance and inspection so that the Portable Test Equipment (PTE) can connect directly into the amplifier while it is operational to set sound levels and perform a diagnostics check to identify any amplifier failure.
- 13.4.3.8. The amplifier design and its mounting shall be approved by NYCT.

Performance Requirements

- 13.4.3.9. The power amplifier shall be capable of delivering a minimum of 35 watts at not more than 1 percent THD in the frequency range of 100 Hz to 8 kHz within the full voltage operating range of Section 2.5.3.
- 13.4.3.10. The input necessary to drive the power amplifier to full-rated output shall be no more than 500 millivolts.
- 13.4.3.11. The frequency response shall be within ± 1 dB from 100 Hz to 8 kHz.
- 13.4.3.12. The signal to noise ratio of the amplifier below the compression threshold shall be at least 65 dB.
- 13.4.3.13. Each amplifier shall be stable and there shall be no oscillation present for any normal operation of the system and for any setting of the amplifier controls.

13.4.4. Interior Speakers

Design Requirements

- 13.4.4.1. A minimum of eight ceiling speakers per car shall be evenly spaced longitudinally in the passenger seating area.
- 13.4.4.2. All interior speakers shall be transportation grade, direct radiating and permanent magnet field type.
- 13.4.4.3. Each speaker shall be protected by a metal or plastic enclosure designed to adequately protect the speaker from the effects of dust, moisture, ferrous materials, or other foreign objects.
- 13.4.4.4. The speaker protective enclosure shall be rustproof, and shall mount on the speaker baffle completely enclosing the speaker from the rear.
- 13.4.4.5. The enclosure shall include knockouts and gaskets for the dust-tight entrance of the speaker connection leads.
- 13.4.4.6. The enclosures shall be constructed so that no mechanical resonances or vibrations occur.

Performance Requirements

- 13.4.4.7. Internal speakers shall meet the requirements of IEEE STD 1477 Section 4.2.5.

13.4.4.8. Average power handling capacity shall be a minimum of 5 watts continuous sine wave input without cone breakup, rattle, etc.

13.4.5. Exterior Speakers

Design Requirements

13.4.5.1. Six weather resistant exterior speakers shall be provided per car, three per side.

13.4.5.2. The loudspeaker shall be University Model MM-2F or as approved by NYCT.

Performance Requirements

13.4.5.3. The loudspeaker shall have a minimum power handling capacity of 15 watts.

13.4.6. Passenger Emergency Intercom

Design Requirements

13.4.6.1. Passenger Emergency Intercom (PEI) stations shall be provided, located diagonally opposite doors as described in Section 15.12.2, three per A Car, two per B Car. One PEI station in the A Car shall be located in the Americans with Disabilities Act of 1990 (ADA) area.

13.4.6.2. Each PEI station shall include the following components:

- a) Speaker.
- b) Microphone.
- c) Recessed heavy duty push-button.
- d) Recessed indicator light.

13.4.6.3. The indicator light shall be a recessed mounted LED that shall be illuminated steady when active and blinking when on-hold.

13.4.6.4. The wording on the PEI Panel shall be centered beneath the button as follows:

-TO TALK-

PRESS AND
RELEASE BUTTON

WAIT FOR
STEADY LIGHT

13.4.6.5. The PEI station shall be vandal resistant and equipped with a heavy-duty faceplate.

13.4.6.6. The design of the station, and the recessed push-button, shall be resistant to inadvertent activation.

Performance Requirements

13.4.6.7. PEI microphones shall have external noise reduction. Compression shall also be applied to the signal.

13.4.6.8. The system shall permit a crew member to hear a passenger speaking at a distance of 20 inches (508 mm) from the PEI unit in a normal tone of voice with ambient noise levels up to 80 dBA. The design shall be subject to NYCT approval.

13.4.6.9. Total harmonic distortion through the system from microphone to Conductor Panel (CP) speaker shall be less than 2 percent.

13.4.6.10. The PEI unit shall provide ambient noise compensation for speaker output such that the crew member's voice may be heard at a minimum distance of 10 inches (254 mm) from the PEI unit with an ambient noise level up to 80 dBA.

Functional Requirements

- 13.4.6.11. Operation of the PEI pushbutton shall signal the crew in any cab. The crew shall thus be able to establish a communication circuit with that PEI station.
- 13.4.6.12. The crew shall have the ability to put that PEI call "On Hold" in order to use the radio or crew intercom.
- 13.4.6.13. If more than one PEI station is pushed, then the crew shall have the ability to answer them in the order received, and to put other PEI stations "on hold" as needed.
- 13.4.6.14. When communication with the PEI station is established, the image from the passenger area CCTV camera shall be displayed on the CCTV TOD as described in Section 13.9.1.
- 13.4.6.15. The Monitoring and Diagnostic System (MDS) TOD shall display the location of the activated PEI station(s).

13.4.7. Crew Intercom

- 13.4.7.1. Each cab shall have a crew Intercom system to allow communications between all cabs in a train.
- 13.4.7.2. Selection of the intercom mode shall cause a communication circuit to be established between the cabs.
- 13.4.7.3. The Push-to-Talk (PTT) button shall be used to communicate from cab to cab.

13.4.8. Door Closing Warning Signal

- 13.4.8.1. At any closing of doors, a local two-tone annunciator using different tones from the automatic announcement tone shall be broadcast over the interior speakers as required in Section 6.4.19.

13.4.9. Communication Control Panel

Design Requirements

- 13.4.9.1. One Communication Control Panel (CCP) shall be provided in each cab.
- 13.4.9.2. The CCP shall include the following:
 - a) Volume Control.
 - b) Volume Level Indicators.
 - c) Interior and Exterior Speaker Indicators.
 - d) Pushbuttons as follows:
 - i. "RAD"; Radio.
 - ii. "PA"; Public Address.
 - iii. "ICS"; Intercom System.
 - iv. "PEI"; Passenger Emergency Intercom.
 - v. "SPKR"; Speaker.
 - vi. "RAD TO PA"; Radio to PA.
 - e) Microphone.
 - f) Speaker.
 - g) Transmit Indicator.
 - h) Radio Control Head.
- 13.4.9.3. CCP pushbuttons shall be backlit and green in color. The pushbutton shall become illuminated when active.

- 13.4.9.4. All CCP controls shall be designed to preclude damage during operation (refer to Section 5.3.1) and have tactile feedback.
- 13.4.9.5. The radio control head, which shall provide the operator interface to the radio, shall be integrated into the CCP.
- 13.4.9.6. The radio control head shall consist of a self-contained keypad/LCD display unit which shall be mounted on the CCP.
- 13.4.9.7. The CCP keypad shall be a 16 key matrix arranged as four rows by four columns. It shall be a sealed unit with membrane type keys.
- 13.4.9.8. CCP keypad keys shall be backlit so that the key legends will be visible in low ambient light conditions.
- 13.4.9.9. The keypad shall have a tactile and audible feedback that a keypad entry has been made. The audible feedback shall be a chirp tone of approximately 100 milliseconds in duration.

Performance Requirements

- 13.4.9.10. The CCP speaker shall be designed to provide intelligible and audible sound reproduction in the voice frequency range from 300 Hz to 3.2 kHz under severe noise conditions.
- 13.4.9.11. The CCP speaker shall be rated for a minimum of 5 watts.
- 13.4.9.12. The CCP speaker input impedance shall match the driver output.
- 13.4.9.13. The microphone shall provide an average discrimination of 12 dB against ambient noise.

Functional Requirements

- 13.4.9.14. The CCP speaker pushbutton shall allow selection between two stages of speaker control (interior, or interior and exterior). The panel LED's shall indicate the proper speaker(s) selection.
- 13.4.9.15. The CCP keypad shall have the following keys:
 - a) Numeric keys (0 through 9) shall be used for upgrades.
 - b) "CH UP" and "CH DN" keys shall scroll through the frequency channels programmed into the radio from the present setting in the order defined in Table 13-1. Table 13-1 lists the associated Channel Aliases that shall be displayed on the LCD display when the frequency channels are scrolled.
 - c) "MON" (Monitoring) shall disable the receiver CTCSS/DTCSS feature.
 - d) "CLR" shall be provided for future use.
 - e) "#" shall be provided for future use.
 - f) "PRI" shall be provided for future use.
 - g) "PTT"; When PTT (Push-to-Talk) is activated, the CCP speaker shall provide a "go-ahead" beep indicating that the operator may begin speaking into the CCP microphone. At the end of the transmission, no additional audio tones (e.g., courtesy beep) shall be transmitted.

13.4.10. Conductor Panel

Design Requirements

- 13.4.10.1. Two Conductor Panels shall be provided in the cab, on the bulkhead, one beside each window.

- 13.4.10.2. The Conductor Panel (including PA/IC Microphone Plate Assembly and Auxiliary Microphone Plate Assembly) shall include the following:
- a) Volume control.
 - b) Volume level indicators.
 - c) Interior and exterior speaker indicators.
 - d) High and low microphone indicators.
 - e) Pushbuttons as follows:
 - i. "MIC"; Microphone Selection.
 - ii. "PA"; Public Address.
 - iii. "ICS"; Intercom System.
 - iv. "PEI"; Passenger Emergency Intercom.
 - v. "SPKR"; Speaker.
 - vi. "PTT"; Push-to-Talk.
 - f) Two microphones at different heights with "MIC" selection pushbutton (see Section 13.4.10.16).
 - g) Speaker.
 - h) Voice level indicator.
 - i) Door Close Warning pushbutton.
- 13.4.10.3. Alternative methods to control the selection of the high and low microphone may be presented to NYCT for approval.
- 13.4.10.4. The Conductor Panel pushbuttons shall be backlit. Pushbuttons shall be green in color except for the Door Close Warning pushbutton which shall be red in color. The pushbutton shall become illuminated when active.
- 13.4.10.5. The auxiliary microphone shall be installed significantly beneath the face plate of the front panel to provide adequate protection from damage by sharp objects.
- 13.4.10.6. No component mounting screws shall be accessible on the front of panel.
- 13.4.10.7. The microphone arrangement shall allow proper operation independent of whether the operator is seated or standing.
- 13.4.10.8. The selection of the microphone and their location in the cab shall be determined for effective operation.
- 13.4.10.9. All Conductor Panel controls shall have tactile feedback.
- 13.4.10.10. The microphone plate, microphone element protective housing, push-to-talk buttons, and the microphone plate assembly protective enclosure shall be constructed of aluminum alloy with an anodized finish to meet requirements of Section 5.3.
- Performance Requirements**
- 13.4.10.11. The microphone free field response shall be within ± 2.0 dB from 100 Hz to 12 kHz, reference 1 kHz.
- 13.4.10.12. The microphone sensitivity shall be $- 50$ dBm ± 1.0 dB reference 1 Pascal (94 dB SPL).
- 13.4.10.13. The visual indicator for proper microphone level shall be visible to the Train Operator or Conductor under all ambient operating conditions.
- 13.4.10.14. The compressor THD shall not exceed 1 percent at levels more than 10 dB below the clipping level.

Functional Requirements

- 13.4.10.15. The Conductor Panel speaker pushbutton shall allow selection between two stages of speaker control (interior, or interior and exterior). The panel LED's shall indicate the proper speaker(s) selection.
- 13.4.10.16. The "MIC" pushbutton shall allow selection between the high and low microphone.

13.5. Passenger Information Displays

13.5.1. General

- 13.5.1.1. The Contractor shall provide a Passenger Information Display system on each car.
- 13.5.1.2. The Passenger Information Display system design shall be approved by NYCT.
- 13.5.1.3. The system for each car shall consist of the following, as a minimum:
- a) Two exterior Side Destination Signs (SDS).
 - b) Two Ceiling Interior Information Signs (CIIS).
 - c) Interior Flexible Ceiling Strip Displays (covering full length of the ceiling cove panel, see Appendix E-1).
 - d) Not used.
 - e) One external End Route Sign (ERS) and one high level destination sign for the No. 1 end of each A Car.
- 13.5.1.4. Displays shall be liquid crystal diode (LCD), Light Emitting Diode (LED), or Organic Light-Emitting Diode (OLED) technology as approved by NYCT.
- 13.5.1.5. All displays described in Section 13.5 shall be suitably protected (dust and moisture proof, IP6x rated) for the operating environment and protected from vandalism.
- 13.5.1.6. SDS and ERS content shall be able to be changed from the MDS TOD located on the cab console in an active cab or an active Conductor's position, on a trainline basis, for all signs on a train.

13.5.2. Side Destination Signs

Design Requirements

- 13.5.2.1. Two exterior SDSs shall be installed on each car, located close to the car's longitudinal centerline. The exact location of the SDS shall be determined during design review.
- 13.5.2.2. The SDSs shall be completely self-contained.
- 13.5.2.3. An additional end destination sign shall be mounted above the storm door at the cab end of the A Car, as shown in Appendix E-1. The SDS requirements shall apply to this sign unless otherwise noted.

Performance Requirements

- 13.5.2.4. The horizontal viewing angle shall comply with the requirements of IEEE STD 1477.
- 13.5.2.5. The color of the SDS lettering shall be adjustable to match the train's selected service per the NYCT route map.
- 13.5.2.6. The background of the SDS shall be black.
- 13.5.2.7. The selected service colors to be used on the SDS shall be confirmed during design review.
- 13.5.2.8. The font character shall be similar to Helvetica style and capable of upper and lower case lettering.
- 13.5.2.9. The letter representing the train's service (the line designation letter) shall be capable of being displayed

within a colored circle or a diamond, depending on service. The line designation letter shall be displayed in white or black on a colored background to match the train's selected service per the NYCT route map. This requirement does not apply to the end destination sign.

- 13.5.2.10. The SDS shall be readable in direct sunlight or complete darkness.
- 13.5.2.11. The SDS shall have a minimum contrast ratio, which is appropriate to daytime or nighttime viewing of 30:1.
- 13.5.2.12. The SDS shall not require any external mask between pixels and shall not require any framing or support structure between characters, which would give the sign a discontinuous appearance.
- 13.5.2.13. All characters shall be readable from a minimum of 75 feet (23 m).

Functional Requirements

- 13.5.2.14. The SDS shall display the following information:
 - a) The line designation letter (A, C, E etc.) representing the train's service shall be displayed at all times. This requirement does not apply to the end destination sign.
 - b) Train service identification (e.g., "8th Avenue Local") alternating with destination (e.g., "World Trade Center"), replaced with "Last Stop" when approaching the final stop on the route.
- 13.5.2.15. The SDS shall be capable of cycling through up to four readings in succession; the two identified in Section 13.5.2.14 b) and two additional optional readings to be defined by NYCT.
- 13.5.2.16. The SDS display shall consist of one letter a minimum of 6 inches (152 mm) high, which shall be displayed at all times, followed by a space and at least 20 alphanumeric characters for descriptive messages and destinations, which shall be capable of scrolling as necessary.
- 13.5.2.17. The end destination sign display shall consist of at least 20 alphanumeric characters for descriptive messages and destinations, which shall be capable of scrolling as necessary.
- 13.5.2.18. The descriptive message shall automatically update as the train progresses along its route.

13.5.3. Ceiling Interior Information Sign

Design Requirements

- 13.5.3.1. The CIIS shall be installed in the low ceiling header panels in each end of the car.
- 13.5.3.2. The CIIS shall be pitched slightly downwards to allow maximum visibility to passengers and minimize reflections on the ceiling.
- 13.5.3.3. The CIIS shall include an easily replaceable vandal-resistant protective transparent cover/window.

Performance Requirements

- 13.5.3.4. The CIIS shall be capable of displaying 4 bit color depth and images.
- 13.5.3.5. CIIS characters shall be a minimum of 2.3 inches (58.4 mm) high.
- 13.5.3.6. There shall be no glare from the mounting frame or from the car's interior, which could affect the display's readability.
- 13.5.3.7. The CIIS characters shall be clearly visible from the opposite end of the car.
- 13.5.3.8. The width of the CIIS shall be maximized to allow for the maximum number of characters to be displayed.
- 13.5.3.9. The CIIS shall include graphic images to be used as message separators.

Functional Requirements

13.5.3.10. The CIIS shall display the following information on a scrolling basis, see Appendix E-1:

- a) Current stop (station name).
- b) Train identification (i.e. line) and destination, (e.g., E - World Trade Center).
- c) Next stop (station name).
- d) Time of day (12-hour clock).
- e) Last stop (station name).
- f) Other messages to match AAS announcements.
- g) Platform side arrows to identify the platform side of the next station stop.

13.5.3.11. The time of day shall be displayed approximately every 5 seconds between stations. The time of day that is displayed shall be the Display Time set by the Train Operator on the TOD.

13.5.3.12. The platform side arrows shall be displayed as text messages using ">>>" or "<<<". The arrow messages shall scroll from left to right or right to left depending on the platform side to indicate.

13.5.4. End Route Sign

Design Requirements

- 13.5.4.1. One exterior ERS shall be provided on each A Car, on the left side of the cab (Section 15.13.4), see Appendix E-1.
- 13.5.4.2. The ERS shall be housed in a dirt and dust-tight enclosure.
- 13.5.4.3. The ERS shall be designed to permit easy installation and removal.

Performance Requirements

- 13.5.4.4. The horizontal viewing angle shall comply with the requirements of IEEE Std. 1477.
- 13.5.4.5. The ERS shall have the capability to display the NYCT alphanumeric line designation letter in white or black on a colored background to match the train's selected service per the NYCT route map.
- 13.5.4.6. The alphanumeric character, a minimum of 12 inches (305 mm) in height and be identifiable at a minimum distance of 300 feet (91.4 m).
- 13.5.4.7. The colored background shall have the capability to be displayed as a circle or a diamond.
- 13.5.4.8. Selected service colors to be used on the ERS shall be approved by NYCT during design review.

Functional Requirements

- 13.5.4.9. The ERS shall display the line designation letter (A, C, E etc.) representing the train's service shall be displayed at all times.

13.5.5. Flexible Ceiling Strip Displays

Design Requirements

- 13.5.5.1. Flexible Ceiling Strip Displays shall be provided throughout the full length of the passenger areas on the ceiling cove panels above the sidewalls, using 20 individual signs, as depicted in Appendix E-1.
- 13.5.5.2. Eight passenger information displays, one above each door, shall be provided by the Contractor. Provision for the installation of a further 12 "third party content" displays per car, 6 per side, shall be made.
- 13.5.5.3. The Contractor shall provide sufficient power and data connections to allow the "third party content" displays to operate, as well as a location, power and data provisions for a central controller. The Contractor shall provide appropriate mechanical mountings and trim surrounds for the displays, and

shall consider both the power demand, and heat emitted from the displays in the design of the car. A detailed Interface Control Document (ICD) defining physical interfaces, data interfaces and testing requirements shall be developed jointly by the Contractor and the third party sign vendor (OUTFRONT Media), not later than Preliminary Design Review.

- 13.5.5.4. Each individual display section shall be self-contained, and of a modular design so that they can be easily replaced.
- 13.5.5.5. Displays shall include an easily replaceable vandal-resistant protective cover for protection from vandalism/damage.

Performance Requirements

- 13.5.5.6. Flexible Ceiling Strip Displays shall have a minimum horizontal viewing angle of 120 degrees.
- 13.5.5.7. Flexible Ceiling Strip Displays shall have a minimum contrast ratio of 350 to 1.
- 13.5.5.8. Flexible Ceiling Strip Displays shall have a minimum luminance of 10 candelas per sq. ft. (108 candelas per sq. m) and a maximum luminance of 28 candelas per sq. ft. (301 candelas per sq. m). The luminance range of the displays shall be consistent throughout the transverse distance of the car when facing the display.
- 13.5.5.9. A method of brightness control shall be provided such the brightness of all of the displays in a car will be matched regardless of the age of the display.
- 13.5.5.10. Flexible Ceiling Strip Displays shall have a minimum of HD resolution.
- 13.5.5.11. Flexible Ceiling Strip Displays shall be viewable from a wide angle under all lighting conditions.

Functional Requirements

- 13.5.5.12. The passenger information displays shall be as close to the full width of the doorway as possible..
- 13.5.5.13. Not used.
- 13.5.5.14. The passenger information displays shall be capable of clearly displaying all stations and transfer points along any possible "B" division route, without the need of overlays or other physical modifications.
- 13.5.5.15. The layout and presentation of the route information shall be reviewed and approved by NYCT.
- 13.5.5.16. All route information displayed shall be automatically selected through the route selection screen for all stored routes in the communications system.
- 13.5.5.17. The system shall have the capability to automatically adjust to reroutes or skipped stations(s) via commands or signals from the wireless data link described in 16.3.8, or the route selection screen on the TOD.
- 13.5.5.18. The system shall indicate any route change.
- 13.5.5.19. All functional details shall be approved by NYCT. [CDRL]

13.5.6. Flexible Wall Displays

- 13.5.6.1. Provision shall be made to install eight Interior Flexible Wall Displays adjacent to door leafs in the car, as shown in Appendix E-1. The exact location of the displays shall be determined during the interior design review.
- 13.5.6.2. The Flexible Wall Displays will be provided by OUTFRONT Media.
- 13.5.6.3. The Contractor shall provide sufficient power and data connections to allow the displays to operate, as well as a location, power and data provisions for a central controller.
- 13.5.6.4. The Contractor shall provide appropriate mechanical mountings and trim surrounds for the displays, and

shall consider both the power demand, and heat emitted from the displays in the design of the car.

- 13.5.6.5. A detailed Interface Control Document (ICD) defining physical interfaces, data interfaces and testing requirements shall be developed jointly by the Contractor and OUTFRONT Media, not later than Preliminary Design Review.
- 13.5.6.6. The areas not designated for Flexible Wall Display, or other equipment, installation shall be finished with standard NYCT advertising card holders as defined in Section 15.12.4.
- 13.5.6.7. The areas designated for Flexible Wall Display installation shall be finished with standard NYCT advertising card holders in the event that cars are delivered without the displays installed.

13.6. Passenger Information System

13.6.1. General Requirements

- 13.6.1.1. The Passenger Information System (PIS) is comprised of the visual information presented on the interior and exterior Passenger Information Displays combined with audio information presented via Manual and Automatic Announcements using the PA system.
- 13.6.1.2. Presentation of the audio, textual, and video messages shall be synchronized.

13.6.2. Memory Capacity

- 13.6.2.1. The PIS shall have sufficient non-volatile data storage capacity to store at a minimum (in addition to maintaining the memory requirements of Section 18.2.2.16) the following:
 - a) A minimum of 2 hours of video and audio programming to accommodate the NYCT video and media information to be displayed on the Flexible Ceiling Strip Displays.
 - b) All B-division routes including all stations, service patterns, with approximately 2,550 transfer announcements and associated automatic audio announcement recordings for current station and next station announcements.
 - c) A minimum of 50 user-selectable messages of 45 seconds duration each, with capacity for future expansion.

13.6.3. Automatic Announcement System

- 13.6.3.1. The PA System shall permit the Train Operator and the AAS to make PA announcements to passengers in all cars of a train and on adjacent platform areas.
- 13.6.3.2. Manual announcements shall always override automatic announcements.
- 13.6.3.3. Manual announcements shall only be possible from a Conductor Panel or Communications Control Panel (CCP) in an active cab or active Conductor's position.
- 13.6.3.4. When the PA button is activated, any automatic announcement that is currently playing shall be interrupted, followed by a beep heard over the speakers. After the beep has sounded the crew member shall be able to make the manual announcement.
- 13.6.3.5. Automatic announcements shall include, but are not limited to the following:
 - a) Route and destination information.
 - b) Transfer information.
 - c) Next station.
 - d) Borough/terminal.
 - e) Station arrival.

- 13.6.3.6. The AAS shall utilize digitally stored messages and present these messages to the passengers at the

designated times over the PA system.

- 13.6.3.7. Textual and video/media displays and messages shall be displayed on appropriate Passenger Information Displays as defined in Section 13.5.
- 13.6.3.8. A test control shall be provided on the TOD AAS Interface screen that will, when activated, cause a test announcement, interior and exterior display message to be repeated every 5 seconds until the test control is deactivated.

13.6.4. Messages and Display Information

- 13.6.4.1. Each audio message, text message and video/media file shall be stored along with information identifying the conditions under which the message and/or animated media display is to be broadcast.
- 13.6.4.2. Modifications to the stored audio and video messages shall be done via the AAS workstation (see Section 13.6.5), and then uploaded to the onboard Communication System via PTE (see Section 22) or an integrated memory storage unit approved by NYCT or by the wireless data link described in Section 16.3.8.
- 13.6.4.3. It shall be possible to download multiple stopping pattern modification files to the AAS system such that they will not take effect until a specified trigger date when the files are to be downloaded via the PTE, or the wireless link described in Section 16.3.8.
- 13.6.4.4. Not Used.
- 13.6.4.5. Wireless communications between the Communication System and wayside equipment shall be secure and encrypted to prevent unauthorized users from accessing the data or system. It shall not interfere with or be interfered with by any other system on the train or wayside.
- 13.6.4.6. The AAS shall support multiple trigger dates. Each stopping pattern file that is downloaded in this way takes away from the total storage capacity specified above.
- 13.6.4.7. Modifications to the stored audio and video messages shall be made from a single point on the train, and all cars on the train shall be automatically updated with the new version of the database.
- 13.6.4.8. Changes entered in one A Car shall be propagated throughout the train to all A Cars within a time limit acceptable to NYCT. Time periods shall be described in the Contractor's design review submittals to NYCT.
- 13.6.4.9. If units with different database versions are coupled, the PIS with the highest database version shall be the master and shall stream automatic announcements.
- 13.6.4.10. The other PISs with a lower database version shall report a PIS database mismatch to the MDS, but shall still be able to play the audio and video messages from the master PIS.
- 13.6.4.11. It shall be possible to modify all aspects of stored message patterns, including content, time of broadcast, trigger points, and addition or subtraction of messages.
- 13.6.4.12. It shall be possible to modify, update, or replace complete patterns and routes, as well as to customize single messages.
- 13.6.4.13. The actual operation of the PIS and its crew interface shall be reviewed and approved by NYCT.
- 13.6.4.14. It shall be possible to add time-critical, temporary special messages to the list of existing user-selectable messages available. These messages shall be played automatically at specific points on the route during designated date and time ranges. The download mode for the temporary special messages shall be independent of other AAS data download on the fleet. The details of the download method, TOD provisions to provide train operator access to the temporary messages, and the method of removal of expired temporary messages will be subject to NYCT approval.
- 13.6.4.15. Each station shall have at least five separate pre-programmed audio announcements similar to the

following:

- a) Current stop (station name) station with available transfers upon entering a station.
 - b) The train's identification and destination (including borough/terminal) while in a station.
 - c) Next stop (station name) station while in a station.
 - d) Next stop (station name) station during departure.
 - e) Last stop (see Section 13.6.4.17).
- 13.6.4.16. Announcements shall meet requirements of NYCT Specification 8020-GENL-99 (see Appendix C-17).
- 13.6.4.17. The "Last Stop" announcement shall include an audio message and visual message on both the Ceiling Interior Information Sign and exterior Side Destination Sign when at the last stop of the currently loaded stopping pattern.
- 13.6.4.18. The last messages displayed on all Displays will remain in their current configuration until the "Cancel" function on the TOD is activated. Following activation of "Cancel," all displays and all indicators, animated media displays and text will be cleared.
- 13.6.4.19. The switching of stopping pattern files on the Trigger Date shall be prevented from taking place while a route file is loaded and running. While the switching of stopping pattern files on the Trigger Date is occurring, the loading of routes and the playing of special messages may be prevented.
- 13.6.4.20. The Train Operator or Conductor shall be able to adjust, modify, or replace the automatic announcements, and appropriate sign messages via the MDS TOD with ease and without disruption, such as when the train is rerouted or station(s) are skipped. See Section 5.4 for details on the MDS TOD.
- 13.6.4.21. When disabling of the PIS is required, the PIS shall behave as follows:
- a) When the PIS is turned off, exterior signs shall remain in the state they were in before the AAS was turned off.
 - b) Interior displays will be turned "off" and manual announcements can be made.
 - c) The CIIS shall display a continuous message scrolling from right to left with the text "Please Listen for Train Crew Announcements" followed by the time of day.
 - d) The Route section of the passenger information Flexible Ceiling Strip Displays shall display "Route Change: This Map is Not in Use" or shall display an approved NYCT message and/or animated media display.
- 13.6.4.22. The PIS on the train shall interface with the Car Network to obtain train travel distance and door status.

13.6.5. AAS Workstation

- 13.6.5.1. The Contractor shall provide an AAS workstation to pre-record, edit, and transfer messages. General requirements for workstations are described in Section 22.9.
- 13.6.5.2. The AAS workstation shall include a user interface to allow editing of text messages and animated media displays, creation of new messages and animated media displays, and addition or deletion of messages and animated media displays, without the need to understand programming or code.
- 13.6.5.3. The AAS workstation shall include the software and hardware capability to digitize the audio portion of the messages either directly or from recordings and control their placement in conjunction with other audio messages or corresponding text messages. They shall also provide the capability to revise trigger points for any message, including revising the route, if necessary.
- 13.6.5.4. Passenger information Flexible Ceiling Strip Displays shall allow for authorized NYCT personnel to modify the layout via the AAS workstation. The extent of the modifications that can be made from the AAS workstation shall be presented to NYCT during design review.
- 13.6.5.5. The AAS workstation shall include the software and hardware capability to conduct a simulation of

“train run” to verify the correct announcements and sign displays.

13.6.6. Door Closing Announcement

13.6.6.1. A pre-recorded announcement advising passengers that doors are closing shall be output over the interior speakers.

13.6.6.2. The announcement shall be initiated by a momentary switch on the Conductor Panel.

13.7. Buzzer System

13.7.1. Each cab shall be equipped with a buzzer system to be used solely for crew communication.

13.7.2. One electric buzzer shall be provided in each cab. The buzzer shall be of substantial construction, designed for electric railway service.

13.7.3. Three buzzer push buttons of an approved design shall be provided in each cab. One pushbutton shall be part of the cab console and one shall be part of each Master Door Controller.

13.7.4. Pushing any buzzer button in any cab in the train shall cause the buzzer in every cab in the train to sound.

13.8. Train Radio

13.8.1. General

Design Requirements

13.8.1.1. All train radio equipment shall be provided by the Contractor. Equipment shall be supplied for each A Car and shall consist of the following subsystems:

- a) Radio transmitter/receiver.
- b) Control panel.
- c) Antenna.
- d) Power supply.
- e) Necessary cables, terminal strips, and hardware items.
- f) Diagnostic Test Equipment interface (see Section 22.8).
- g) Speaker and microphone.

13.8.1.2. The Train Radio shall be commercially available, FCC certified, and approved by NYCT.

13.8.1.3. All Train Radio equipment shall be fully solid state with maximum use of integrated circuits.

13.8.1.4. Controls for minor frequency adjustments shall be available without being disassembled.

13.8.1.5. Equipment housings shall be dust, moisture, and splash proof and shall not incorporate external forced air ventilation. The housings shall be fabricated from heavy gauge metal or high-impact material as approved by NYCT.

13.8.1.6. The control panels shall be module designed or equipped with maintenance hangers to allow access to all components and circuitry while retaining full use of all controls and functions on the panel face, without placing undue strain on cables and connectors.

13.8.1.7. All components shall be clearly labeled. All components behind the panel shall be clearly and legibly displayed in a prominent location and shall be in plain view upon removal of the unit from its enclosure.

Performance Requirements

13.8.1.8. Train Radio equipment shall conform to the requirements of IEEE Std. 1477 Section 4.3.

- 13.8.1.9. The minimum standards and measurements of the Telecommunications Industry Association and Electronics Industry Association (TIA/EIA) 603, "Land Mobile FM or PM Communications Equipment Measurement and Performance Standards" shall be met or exceeded without explicit reference.
- 13.8.1.10. Frequency stability of both the transmitted carrier and the receiver tuning oscillator shall be within ± 0.0005 percent over the ambient temperature range of -22°F to +140°F (+77°F reference) (-30°C to +60°C) (+25°C reference) with a ± 20 percent variation in input supply voltage and without the use of heaters.
- 13.8.1.11. Radio Frequency (RF) impedance at the antenna terminals shall be 50 ohms.

Functional Requirements

- 13.8.1.12. The Train Radio assembly shall be designed to function with the existing train to wayside communications system consistent with Table 13-1: Radio Frequency.

Table 13.1: Train Radio Frequency Table

Channel	Channel Name	RX Frequency (MHz)	RX CTCSS (Hz)	TX Frequency (MHz)	TX CTCSS (Hz)	Channel Spacing (kHz)
1	A-CMD	161.1900	127.3	158.8800	141.3	12.5
2	A-TR-TR	161.1900	127.3	161.1900	127.3	12.5
3	BLANK	134.0000	127.3	-----	-----	12.5
4	B1-CMD	161.5050	127.3	158.7750	100.0	12.5
5	B1-TR-TR	161.5050	127.3	161.5050	127.3	12.5
6	BLANK	134.0000	127.3	-----	-----	12.5
7	B2-CMD	161.5650	127.3	158.8050	114.8	12.5
8	B2-TR-TR	161.5650	127.3	161.5650	127.3	12.5
9	BLANK	134.0000	127.3	-----	-----	12.5
10	A YARD	160.8450	141.3	160.8450	141.3	12.5
11	B1 YARD	160.8450	100.0	160.8450	100.0	12.5
12	B2 YARD	160.8450	114.8	160.8450	114.8	12.5

- 13.8.1.13. The Train Radio shall have a minimum of 14 distinct channels.
- 13.8.1.14. Emission designators for the Train Radio shall conform to Federal Communications Commission (FCC) rules and regulations as they apply to type acceptance and reframing.
- 13.8.1.15. The Continuous Tone Coded Squelch System (CTCSS) and Digital Tone Coded Squelch System (DTCSS) shall be in accordance with Table 13-1 and shall be programmable on a per-channel basis.

13.8.2. Transmitter

Design Requirements

- 13.8.2.1. The transmitter shall consist of an exciter, a power amplifier, a harmonic filter, anti-mismatch protection and an antenna switch. The modulator, consisting of an audio amplifier, limiter, and post-limiter filters shall be contained in a plug-in integrated circuit module.
- 13.8.2.2. The transmitter shall have a protective circuit that will prevent damage to the RF stages should the antenna circuit fail. The transmitter shall automatically reset when proper operation is restored.
- 13.8.2.3. The transmitter shall have a timer to cut off transmissions in the event of a transmission or a radio malfunction that results in continuous RF power being radiated for more than 1 minute.

- 13.8.2.4. A 1.0 kHz tone shall alert the Train Operator during time-out and the timer shall reset automatically when normal conditions are restored.
- 13.8.2.5. The timer shall be adjustable up to 3 minutes via PTE.
- 13.8.2.6. The Train Radio shall provide a tone to the user to indicate that the radio is ready and that the user may begin speaking with assurance that the message is being transmitted. The tone shall be programmable as an On/Off feature. The radio's microphone shall be muted during transmission of its identification data.
- 13.8.2.7. Transmitter tuning controls shall be accessible without disassembly.
- 13.8.2.8. The Train Radio RF output connector shall be connected directly to the antenna.
- 13.8.2.9. The transceiver shall be of a modular design, and capable of being mounted into a shelf compartment.

Performance Requirements

- 13.8.2.10. The transmitter duty cycle shall be EIA intermittent.
- 13.8.2.11. The transmitter shall comply with all applicable EIA standards and FCC rules and regulations.
- 13.8.2.12. The transmitter output (watts) shall be capable of being adjusted, as approved by NYCT, into a 50 ohm load under intermittent duty conditions.
- 13.8.2.13. The output adjustment shall be between 2 to 10 watts without the use of an external attenuator, with a minimum of 3 incremental/detrimental steps, as approved by NYCT.
- 13.8.2.14. The overall output of the radio to the car antenna shall be 5 watts (-0, +1 watts) upon delivery to NYCT.
- 13.8.2.15. Conducted spurious and harmonic emission shall be attenuated at least 70 dB relative to the carrier level. If the radio is capable of other modes of transmission and bandwidths, the specifications must conform to FCC rules and regulations for operation in this mode.
- 13.8.2.16. Deviation shall be limited to ± 5.0 kHz relative to the center frequency. An instantaneous deviation limiter shall be incorporated in the design to restrict the deviation to this width. The deviation limiter shall have performance characteristics such that a 20 dB increase in the audio signal input level over that required for a 3.0 kHz deviation shall not increase the deviation to greater than 5.0 kHz. A 1,000-Hz tone shall be used as a standard reference frequency in setting the deviation control.
- 13.8.2.17. FM noise and residual hum shall be at least -45 dB relative to audio standard level.
- 13.8.2.18. Audio harmonic distortion shall not exceed 3 percent with a test tone of 1,000 Hz at an amplitude sufficient to produce 60 percent of maximum modulation.
- 13.8.2.19. The transmitter shall incorporate a subsonic continuous tone encoder, which generates a continuous, pure, highly stable tone.

13.8.3. Receiver

Design Requirements

- 13.8.3.1. All essential parameter/values shall be available for general maintenance without disassembly.
- 13.8.3.2. Squelch sensitivity control shall be available without being disassembled.

Performance Requirements

- 13.8.3.3. At least two transistorized limited stages shall precede the discriminator. Essentially, noise excitation alone shall saturate the second limiter at all times. FM noise shall be at least 60 dB below 2/3 rated deviation at 1,000 Hz.
- 13.8.3.4. The receiver modulation acceptance shall be ± 7.0 kHz minimum.

- 13.8.3.5. The intermodulation spurious response at the usable sensitivity level (12 dB Signal-to-Noise and Distortion ratio (SINAD)) shall be attenuated at least 75 dB.
- 13.8.3.6. Employing the two signal SINAD method as described in EIA/TIA 603 Standards, the minimum adjacent channel selectivity shall be at least -70 dB (narrowband 12.5 KHz). Desensitization at ± 200 kHz shall be at least -95 dB, and -100 dB at ± 1 MHz.
- 13.8.3.7. All spurious responses, including image response, shall be attenuated by a minimum of 80 dB relative to that resonant frequency signal level that produces 20 dB of noise quieting.
- 13.8.3.8. The audio frequency response shall be within +2 dB to -8 dB of the normal 6 dB per octave de-emphasis characteristics from 300 Hz to 3 kHz.
- 13.8.3.9. The receiver 12 dB SINAD sensitivity shall not exceed 0.5 microvolts.
- 13.8.3.10. All noise and residual hum shall be at least 40 dB below the audio output level.
- 13.8.3.11. The audio stages of the receiver shall deliver an output of at least 5 watts or, if a more effective system is proposed by the Contractor, the system shall demonstrate to the satisfaction of NYCT, that the audio output is of sufficient level to override the ambient noise level inherent in the Train Operator's cab.
- 13.8.3.12. Total audio distortion shall be less than 5 percent at rated output.
- 13.8.3.13. The squelch circuitry shall be a noise compensated type activated by carrier and tone with an adjustable sensitivity of 0.35 microvolts or less.

13.8.4. Train Radio Antenna

Design Requirements

- 13.8.4.1. A low-profile transit-type antenna shall be provided for each Train Radio.
- 13.8.4.2. The Train Radio Antenna shall be completely enclosed in a non-conductive, high impact resistant case with the exception of an approved RF connector and, if required, a tuning adjustment which shall have a weatherproof seal.
- 13.8.4.3. A waterproof method of mounting the antenna to the train surface shall be provided, as approved by NYCT.
- 13.8.4.4. The antenna shall be mounted behind the cab end bonnet, as approved by NYCT. An alternate location can be proposed by the Contractor for approval by NYCT.

Performance Requirements

- 13.8.4.5. The antenna shall maintain a VSWR of less than 2:1 over a frequency range between 150 MHz to 162 MHz minimum RF bandwidth, after being mounted and connected on a car.
- 13.8.4.6. The coaxial antenna cable shall be a low loss UHF-RG-213/U, solid conductor cable with a 50 ohm impedance and a nominal attenuation of not greater than 3.5 dB/100 feet, unless otherwise approved by NYCT.
- 13.8.4.7. The antenna shall be mounted so as to provide a vertically polarized omnidirectional radio signal.
- 13.8.4.8. The Contractor shall validate the Train Radio Antenna design via analysis through software program FEKO (translation - field calculations involving bodies of arbitrary shape) or NYCT approved equal.

13.9. Onboard Train CCTV System

13.9.1. General

Design Requirements

- 13.9.1.1. The Contractor shall provide an Onboard Train CCTV System (OTCS) on each car to monitor and record

onboard activity.

- 13.9.1.2. The OTCS shall include, but not be limited to, the following elements:
- a) Passenger Viewing CCTV cameras.
 - b) Train Crew Viewing CCTV cameras.
 - c) Forward Facing CCTV cameras.
 - d) Digital Video Recorders (DVRs).
 - e) CCTV Train Operator Display (CCTV TOD).
 - f) Rugged Internet Protocol (IP) switches.
 - g) Cab Audio Recording.
 - h) Remote Video Request System (RVRS).
- 13.9.1.3. The OCTS shall make use of Commercial Off-The-Shelf (COTS) equipment wherever possible.
- 13.9.1.4. The design of the OTCS shall be approved by NYCT.
- 13.9.1.5. The CCTV system shall be powered by the LVDN with a separate circuit breaker in each car to protect the CCTV equipment.
- 13.9.1.6. CCTV equipment shall communicate over the train Ethernet backbone. Information from one Unit in a coupled train shall be available to the other Unit of that train. The recorded information shall reside on the Unit on which it was recorded.
- 13.9.1.7. Licenses shall not be required for any of the CCTV technology used.
- 13.9.1.8. Each car shall have two video surveillance decals to alert passengers that they may be recorded for their safety and security, and such video recordings may be used for criminal prosecution.
- 13.9.1.9. Each cab shall have video surveillance decals stating that activity inside the cab may be recorded. The decal shall also state that audio activity may be recorded.
- 13.9.1.10. All decals shall meet the graphic requirements specified in Section 15.14.1. All text to be shown shall be approved by NYCT.
- 13.9.1.11. A CCTV laptop shall be provided to allow retrieval of data from a DVR via a local port or the wireless data link described in 16.3.8. The laptop shall have access controls as required to ensure Chain of Custody and Chain of Evidence will be maintained. The access control measures shall be approved by NYCT. The laptop application shall be a Windows-based standalone application that allows authorized users to view and download data from the DVR.

Performance Requirements

- 13.9.1.12. The OTCS shall meet the "Recognize" Operational Objective of APTA Recommended Practice APTA-IT-CCTV-RP-001-11. All camera and screen resolutions shall be designed to meet this requirement and shall be approved by NYCT.

Functional Requirements

- 13.9.1.13. During train operation, the OTCS shall record the passenger compartment, the cab, and external front of the active cab. The OTCS shall capture all images within the each camera's Field of View (FoV).
- 13.9.1.14. Security and law enforcement personnel shall have the capability to view and monitor passenger area activity in real-time through the CCTV TOD via a CCTV Control key switch on the cab console.
- 13.9.1.15. OTCS failures and faults, including camera obstructions and physical damage, shall be automatically annunciated to the MDS and displayed on the MDS TOD.

- 13.9.1.16. If the CCTV TOD fails, it shall be possible to switch the CCTV views from the CCTV TOD to the MDS TOD via soft keys on the MDS TOD.
- 13.9.1.17. DVR recorded data shall not be accessible via the CCTV TOD.
- 13.9.1.18. The CCTV PTE shall be used to diagnose the health of each component of the OTCS. The CCTV PTE shall be capable of viewing real time video from individual CCTV cameras for maintenance purposes.
- 13.9.1.19. Provisions shall be included to allow the images from the Forward Facing CCTV camera in the non-active end car (the rear of the train) of a train to be displayed on the CCTV TOD in the active cab of the train when the Master Controller Reverser Switch is in the Reverse position.
- 13.9.1.20. Provisions shall be included to allow the image from the Passenger Viewing CCTV camera to be displayed on the CCTV TOD in the cab where the PEI activation was acknowledged. When communication with an activated PEI station is established, the CCTV camera with the best view of the activated PEI station would be available for display on the CCTV TOD in the cab where the PEI activation was acknowledged.

13.9.2. CCTV Cameras

Design Requirements

- 13.9.2.1. The passenger area of each car shall be equipped with four to eight fix-mounted, digital, color, Internet Protocol (IP) type Passenger Viewing CCTV cameras, as needed to provide complete coverage.
- 13.9.2.2. Cameras shall communicate via Ethernet, and shall utilize Power over Ethernet (PoE) technology.
- 13.9.2.3. The Passenger Viewing CCTV cameras shall be arranged in the passenger area such that the camera's FoVs capture in aggregate the full view of the car's interior. Blind spots created by any single camera failure shall be minimized.
- 13.9.2.4. Two of the Passenger Viewing CCTV cameras shall be covertly mounted. The others shall be overtly mounted.
- 13.9.2.5. Passenger Viewing CCTV cameras shall be mounted on the ceiling of the car in vandal resistant, tamperproof enclosures.
- 13.9.2.6. Final location of all Passenger Viewing CCTV cameras shall be approved by NYCT.
- 13.9.2.7. Each cab shall be equipped with three cab CCTV cameras.
 - a) One Forward Facing CCTV camera to record the same forward facing view as that of the Train Operator.
 - b) One inward facing Train Crew Viewing CCTV camera to record the Train Operator position.
 - c) One inward facing Train Crew Viewing CCTV camera to record the left-side MDC and window.
- 13.9.2.8. The Train Crew Viewing CCTV cameras shall be mounted such that the FoV will capture the Train Operator or Conductor's face and upper body when in the seated position, and all train control devices such as the Master Controller, all console-mounted switches, the left side window, and MDC.
- 13.9.2.9. The Forward Facing CCTV camera shall be mounted to view the forward traveling direction of the train. The field of view shall cover the signals, track, and wayside ahead of the train, as seen by the Train Operator.
- 13.9.2.10. All cab CCTV cameras shall be overtly mounted in a manner that will not obstruct the Train Operator's or Conductor's normal view through the cab and cab side windows.

Performance Requirements

- 13.9.2.11. CCTV cameras shall have the following properties:

- a) Color cameras.
 - b) Fixed lens.
 - c) Minimum frame rate for Passenger Viewing and Train Crew cameras shall be at least 7.5 frames per second (fps).
 - d) Minimum frame rate for Forward Facing camera shall be at least 30 fps.
 - e) Video data format shall be MPEG-4 Part 10 (H.264) or later.
 - f) Resolution of the passenger area and inward facing cab cameras shall meet, at a minimum, the requirements of 4CIF (Common Interchange Format) (704 horizontal pixels x 576 vertical pixels).
 - g) Resolution of Forward Facing cab cameras shall be no less than 1280 horizontal pixels x 720 vertical pixels.
- 13.9.2.12. The CCTV camera coverage and resolution shall be such so as to be able to positively recognize individual faces on the train with 80 percent of the lights out in the car.
- 13.9.2.13. All onboard CCTV cameras shall be capable of operating (adjust automatically) in low light (0.01 lux) conditions, glare, and under the rapid ambient lighting changes experienced inside the car during operation.
- 13.9.2.14. CCTV Camera failures, due to either obstruction or physical damage, shall be detected and recorded by the MDS.

13.9.3. Digital Video Recorders (DVRs)

Design Requirements

- 13.9.3.1. Two DVRs shall be provided per Unit. One DVR shall be installed in each A Car, in a secured and locked enclosure. The key for the enclosure shall be unique for the application, and the DVR itself shall be equipped with a key lock on the video storage compartment. Both keys shall be proposed by the Contractor and approved by NYCT.
- 13.9.3.2. Each DVR in the unit shall record the video images and audio data from all cameras in that Unit. For redundancy, both DVRs shall record the same video images from all of the cameras installed in the Unit.
- 13.9.3.3. DVR recordings shall be stored in non-volatile memory such that all recorded information will be retained in the event of a power loss.
- 13.9.3.4. The DVR shall include a removable media with storage capacity as required in Section 13.9.3.7.
- 13.9.3.5. Each DVR shall be equipped with a communication port to allow local download of data directly from a DVR to a CCTV laptop.
- 13.9.3.6. Recorded audio and video data shall be synchronized.
- 13.9.3.7. The DVR shall monitor the service life of its storage media, and shall annunciate to the MDS when it needs to be replaced.

Performance Requirements

- 13.9.3.8. The DVR shall have the following properties:
- a) Aggregate frame rate of at least 360 fps.
 - b) 97 day storage capacity for Passenger Viewing CCTV cameras, or as approved by NYCT.
 - c) 30 day storage capacity for Train Crew Viewing CCTV cameras, or as approved by NYCT.
 - d) 10 day storage capacity for Forward Facing CCTV cameras, or as approved by NYCT.
 - e) Video data format shall be MPEG-4 Part 10 (H.264) or later.

- f) Resolution of Passenger Viewing and Train Crew cameras shall meet, at a minimum, the requirements of 4CIF (704 horizontal pixels x 576 vertical pixels).
- g) Resolution of Forward Facing cameras shall be no less than 1280 horizontal pixels x 720 vertical pixels.

Functional Requirements

- 13.9.3.9. The DVR shall record the images from all Passenger Viewing, and Train Crew Viewing CCTV cameras whenever the system detects an active cab or active Conductor's position by the Master Controller Key, the Master Door Controller Key, or the Maintenance Key.
- 13.9.3.10. The DVR shall record the images from the Forward Facing CCTV camera only in an active cab (Master Controller keyed up).
- 13.9.3.11. Both DVRs on a unit shall record the same video data from all cameras on that unit for redundancy.
- 13.9.3.12. The DVR shall continue to record for an adjustable time (up to 1 hour) after the cab is deactivated. This time shall be PTE adjustable. There shall be independently adjustable time lengths for the Passenger Viewing CCTV cameras, Train Crew Viewing CCTV cameras and Forward Facing CCTV cameras.
- 13.9.3.13. The DVR, when the OTCS is in an inactive state, shall automatically begin to record images upon detecting significant amounts of motion within the FoV of those cameras that detected the motion. The method of detecting motion and the triggering criteria to begin autonomously recording shall be subject to NYCT approval.
- 13.9.3.14. Overwriting of recorded images shall be on a First-In First-Out basis once the DVR has reached its storage limit, with the oldest recordings of each type (i.e. each retention type) being replaced by the newest of the same type.
- 13.9.3.15. The recorded images from all onboard CCTV cameras shall be time/date stamped. The car number and camera number shall also be stamped in the recorded image. The stamps shall be located and sized not to interfere with the recorded image; this data may be stored in the header/metadata of the video file(s) stored on the DVR with NYCT approval.
- 13.9.3.16. The recorded images on the DVR shall be digitally signed and secured to ensure proper chain of evidence is preserved. A hashing function such as SHA-2 or SHA-3 shall be used.
- 13.9.3.17. The DVR shall record trigger based events such as PEI or PEHU activations and Emergency Brake (EB) applications. There shall be no less than 10 types of trigger events. The list of trigger events shall be reviewed and approved by NYCT. Video data around the trigger events shall be 'tagged' with the event type, camera number, and time for accessibility when downloading video data. Data will be tagged 10 minutes prior to, and 10 minutes after the trigger event.
- 13.9.3.18. The DVR shall not utilize compression techniques that permanently lower the quality of the images without NYCT approval.

13.9.4. CCTV Internet Protocol (IP) Switches

- 13.9.4.1. CCTV IP switches shall be provided as required. These switches shall be the pathway by which the On-Board Train CCTV cameras connect to the Ethernet backbones of the vehicle, to transmit video images to the DVR(s), TODs, and other devices as applicable.
- 13.9.4.2. CCTV recording shall not be interrupted by any single-point failure of the network architecture. In the event that any such single-point failure creates a bandwidth bottleneck that would prevent all network functionality from operating, network features may be disabled to ensure CCTV recording continues. All such single-point failures shall be identified by the Carbuilder at PDR and mitigations for each shall be proposed before CDR.
- 13.9.4.3. The IP Switch shall be a ruggedized IP Switch, with sufficient Ethernet ports to support the camera

arrangement specified in Sections 13.9.2.1, two redundant connections to the Vehicle Ethernet Backbone, and connection to the DVR plus at least four (4) PoE spares. The IP Switch shall support Power over Ethernet technology.

13.9.5. CCTV Train Operator Display (TOD)

- 13.9.5.1. The Cab CCTV Train Operator Display (TOD) shall be a color, touch screen enabled display. The location and design requirement of the CCTV Display is described in Section 5.4.1. The functional requirements for the CCTV TOD are described in Section 5.4.5.
- 13.9.5.2. Requirements for the CCTV TOD shall be reviewed and approved by NYCT.
- 13.9.5.3. The Cab CCTV TOD shall have the following properties:
 - a) Minimum 12.1 inches (307 mm) diagonal in size.
 - b) Minimum 1080p resolution. Alternative resolutions may be proposed to NYCT for consideration.

13.9.6. Cab Audio Recording

- 13.9.6.1. Redundant microphones shall be installed in each Cab to record its aural environment. The microphones shall be configured to record the voice of the Train Crew and/or Train Radio over ambient operating noise in all normal service conditions.
- 13.9.6.2. All microphone performance specifications, mounting arrangements and other criteria to meet this requirement shall be proposed by the Contractor for NYCT approval,
- 13.9.6.3. The Cab Audio recording equipment shall start and stop recording audio in sync with the activation and deactivation of the cab-mounted cameras
- 13.9.6.4. Cab Audio recording shall be capable of enabling/disabling cab audio recording via PTE. The recording of audio shall default to OFF.
- 13.9.6.5. Cab Audio shall be retained for no less than 30 days before overwriting.
- 13.9.6.6. A decal stating that audio activity in the cab may be recorded shall be incorporated into the decal described in Section 13.6.2.1. The text shall be approved by NYCT.

13.9.7. Remote Video Request System (RVRS)

General

- 13.9.7.1. The OTCS shall be capable of transmitting and receiving video and control data wirelessly to support specific wayside-based functions. This shall include downloading from the vehicle specific portions of stored video based on specific selections, such as but not limited to: camera #, camera type, time/date range, and/or PEHU/PEI activation tags, on an individually selected car or unit basis.
- 13.9.7.2. It shall be possible to request downloads of specific CCTV video from the vehicle using a network enabled client application, to be provided by the Carbuilder. This client application will queue the request for data on a centralized server dedicated for this purpose, and the server shall be capable of automatically downloading the data when the appropriate vehicle is detected in wireless connectivity range. The server will then provide that data for download to the original requestor over an Ethernet network connection.
- 13.9.7.3. The Contractor shall provide all RVRS equipment as required by this Section. The wireless data link specified in Section 16.3.8 may be used by the RVRS as approved by NYCT.
- 13.9.7.4. Not Used.
- 13.9.7.5. Not Used.

Vehicle Equipment

- 13.9.7.6. The OTCS shall employ a Mobile Access Router (MAR) in each A Car capable of communicating with the vehicle Ethernet backbone.
- 13.9.7.7. The MAR shall support a wide variety of wireless communications mediums, including but not limited to 802.11xx Wi-Fi, and the most common 3G/4G cellular frequencies.
- 13.9.7.8. Specific antennas/frequencies proposed shall prioritize achievable data transmission speed and interoperability with existing NYCT wireless systems. Antennas and specific frequencies proposed shall be subject to NYCT approval. Antennas shall be COTS equipment unless otherwise approved by NYCT.
- 13.9.7.9. The MAR shall be capable of routing selected CCTV images to specific locations, utilizing the wayside request system described in this Section.
- 13.9.7.10. A multipurpose antenna module that supports as many of the wireless communication channels as those supported by the MAR shall be installed in each A Car. The antenna shall be placed in the bonnet, or other location with NYCT approval, to maximize wireless performance without interfering with existing vehicle equipment.

Wayside Equipment

- 13.9.7.11. The server provided to support the RVRS shall be capable of communicating with client applications over a secured Ethernet channel to receive and queue requests for video data.
- 13.9.7.12. Access to the server shall require authentication.
- 13.9.7.13. The server shall be capable of scaling, configuring, and managing an approved number of concurrent wireless connections to CCTV-enabled A Cars in connectivity range on a single platform. It shall be capable of IP discovery, registration, and diagnostics of CCTV-enabled vehicles in connectivity range.
- 13.9.7.14. Data downloaded from CCTV-enabled vehicles shall be retained on the server indefinitely until it is confirmed to have been retrieved by the requestor. After it has been retrieved, it will be automatically deleted after thirty (30) calendar days have elapsed.
- 13.9.7.15. The server shall have sufficient storage to retain to retain, at minimum, 250 individual data requests, each request comprising 20 minutes of data from each camera on an A Car; storage shall be configured such that the failure of any single disk drive does not cause loss of data.
- 13.9.7.16. The Server shall retain logs of all RVRS activity, including but not limited to user logins, user video requests, download completions, video deletions, vehicle IP discovery, etc.
- 13.9.7.17. All server hardware shall be COTS equipment, unless otherwise specifically approved by NYCT and shall support standard rack mounting. Detailed specifications for the server shall be determined by the Carbuilder and proposed to NYCT no sooner than six months prior to intended delivery of the equipment.
- 13.9.7.18. Not Used.

Client Application

- 13.9.7.19. The client application shall be a Windows-based standalone application that allows authorized users to log requests for data with the RVRS.
- 13.9.7.20. Users shall be able to request segments of video data based on all the available selection up to a configurable total amount of camera time. Requests will not begin downloading from connected vehicles until they are authorized in the system by an authorized administrator.
- 13.9.7.21. Users with administrator access shall be capable of reviewing all pending data requests, and have access to all required information related to each request to ascertain their validity.
- 13.9.7.22. Users shall be able to access a log of their requests and their approval and download completion statuses in the program, and generate reports of this data on demand. The program shall support exporting video segments to disc, and to portable memory.

13.9.7.23. The client application shall have a built-in video player with the following minimum set of functions:

- a) Video playback, including Play, Pause, Stop, and frame-by-frame sequential playback.
- b) Synchronized playback of up to 4 video recordings on a single display.
- c) Playback of recordings synchronized with cab audio.
- d) Video playback with encoded metadata displayed in a separate window.
- e) Video playback with encoded metadata overlaid on video.
- f) Still print/export to Adobe® PDF format displayed video.
- g) Export video formatted with metadata overlaid on video recording.

13.10. Platform Edge CCTV

13.10.1. The Contractor shall include provisions for future installation of a Platform Edge CCTV system on each train. The system itself is not included within the scope of this Contract.

13.10.2. Platform Edge CCTV provisions shall consist of identified space for carborne equipment, power allocation, circuit breaker(s), and interface with the TODs in the cab and train subsystems as approved by NYCT.

13.10.3. The Platform Edge CCTV system will receive data from platform mounted CCTV cameras via a wireless data link and shall display the images on the CCTV TOD in the cab. The system will be capable of displaying the video while the train is entering and exiting the station. The wireless data link specified in Section 16.3.8 may be used by the Platform Edge CCTV system as approved by NYCT.

13.11. Platform Screen Door (PSD) Interface

13.11.1. Provisions shall be included to allow for a train to wayside wireless data interface to automatically control Platform Screen Doors (PSD) in stations. The system itself is not included within the scope of this Contract.

13.11.2. PSD provisions shall consist of identified space for carborne equipment, power allocation, circuit breaker(s), and interface with train subsystems as approved by NYCT.

13.11.3. The PSD system will communicate via a wireless data link with the PSD system in the station. The wireless data link specified in Section 16.3.8 may be used by the PSD system as approved by NYCT. The PSD system will be capable of determining when the train is berthed in the station and the correct platform side. The PSD system will be able to coordinate the safe operation of the PSDs with the train doors.

13.12. Not Used

13.13. Maintainability Requirements

13.13.1. All Communications Systems equipment shall meet the maintainability design requirements of Section 2.14.4.

13.13.2. All Communications Systems hardware shall comply with the requirements of Section 19, Materials, Processes and Workmanship.

13.13.3. All Communications Systems software shall comply with the requirements of Section 18, Software Systems.

13.14. Validation Requirements

13.14.1. A validation program of analysis and/or testing of the Communications Systems shall be undertaken to demonstrate compliance to this Section. [CDRL]

- 13.14.2. Conductor Panel Impact Test: The microphone plate assembly shall withstand the impact from a drop of a 1 pound (0.45 kg) steel ball from a height up to 6 feet (1.8 m), anywhere on the front surface of the assembly, for 10 times in succession, without incurring any damage.
- 13.14.3. The Conductor Panel momentary push buttons shall be vandal-resistant and shall be designed and type tested for 10 million failure-free operations or as approved by NYCT.
- 13.14.4. The Contractor shall test the Communications Antenna, after being mounted and connected on a train car, to demonstrate that it maintains a Voltage Standing Wave Ratio (VSWR) of less than 2:1 over a frequency range between 150 MHz to 162 MHz minimum RF bandwidth.
- 13.14.5. The radio transmitter and receiver shall meet all vibration and shock stability requirements of the applicable paragraphs of TIA/EIA 603.
- 13.14.6. The control panel, power supply, and antenna shall meet all technical and operational specifications after completion of vibration and shock stability tests as set forth for land mobile receivers in TIA/EIA 603.
- 13.14.7. The Contractor shall provide a sample passenger information Flexible Ceiling Strip Display along with sample screen shots for NYCT review and approval. [CDRL]
- 13.14.8. The Contractor shall provide calculations to NYCT during design review confirming: [CDRL]
- The proposed PA and speaker design can meet the intelligibility requirements of IEEE STD 1477 Section 4.5.2.
 - The proposed PIS system has sufficient storage capacity as required by Section 13.6.2.1.
 - The onboard network has sufficient bandwidth to support the audio and video data transfer as required in Section 16 - Trainline and Network Architecture.
 - The train to wayside network has sufficient capacity to support uploading video and audio data as required in this Section. The estimated time to upload 1 hour of media shall be provided.
- 13.14.9. The Contractor shall develop a test to demonstrate the performance of the communication system, including PEI, interior and exterior speakers, signs and displays, and other interfaces as specified in this Section. This test shall be conducted on the first two Units at the site of final assembly, and may be combined with the Passenger Information Systems Qualification Test if the two systems are integrated and supplied by a single vendor.
- 13.14.10. The Contractor shall demonstrate the performance of the PIS installed on the first two Units at the final assembly site.
- 13.14.11. The Contractor shall develop tests to confirm the performance of the OTCS and RVRS as detailed in Section 13.9. These tests shall be performed on the first 2 Units at the final assembly site.
- 13.14.12. The train radio, PA system, and PIS shall be tested. Output power from the train radio shall be measured at the antenna. Sound pressure level measurements of each speaker shall be made using a test tone generator, see Section 13.8.2.18, and adjusted to meet predetermined criteria. All emergency call stations shall be tested. The PIS shall be tested using predetermined test script software.
- 13.14.13. The Contractor shall develop tests to demonstrate the functional performance of the train radio within the Authority's system, including tunnels, to verify compliance with Section 13.8.
- 13.14.14. Not used.
- 13.14.15. Prior to the 30-day Operations Passenger Service test, the first two Units shall go through one simulated service trip on a route designated by NYCT, to ensure communication system operational compliance with this Section.
- This simulated service trip shall test the proper operation of radio, PA, all visual signs, AAS, door chime and door warning, crew intercom, passenger emergency intercom, and the interface of

- communication system with other systems.
- b) Uniformity of audio sound level and AAS routine setup shall also be tested. The train shall make simulated station stops and cycle the doors on the offside of station platforms, at each station along the selected route during the test.
 - c) At the end of the test, the event log from the monitoring and diagnostic system shall be made available for NYCT review.
 - d) Any failure of the communication system during the simulated run shall cause the entire test to be repeated.
- 13.14.16. All electrical and electronic assemblies shall be functionally tested and certified for performance in accordance with the manufacturer's specifications and test codes, as approved by NYCT.

13.15. Deliverables

The following Contract Deliverables are defined in this Section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
13-1	13.5.5.19	Functional details of flexible ceiling strip displays	PDR
13-2	Not used	Not used	Not used
13-3	Not used	Not used	Not used
13-4	Not used	Not used	Not used
13-5	Not used	Not used	Not used
13-6	13.14.1	Communications System validation program	CDR
13-7	13.14.7	Sample passenger information Flexible Ceiling Strip Display along with sample screen shots	CDR
13-8	13.14.8	Communications System performance calculations	CDR

Section 14

Train Control System

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14. Train Control System

14.1. Introduction and General Requirements

- 14.1.1. This section defines the requirements and Contractor responsibilities for the Train Control System elements to be installed on the R211 cars. For purposes of this Section "R211" shall refer specifically to the "R211A" and "R211T" cars.
- 14.1.2. NYCT is currently in the process of overlaying a Communications-Based Train Control (CBTC) signaling system on the existing block signaling system. The carborne portion of the CBTC system shall be installed on the R211 trains.
- 14.1.3. NYCT's Capital Program Management (CPM) will be responsible for procuring the carborne CBTC equipment and associated software and supplying it to the Contractor as described in this Section. The carborne CBTC equipment will be provided to the Contractor as a kit. Each kit will contain all of the carborne CBTC equipment for one R211 Unit.
- 14.1.4. Unless otherwise noted the term "CBTC system supplier" used in this Specification refers to the party responsible for the supply of the carborne CBTC equipment portion of the R211 program, under a separate contract with NYCT.
- 14.1.5. The Contractor shall provide all electrical and mechanical interfaces between the carborne CBTC equipment and the vehicle systems on the R211 units, and integrate the carborne CBTC system into the R211 cars as described in this Section.
- 14.1.6. CBTC installation responsibilities shall be as follows:
 - a) The Contractor shall provide all personnel required to install the carborne CBTC equipment on all R211 Units.
 - b) The CBTC system supplier will be present at the Contractor's facility to support all CBTC equipment installation. The installation of the first two R211 Units will be used to train the Contractor's personnel for the proper installation of the CBTC equipment.
 - c) The Contractor shall provide NYCT with an estimated installation schedule and installation labor requirements so that adequate resources can be made available and equipment delivery schedules developed to support the installation. The estimate shall include estimates for the CBTC installation on the test track. [CDRL]
- 14.1.7. The carborne CBTC equipment is defined as all CBTC equipment and interfaces installed inside lockers and equipment compartments located in the cab, as well as undercar, on the truck, and on the axles and/or gear housings. A list of the CBTC hardware is described in Section 14.3.11.
- 14.1.8. Baseline Mechanical, Electrical and Functional R211 Interface Control Documents (ICDs) are included in Appendix E-2. The R211 ICDs shall serve as the baseline for the CBTC interface design. Modifications to the ICDs shall be integrated into each document up to the completion of the Critical Design Review (CDR). The Contractor shall update the baseline R211 ICDs as detailed in Section 14.6.2.
- 14.1.9. The CBTC system supplier will be available for working sessions to assist the Contractor in the interface design and integration of the carborne CBTC system on the R211 trains as defined in Attachment 14-A, "Responsibility Matrix for CBTC – R211 Contractor/NYCT".
- 14.1.10. The Contractor shall participate in system interface design meetings prior to Preliminary Design Review (PDR), In-Process Design Review (IPDR), and CDR for the carborne CBTC system.
- 14.1.11. All cab controls, mounting hardware and interconnecting cabling and conduit shall be provided by the Contractor. See Attachment 14-A for further detail.

- 14.1.12. The Contractor shall provide all required interface and interconnection equipment required to provide a fully functional carborne CBTC system, including, but not limited to equipment enclosures, mounting hardware, circuit breakers, pushbuttons and indicators, wiring, conduits, junction boxes, etc.
- 14.1.13. The Contractor shall be responsible for testing and verifying the functionality of all train interfaces to the carborne CBTC system. NYCT and the CBTC system supplier will provide engineering support for verifying and troubleshooting of the train interfaces.
- 14.1.14. Static and dynamic CBTC Post Installation Check-Out (PICO) testing will be performed on each R211 unit by the CBTC system supplier, on behalf of NYCT CPM, at the Contractor's facility prior to shipment to NYCT. The Contractor shall support the static and dynamic PICO testing.
- 14.1.15. NYCT CPM will supply the necessary wayside CBTC equipment and/or simulators to the Contractor in order to equip the Contractor's test track for dynamic PICO testing. The Contractor shall work with NYCT CPM and the CBTC system supplier to determine the characteristics of the Contractor's test track. The Contractor shall install the wayside CBTC equipment on the test track at the Contractor's facility.
- 14.1.16. NYCT CPM will provide all documentation required to install, set-up, configure and commission the wayside CBTC equipment/ simulators on the Contractor's test track. The CBTC system supplier, on behalf of NYCT CPM, will be available for any engineering support needed to make the test track equipment functional to support testing of a series production schedule of the entire fleet. The CBTC system supplier, on behalf of NYCT CPM, will perform required regular maintenance activities on the CBTC test track equipment for the duration of the R211 project.
- 14.1.17. Safety Certification of the functional carborne CBTC system in conjunction with other CBTC subsystems and infrastructure elements on a typical NYCT line will be the responsibility of the CBTC system supplier, on behalf of NYCT CPM.
- 14.1.18. See Articles 203, 205, 207, 901, 905, 906, and 908 of the Contract Terms and Conditions for details regarding scheduling, maintainability, equipment warranty, and equipment reliability.

14.2. Functional Requirements

- 14.2.1. The carborne CBTC System performs the following functions:
 - a) Automatic Train Protection (ATP).
 - b) Propulsion and braking commands in Automatic Train Operation (ATO) Mode.
 - c) Station stopping management.
 - d) Door Enable management.
 - e) Stop functions on trains.
 - f) Speed control.
 - g) Display information to the train crew.
 - h) Provide automated announcements to the train's communications system.
 - i) Provide operation and maintenance data to the NYCT wayside CBTC system.

- 14.2.2. CBTC equipped trains operate in the following train operating modes (the descriptions below are general descriptions provided as a brief overview of each mode, and do not contain all details relevant to each mode):
- a) Automatic Train Operation (ATO) Mode: The train operates automatically from station to station with the carborne CBTC system providing propulsion and braking commands and providing full ATP. The Train Operator commands train departure using the ATO Start pushbutton. Master Controller is left in the Full Service Brake position. Door Enable command is controlled by carborne CBTC system. Train crew commands opening and closing of doors.
 - b) Automatic Train Protection Manual (ATPM) Mode: The Train Operator controls braking/propulsion commands using the Master Controller, and the carborne CBTC system provides full ATP. Door Enable command is controlled by carborne CBTC system. Train crew commands opening and closing of doors.
 - c) Auxiliary Wayside Protection (AWP) Mode: Mode when the carborne CBTC system loses communication with the wayside CBTC system. The Train Operator controls braking/propulsion commands using the Master Controller. Carborne CBTC system enforces civil speed limitation.
 - d) Civil Speed Protection (CSP) Mode: Mode in CSP territories. The Train Operator controls braking/propulsion commands using the Master Controller. Carborne CBTC enforces civil speed limitation.
 - e) Yard Mode: Mode when the train detects that it is in the yard. Carborne CBTC system provides civil speed enforcement, head-to-head management and end of guideway / bumper block protection.
 - f) Wayside Signal Protection (WSP) Mode: Mode used when the train determines that it is outside of CBTC territory. The Train Operator controls braking/propulsion commands using the Master Controller and operates in accordance with wayside signal aspects. Carborne CBTC system performs no train control or supervisory functions.
 - g) Restricted Manual (RM) Mode: The Train Operator controls braking/propulsion commands using the Master Controller. Train subsystems restrict the train to a 10 mi/h speed limit.
 - h) Bypass Mode: Carborne CBTC system is bypassed. The Train Operator controls braking/propulsion commands using the Master Controller and operates in accordance with wayside signal aspects.
- 14.2.3. The train operating mode depends on the operational status of the onboard and wayside CBTC equipment, and the territory that the train is operating in.
- 14.2.4. The carborne CBTC equipment shall be able to perform its train control functions from any A Car in the train, working in conjunction with a Train Operator in the lead car and a Conductor, if present, in another A Car.
- 14.2.5. Train Operator's commands shall be provided to the carborne CBTC system by the train subsystems only from the active cab.
- 14.2.6. ATO shall only be available in an active, lead cab.
- 14.2.7. The carborne CBTC system is not designed to support operation of trains without crews.
- 14.2.8. CBTC functions do not include the automatic opening or closing of train doors. The train door functions will be performed by a Train Operator or a Conductor, once enabled by the CBTC system when in CBTC mode.
- 14.2.9. The train subsystems shall prevent more than one cab from being active at the same time.
- 14.2.10. In the RM or Bypass Modes, the carborne CBTC system shall be inhibited from controlling any part of the train including emergency brakes, door enable, and traction controls.

14.3. General Design Requirements

- 14.3.1. A revenue CBTC train shall consist of either one or two operating Units, with the constraint that the maximum revenue train length shall not exceed 11 cars. R211 units shall be 4-car, 5-car, or 6-car minimum operating lengths. See Section 2.2 for Unit configuration details. Within a train the Units can be coupled in any orientation and the CBTC system will accommodate this flexibility in train make-up. The carborne CBTC system will automatically determine the train length and inhibit CBTC operation if the train length exceeds 11 cars.
- 14.3.2. As required by Section 2.2.1.2, one truck of the A1 Cars shall be unpowered and one axle on that truck shall be unbraked, or free. The Contractor shall make provision for the following:
- a) Two CBTC speed sensors to be installed on the unpowered axles. One speed sensor shall be installed on each axle.
 - b) Two CBTC tachometers to be installed on each end of the free axle.
- 14.3.3. The specific quantity and configuration of the R211 speed sensors shall be determined through the design review process.
- 14.3.4. A CBTC locker shall be provided in the cab of each A1 and A2 Car to house CBTC equipment. The cab locker shall be designed to house all of the carborne CBTC equipment per the requirements of the R211 ICD.
- 14.3.5. The CBTC locker shall also provide sufficient space to house the Staten Island Railway (SIR) Automatic Train Control (ATC) cab equipment. See Section 25 for further details.
- 14.3.6. The Contractor shall provide a temperature and heat dissipation analysis for the equipment in the CBTC locker.
- a) The analysis shall demonstrate that the heat from the CBTC equipment located in the proposed equipment lockers can be dissipated such that the equipment will not be exposed to temperatures that are in excess of the equipment's rated limits. The analysis shall take into consideration all equipment that is located in the equipment lockers along with the CBTC equipment.
 - b) Maximum temperature outside the cars shall be considered as 125°F (52°C), with the HVAC system OFF, car under full solar load, and the CBTC equipment in full power.
 - c) Simulated images from Thermal Imaging Analysis modeling software shall be submitted to show that the temperature limits are not exceeded.
 - d) The study shall include 3-D renderings of the relevant CBTC equipment locker clearly showing the location of all of the CBTC equipment and all relevant tolerances.
 - e) The analysis shall be submitted to NYCT for approval. [CDRL]
- 14.3.7. The Contractor shall provide terminal blocks in, or adjacent to, the CBTC locker to provide connection points between the carborne CBTC equipment and the other car subsystems. Terminal blocks shall meet the requirements of Section 19.25.
- 14.3.8. The CBTC system supplier will supply a CBTC mounting rack. The Contractor shall install the CBTC mounting rack in the CBTC locker, and provide the cables and wiring between the CBTC mounting rack/CBTC modules and the terminal blocks. CBTC mounting rack details and air flow requirements are detailed in the R211 ICD.
- 14.3.9. The Contractor shall propose a new key design for the key that will be used to access the CBTC equipment locker. The new CBTC Key shall be used only for access to the CBTC lockers and shall also be used for SIR ATC locker access.
- 14.3.10. The new CBTC Key will not be used to access the CBTC Bypass Panel, which will continue to be accessed by the Master Door Controller key. The new CBTC Key design shall be submitted to NYCT for approval. [CDRL]

- 14.3.11. The following CBTC carborne equipment will be supplied by NYCT CPM to the Contractor for installation on each R211 Unit (The following list is an estimate of the equipment to be supplied based on previous CBTC projects. The final list may differ depending on the CBTC vendor and any CBTC design modifications):
- a) CBTC equipment mounting rack, which shall be installed in the CBTC Locker of each A1 and A2 Car.
 - b) On-Board Control Unit (OBCU), which shall be installed in the CBTC Locker in each A1 Car.
 - c) Input / Output module, which shall be installed in the CBTC Locker of each A1 Car.
 - d) Carborne Radio Equipment (CRE), which shall be installed in the CBTC Locker of each A1 and A2 Car.
 - e) CBTC Transponder Reader Board (TRB) module, which shall be installed in the CBTC Locker of each A1 Car.
 - f) Speed Detection Module, which shall be installed in the CBTC Locker of each A1 Car.
 - g) Accelerometers, which shall be installed in the CBTC Locker of each A1 Car.
 - h) Conductor Remote Display (CRD), which shall be mounted in proximity to the left side Master Door Control Panel in the cab of each A1 and A2 Car.
 - i) CBTC Radio Antennas, which shall be installed in the bonnet area above the cab of each A1 and A2 Car (one in each car).
 - j) Speed sensors/tachometers, which shall be mounted as described in Section 14.3.2.
 - k) CBTC Transponder Interrogator Antenna (TIA), which shall be mounted on the inside end of the No. 1 truck of each A1 Car.
 - l) Cable connectors (CBTC side supplied and installed by CBTC vendor. Carbody side connectors supplied by CBTC vendor and installed by the Contractor).
 - m) Appropriate circuit breakers shall be provided for the carborne CBTC equipment.
- 14.3.12. The following equipment shall be provided by the Contractor:
- a) CBTC Train Operator Display (TOD) as described in Section 5.4.3.
 - b) CBTC Cab Controls as described in Section 5, Cab and Cab Controls.
 - c) Communication Interface Unit (CIU), which shall be installed in the CBTC Locker of each A1 and A2 Car.
 - d) All required brackets and mounting hardware.
 - e) Interconnecting wires, cabling, conduits, and raceways.
 - f) Mechanical interface and mounting hardware for speed sensors.
 - g) Mechanical interface and mounting hardware for the TIA.
 - h) Terminal blocks.
 - i) Grounding and power supply close to CBTC equipment.
- 14.3.13. The Contractor shall be responsible for the integration and installation of the carborne CBTC equipment on the cars, including all required wiring, mounting hardware and interface equipment.
- 14.3.14. The carborne CBTC equipment shall be powered from the Low Voltage Distribution Network (LVDN).
- 14.3.15. The Contractor shall follow installation and system connectivity diagrams which will be provided by NYCT in order to support the reliability, redundancy and system architecture of the carborne CBTC system.

14.4. Interfaces with Other Car Equipment

14.4.1. General

- 14.4.1.1. The Contractor shall supply, install, and test all required interfaces between the carborne CBTC system and the car subsystems.
- 14.4.1.2. The R211 interfaces are detailed in the baseline R211 ICDs. The Contractor shall work in conjunction with the CBTC system supplier to finalize all interface requirements.
- 14.4.1.3. The Contractor shall supply, install, and test all cables, wires, junction boxes, conduit, raceways, etc. that are necessary to interconnect CBTC equipment and to connect CBTC equipment to car equipment, as approved by NYCT.
- 14.4.1.4. The Contractor shall provide approved wiring support and isolation for all CBTC wiring between CBTC components, between CBTC and other components, and between CBTC components and trainline couplers/jumpers.
- 14.4.1.5. Certain circuits require special provisions, such as shielding and physical isolation from other circuits, which shall be defined in the R211 ICDs. The Contractor shall conform to these requirements.
- 14.4.1.6. The carborne CBTC system is a safety critical system and all installation and wiring shall be in accordance with the corresponding requirements of the R211 ICDs.
- 14.4.1.7. For vital circuits, the car interface with the carborne CBTC equipment shall incorporate fail-safe design principles where required, in accordance with the R211 ICDs and Section 2.12.
- 14.4.1.8. The Contractor shall submit a detailed plan regarding the identification and manner of transmission of all control signals. This plan shall include a Preliminary Hazard Analysis, as defined by Section 21.3.4. All vital functions shall be analyzed and proven to be fail-safe. [CDRL]
- 14.4.1.9. The contractor shall supply and install network and discrete interfaces for CBTC functions that shall not be susceptible to Electromagnetic Interference (EMI) and noise in the car environment, as specified in Section 19, Materials, Processes, and Workmanship.
- 14.4.1.10. The Contractor shall provide grounding and bonding for the carborne CBTC equipment. The grounding and bonding design scheme will be provided by the CBTC system supplier.

14.4.2. Communication Interface Unit

- 14.4.2.1. The Contractor shall provide a CIU in the CBTC Locker of each A1 and A2 car. Alternate CIU arrangements may be presented to NYCT for approval.
- 14.4.2.2. The CIU shall route information between the CBTC Onboard Control Unit (OBCU) and the train's networks so that information may be exchanged between the OBCUs in a train, and between the OBCU and the train's subsystems.
- 14.4.2.3. The CIU shall contain two redundant units, connecting to the left side and right side train networks separately.
- 14.4.2.4. The interface between the onboard CBTC system and the CIU, including the transmission protocols, packet content, bandwidth, and timing requirements are detailed in the R211 ICD.
- 14.4.2.5. The CIU shall be powered from the Low Voltage Distribution Network (LVDN).

14.4.3. CBTC Cab Controls

14.4.3.1. The CBTC cab controls shall be provided in the cab as described in Section 5, Cab and Cab Controls:

- a) One 3- Position, maintained, "CBTC Mode" selector switch with the following positions:
 - Normal.
 - RM.
 - AWP.
- b) One 2-Position, maintained "CBTC Bypass" selector switch with the following positions:
 - CBTC.
 - Bypass.
- c) One 2-Position, maintained, "RM Release" selector switch with the following positions:
 - Normal.
 - Release.
- d) One "ATO Start" momentary pushbutton with green protective cover.
- e) One "Alerter" momentary pushbutton with integral orange indicator.

14.4.3.2. The Contractor shall provide an Alerter buzzer as described in Section 5.5.13.1.

14.4.3.3. The Alerter pushbutton shall input directly to the CBTC OBCU.

14.4.3.4. The Alerter buzzer shall be driven by the CBTC OBCU.

14.4.3.5. The Alerter pushbutton and buzzer functions shall only be active when the CBTC system indicates that the train is in ATO mode.

14.4.3.6. Cab controls shall perform their function in, and only in, the active cab.

14.4.3.7. The number and configuration of contacts for each cab control described in Section 14.4.4.1 is defined in the R211 ICDs.

14.4.3.8. The interfaces to the CBTC Mode selector switch, CBTC Bypass selector switch, and RM Release selector switch shall all be implemented in a vital manner as described in the R211 ICDs.

14.4.3.9. The CBTC Bypass selector switch and the RM Release selector switch shall be capable of being sealed in either position as described in Section 5.5.9.3.

14.4.4. Discrete Signal Interfaces

14.4.4.1. The carborne CBTC system shall interface to various trainline, unitline, and local signals.

14.4.4.2. The interface details between the discrete signals and the carborne CBTC system shall be initially based on the R211 ICDs, but shall be developed by the Contractor and the CBTC system supplier during the design of the R211.

14.4.5. CBTC TOD

14.4.5.1. The CBTC TOD shall be connected to the Train Networks (see Section 16.3.4) via the CIU.

14.4.5.2. In the event that the CBTC TOD becomes defective, a switch on the cab console shall allow the operator to switch the CBTC Display to the MDS TOD. The Operator shall be able to switch the CBTC TOD back to its normal connection, using the same console switch. Refer to Section 5.3.1.19 for details on the CBTC TOD Select selector switch.

14.4.5.3. The data rate to the CBTC TOD shall allow complete screen rewrites at least every 100 ms.

- 14.4.5.4. Local circuits shall identify to the carborne CBTC system whether the cab is active and whether door controls are activated. The onboard CBTC system will use this information to activate the CBTC TOD.
- 14.4.5.5. The CBTC TOD hardware is described in Section 5.4.
- 14.4.6. Trainline and Network Controller**
- 14.4.6.1. The Contractor shall supply, install, and test all signal connections between the carborne CBTC system, the cab controls, the CIU, and the Trainline and Network Controller (TLNC) to allow the carborne CBTC system to send and receive commands and status information to the car subsystems.
- 14.4.6.2. The data provided by the carborne CBTC System shall be used to control train operation and provide necessary information to the CBTC TOD and Monitoring and Diagnostic System (MDS) TOD.
- 14.4.6.3. The carborne CBTC system shall coordinate control of train operation in conjunction with the active cab’s TLNC.
- 14.4.6.4. The TLNC shall arbitrate between console commands and CBTC commands, and provide the appropriate commands to the trainlines. The design of the train subsystems and their arbitration functions shall be presented to NYCT for approval. **[CDRL]**
- 14.4.6.5. The carborne CBTC system provides commands to the TLNC such as power, coast, brake (encoder values), and Emergency Brake (Door Enable command is not done via TLNC).
- 14.4.6.6. The TLNC design shall be such that CBTC operation is transparent to all trainline controlled equipment.
- 14.4.6.7. The TLNC shall use inputs from the cab controls, and from the carborne CBTC System to select train operating modes.
- 14.4.6.8. The TLNC shall impose basic modes of train operation upon the train. These modes are distinguished by which equipment controls the traction systems, which performance curve (hot or cold) is enabled, and which equipment provides speed enforcement. Table 14-1 identifies the modes and the distinguishing factors.

Table 14-1: Train TLNC Modes

TLNC Mode	High Performance Enable Trainline	Propulsion & Brake Control	Performance Curve
Automatic	High	CBTC	Hot
Manual	High	Train Operator*	Hot
	Low	Train Operator*	Cold
CBTC Bypass	Low	Train Operator	Cold
Restricted Manual	Low	Train Operator	Cold
Other	Low	Train Operator	Cold

**Except that the carborne CBTC system shall command the removal of power and the application of brake.*

Note: The High Performance Curve shall be allowed only under CBTC supervision.

Note: "Other" TLNC Modes include "Idle", "Standby", "Special Charge", and "Emergency Brake".

Refer to the R211 ICDs for TLNC Mode details.

- 14.4.6.9. When the train is in RM Mode, the TLNC shall enforce an adjustable speed limit that both removes power and applies brakes using an approved tapered function of speed. The initial setting for the maximum speed limit in RM Mode shall be 10 mi/h (4.47 m/sec).
- 14.4.6.10. There shall be four additional individually adjustable speed limits, enforced by the propulsion systems of each car. These speed limits shall remove power when exceeded, limiting the train to Coast.

14.4.6.11. The relationship between the TLNC modes, the speed limit designation and the adjustable speed limits shall be as depicted in Table 14-2.

Table 14-2: TLNC Control Modes

TLNC Mode Received by Propulsion	High Performance Enable Trainline State	Speed Limit Designation	Initial Speed Limit Setting
Automatic	High	Automatic	55 mi/h
Manual	High	Manual Hot	55 mi/h
CBTC Bypass	Low	CBTC Bypass	50 mi/h
Any other combination of TLNC Mode and High Performance Enable Trainline state		Manual Cold	50 mi/h

14.4.6.12. The Contractor may submit alternate control schemes, complete with analysis of the alternate scheme for NYCT approval.

14.4.7. Network Interfaces

Dedicated CBTC Networks

14.4.7.1. Two dedicated, redundant networks shall be provided for CBTC communication:

- a) CBTC Train Network. Two trainlined networks shall be provided for the CBTC Train Network. The network data is exchanged between the OBCUs in a train and does not interface with any other car systems. The CBTC Train Network data shall be transmitted to the other Unit on the same train.
- b) CBTC Data Radio Network. Four network trainlines shall be provided for the CBTC Data Radio Network. Two shall be spare for future use. The network data is exchanged between the OBCUs in a train and does not interface with any other car system. This network shall be transmitted to the other unit independently from any other train networks. Grounding requirements for the network trainlines are detailed in the R211 ICD.

14.4.7.2. Specific network requirements are detailed in Section 16, Trainline and Network Architecture, and in the R211 ICDs.

Train Control Network Interface

14.4.7.3. The carborne CBTC system shall interface with the Train Control networks via the CIU to send and receive information regarding train status, Master Controller position, and propulsion/brake control commands between the CBTC system, the TLNC, and other train subsystems.

14.4.7.4. Specific requirements are detailed in Section 16 and in the R211 ICDs.

Monitoring and Diagnostic System Network Interface

14.4.7.5. The carborne CBTC system shall interface with the MDS Network via the CIU as described in the R211 ICDs.

14.4.7.6. The carborne CBTC system shall provide the information to the MDS as defined in Section 17.4.

14.4.7.7. The MDS shall allow the carborne CBTC system to interrogate for specific MDS status information and respond by sending MDS data back to the CBTC system. The MDS status information that is transmitted to the carborne CBTC system shall include, but is not limited to status and fault information on the following:

- a) Train consist.
- b) Brake in Emergency (BIE) related.
- c) Propulsion.
- d) Doors.

- e) Network.
- f) Circuit Breakers.
- g) Car subsystems.

Detailed requirements are included in the R211 ICD.

- 14.4.7.8. The carborne CBTC system shall provide the Automatic Train Supervision (ATS) time to the MDS to synchronize the MDS master clock (see Section 17.3.6).

Event Recorder

- 14.4.7.9. The carborne CBTC system shall provide the information defined in Section 17.5 to the Event Recorder as described in the R211 ICDs.

Passenger Information and Communication System Interface

- 14.4.7.10. The carborne CBTC system shall interface with the Passenger Information and Communication System as described in the R211 ICDs.
- 14.4.7.11. The CBTC system shall provide triggers to the Communications System and the MDS to play special messages (see Section 13.6.2.1 c) and 13.6.4.14) via the Public Address (PA) system and Ceiling Interior Information Sign.

14.4.8. Car Performance Interfaces

- 14.4.8.1. The Contractor shall provide performance information that is pertinent to the carborne CBTC design [**CDRL**].
- 14.4.8.2. The Contractor shall provide nominal, minimum and maximum characteristic data for, at minimum, the following:
- a) Complete tractive effort characteristics as a function of speed, load, and third rail voltage, for motoring and braking.
 - b) Response times from CBTC command change to tractive effort change.
 - c) Response time from CBTC command to Emergency Brake application.
 - d) Rate of tractive effort change under all conditions.
 - e) Transfer function from CBTC command to tractive effort output.
 - f) Wheel Spin/Slide System operational characteristics.
 - g) Failure Modes, Effects and Criticality Analysis (FMECA) for vital circuits.
 - h) Selected failure mode information for other circuits and systems.
 - i) Propulsion and Braking Test Data.
 - j) EMC characteristics.

- 14.4.8.3. The Contractor shall provide characteristic data for the minimum emergency brake rate. The minimum emergency brake rate is the minimum rate defined from the worst case adhesion and failure hypothesis.

14.4.9. Mechanical Interfaces

- 14.4.9.1. The mechanical interface details between the discrete signals and the carborne CBTC system shall be initially based on the R211 ICD, but shall be developed by the Contractor and the CBTC system supplier during the design of the R211.

14.5. Maintainability Requirements

- 14.5.1. All carborne CBTC system interfaces shall comply with the maintainability design requirements of Section 2.14.4.
- 14.5.2. The CIU shall comply with the maintainability design requirements of Section 2.14.4.

- 14.5.3. The CIU hardware shall comply with the requirements of Section 19, Materials, Processes and Workmanship.
- 14.5.4. The CIU software shall comply with the requirements of Section 18, Software Systems.
- 14.5.5. Training manuals, maintenance manuals, Portable Test Equipment (PTE) and Bench Test Equipment (BTE) shall be provided for the CIU as required in Section 22, System Support.

14.6. Validation Requirements

14.6.1. Testing

- 14.6.1.1. The Contractor shall validate all discrete and network interfaces between the train subsystems and the carborne CBTC system. The CBTC interface test procedure shall be submitted to NYCT for review and approval. The results of the interface tests shall be submitted to NYCT.
- 14.6.1.2. The CBTC interface testing shall be successfully completed before the Static and Dynamic CBTC PICO testing described in Section [14.6.1.6](#) can begin.
- 14.6.1.3. The CIU shall be validated to the requirements of Section 19.29.1.
- 14.6.1.4. The CIUs shall be included in the train network testing required in Section 16.6.
- 14.6.1.5. The Contractor shall provide the temperature and heat dissipation analysis for the CBTC locker as detailed in Section 14.3.6.
- 14.6.1.6. All R211 Units shall pass CBTC Static and Dynamic PICO testing at the Contractor's facility prior to shipment to NYCT.
- 14.6.1.7. Static and Dynamic PICO testing will be performed by the carborne CBTC system supplier.
- 14.6.1.8. The Contractor shall provide engineering support for the Static and Dynamic PICO testing.
- 14.6.1.9. Static and Dynamic PICO test plans and procedures will be provided by the CBTC system supplier.
- 14.6.1.10. The Dynamic PICO testing shall test the units in all modes of operation including ATO at speeds up to 10 mi/h (4.47 m/s).

14.6.2. Interface Control Documents

- 14.6.2.1. Baseline Mechanical, Electrical and Functional Interface Control Documents (ICDs) for the R211 are included in Appendix E-2. The ICDs shall serve as the baseline for the carborne CBTC interface design.
- 14.6.2.2. The Contractor, working together with NYCT and the CBTC system supplier, shall update the baseline ICD as needed to reflect the final R211 CBTC system design to provide a final R211 ICDs for review and approval by NYCT. R211 detailed design documents shall be added as appendices to the final R211 ICDs and identified and listed in the body of the final R211 ICDs. **[CDRL]**
- 14.6.2.3. The appendices of the final R211 ICDs shall contain details of the final configuration of all electrical and mechanical interfaces to the R211 car.
- 14.6.2.4. The appendices of the final R211 ICDs shall contain all details for the electrical interfaces including, but not limited to, the following details:
 - a) Performance requirements.
 - b) Voltage levels.
 - c) Current ratings.
 - d) Wiring requirements.
 - e) Network protocols.
 - f) Network packet definitions.
 - g) Network message transmission sequences and timing.
- 14.6.2.5. The appendices of the final R211 ICDs shall include as built drawings detailing all mechanical and electrical interfaces between the carborne CBTC system and the R211 car subsystems.

14.7. Deliverables

The following Contract Deliverables are defined in this Section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
14-01	14.1.6	Installation schedule and personnel estimate for the carborne CBTC equipment and test track installation	3 months from Notice to Proceed (NTP)
14-02	14.3.6	Study of available space and temperature/heat dissipation	PDR
14-03	14.3.10	New key design for CBTC locker	CDR
14-04	14.4.1.8	Preliminary Hazard Analysis for control signals	CDR
14-05	14.4.6.4	Design of the Train Network Controller interfaces with train subsystems and its arbitration functions	PDR
14-06	14.4.8.1	Car performance information pertinent to the CBTC system	PDR
14-07	14.6.2.2	Final R211 Interface Control Documents for CBTC	CDR

Attachment 14-A - R211 CBTC Responsibility Matrix

1. NYCT CPM will provide the carborne CBTC equipment to the R211 Contractor for installation on the R211 trains as shown in the table below.
2. NYCT CPM and the CBTC equipment supplier will provide technical and engineering support for the interface design and installation of CBTC equipment on the R211 Units as shown in the Table below.
3. The Contractor’s responsibilities are as shown, but not limited to, in the Table below (the following list is an estimation of the equipment to be supplied based on previous installations. The final list may differ slightly depending on the CBTC vendor and any CBTC design modifications):

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
1	CBTC CARBORNE EQUIPMENT		
a	CBTC Equipment Locker(s)	Design, supply and install	None
b	CBTC Mounting Rack(s)	Install	NYCT CPM and the CBTC supplier will design and supply the CBTC mounting rack(s)
c	CBTC Terminal Blocks(s)	Design, supply and install	None
d	Onboard Control Unit (OBCU)	All wiring and cables between the OBCU, the CBTC terminal blocks, and car subsystems shall be supplied, installed, and tested by the Contractor. All wires and cables between the OBCU and other CBTC modules shall be installed and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply the OBCU and all required software and databases. NYCT CPM and the CBTC supplier will supply all wires and cables between the OBCU and other CBTC modules.
e	Communications Interface Unit (CIU)	Design, supply and install All wiring and cables between the CIU, the CBTC terminal blocks, other CBTC modules, and car subsystems shall be supplied, installed, and tested by the Contractor.	None
f	Input/ Output Module	All wires and cables between the Input/ Output Module, the CBTC terminal blocks, and car subsystems shall be supplied, installed, and tested by the Contractor. All wires and cables between the Input/ Output Module and other CBTC modules shall be installed and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply the Input/Output Modules and all required software. NYCT CPM and the CBTC supplier will supply all wires and cables between the Input/ Output Module and other CBTC modules.

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
g	Transponder Reader Board (TRB) Module	<p>All wires and cables between TRB Module and the Transponder Antenna shall be supplied, installed, and tested by the Contractor.</p> <p>All wires and cables between the TRB Module and other CBTC modules shall be installed and tested by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the TRB Module and all required software.</p> <p>NYCT CPM and the CBTC supplier will supply all wires and cables between the TRB Module and other CBTC modules.</p> <p>Note: Some CBTC suppliers will incorporate the TRB in their OBCU</p>
h	Speed Detection Module	<p>All wires and cables between the speed sensors and the Speed Detection module, shall be supplied, installed, and tested by the Contractor.</p> <p>All wires and cables between the Speed Detection Module and other CBTC modules, the speed sensors, accelerometers, and the car subsystems shall be installed, and tested by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the Speed Detection Module and all required software.</p> <p>NYCT CPM and the CBTC supplier will supply all wires and cables between the Speed Detection Module and other CBTC modules.</p> <p>Note: Some CBTC suppliers will incorporate the Speed Detection Module in their OBCU</p>
i	Carborne Radio Equipment (CRE)	<p>All wires and cables between the CRE and the CBTC radio antennas, and car subsystems shall be supplied, installed, and tested by the Contractor.</p> <p>All wires and cables between the CRE and other CBTC modules shall be installed and tested by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the CRE and all required software.</p> <p>NYCT CPM and the CBTC supplier will supply all wires and cables between the CRE and other CBTC modules.</p>
j	CBTC Radio Antennas	All cables between the Radio Antennas and CRE shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply CBTC Radio Antennas.
k	Radio Antenna Mounting Bracket	Install.	NYCT CPM and the CBTC supplier will design and supply the radio antenna mounting bracket
l	Accelerometers	All cables between Accelerometers and other CBTC modules shall be installed and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply Accelerometers and all required mounting plates and mounting hardware.

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
			<p>NYCT CPM and the CBTC supplier will supply all cables between Accelerometers and other CBTC modules.</p> <p>NYCT CPM and the CBTC supplier will calibrate the Accelerometers.</p> <p>Note: Some CBTC suppliers will incorporate the accelerometers in their speed detection module</p>
m	Speed Sensors/Tachometers	<p>All cables between Speed Sensors/Tachometers and other CBTC modules shall be supplied, installed, and tested by the Contractor. Pigtail length and mechanical interface to be confirmed by the Contractor during detailed design.</p> <p>Mounting hardware for speed sensors shall be supplied and installed by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the speed sensors. Speed sensors will be supplied with a terminated pigtail cable.</p> <p>Note: Specific Speed Sensor/Tachometer design may vary between CBTC suppliers</p>
n	Transponder Interrogator Antenna (TIA)	<p>The TIA shall be installed by the Contractor.</p> <p>The TIA pigtail cable shall be installed by the Contractor.</p> <p>All cables between the TIA connection box and the TRB Module shall be supplied, installed, and tested by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the TIA with pigtail cable. Transponder antennas will be supplied with a 3 ft. long pigtail cable.</p>
o	CBTC Relays	<p>All wires and cables between the CBTC Relays, the CBTC terminal blocks, and car subsystems shall be supplied, installed, and tested by the Contractor.</p>	<p>NYCT CPM and the CBTC supplier will supply the CBTC relays.</p>
p	TIA Mounting Bracket	<p>Design, supply, install, and test.</p>	<p>None</p>
q	Network Cabling	<p>Design, supply, install and test including all terminations.</p>	<p>None</p>

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
r	Input/output Cabling	Design, supply, install and test including all terminations.	None
s	Radio Cabling	Supply, install and test including all terminations	NYCT CPM and the CBTC supplier will design the radio cabling.
t	Hangers, Conduit, Junction Boxes, Brackets & Mounting Hardware	Design, supply and Install.	None
u	Conductor's Remote Display (CRD)	All cables between the CRD and CIU shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply CRD.
v	Connectors	Install carbody side of cable connectors	Supply and install CBTC side of cable connectors. Supply carbody side of cable connectors.
2	CBTC WAYSIDE EQUIPMENT (FOR THE CONTRACTOR'S ON-SITE CBTC TEST TRACK TO FACILITATE THE DYNAMIC PICO TESTING)		
a	Zone Controller (ZC)	All wires and cables between the ZC and other CBTC systems shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply the ZC and all required software and databases. NYCT CPM and the CBTC supplier will safety certified all software and databases.
b	Data Communication System (DCS)	All wires and cables between the DCS and other CBTC systems shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply the DCS and all required software.
c	Wayside Radio Unit	All wires and cables between the Wayside Radio Unit and other CBTC systems shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply all required Wayside Radio Unit and all required software.
d	Wayside Radio Antennas	All wires and cables between the Wayside Radio Antennas and other CBTC systems shall be supplied, installed, and tested by the Contractor.	NYCT CPM and the CBTC supplier will supply all required Wayside Radio Antennas.

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
		Antenna masts provided by the Contractor.	NYCT CPM and the CBTC supplier will design the antenna masts.
e	Transponder Tags	Install Transponder Tags. Supply and install mounting brackets.	NYCT CPM and the CBTC supplier will supply all required Transponder Tags and all required programming.
f	Network Cabling	Supply, install and test including all terminations.	NYCT CPM and the CBTC supplier will provide the design requirements.
g	Input/output Cabling	Supply, install and test including all terminations.	NYCT CPM and the CBTC supplier will provide the design requirements.
h	Radio Cabling	Supply, install and test including all terminations.	NYCT CPM and the CBTC supplier will provide the design requirements.
i	Hangers, Conduit, Brackets, Duct Banks and Mounting Hardware	Design, supply and Install.	None
j	Grounding	Supply, install and test.	NYCT CPM and the CBTC supplier will provide the design requirements.
k	CBTC Equipment Maintenance	None	NYCT CPM and the CBTC supplier will provide the required maintenance for the CBTC test track equipment.
3	DESIGN ACTIVITIES		
a	System Design & Integration	The Contractor shall organize system design and integration activities with NYCT and the CBTC supplier. The Contractor shall incorporate all CBTC system design and integration documentation into the required R211 design documentation. These activities include but are not limited to, advising NYCT and the CBTC Supplier of the schedule	NYCT and the CBTC supplier will provide all required design and integration documentation to the Contractor. NYCT and the CBTC supplier will attend all CBTC related design and integration meetings.

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
		of review of interface design throughout the PDR and CDR process and the associated timing, so that the appropriate NYCT and CBTC Supplier personnel may be present at those meetings. The Contractor shall also advise NYCT and the CBTC Supplier of the required schedule for delivery of all onboard CBTC equipment to support its production schedule, as well as the schedule of the on-site work at the Contractor’s facility so that NYCT and CBTC Supplier personnel may be present to supervise installation of the onboard CBTC equipment and witness validation testing.	
b	Reliability, Availability, Maintainability (RAM)	The Contractor shall organize RAM activities with NYCT and the CBTC supplier. The Contractor shall incorporate all CBTC system RAM data into the required R211 design documentation.	NYCT and the CBTC supplier will provide all required RAM documentation to the Contractor. NYCT and the CBTC supplier will attend all CBTC related RAM meetings.
c	Installation Schedule	The Contractor shall provide NYCT with a schedule for the installation of the onboard CBTC equipment.	NYCT CPM and the CBTC supplier will review the schedule and coordinate the carborne CBTC equipment deliveries with the Contractor.
d	Labor Effort	The Contactor shall provide NYCT with a labor effort estimate for the installation for the carborne CBTC equipment.	NYCT CPM and the CBTC supplier will review the labor effort estimate and coordinate the CBTC installation training with the Contractor.
4	TESTING		
a	CBTC Interface Testing	Contractor shall validate all interfaces between the carborne CBTC system and other car subsystems. Contractor shall provide interface test procedure and interface test report.	NYCT CPM and the CBTC supplier will provide engineering support.

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT			
	Description	R211 Contractor	NYCT
b	Static Post Installation Check Out (PICO)Testing	Contractor shall provide engineering support.	NYCT CPM and the CBTC supplier will perform Static PICO testing on all R211 Units at the Contractor’s facility before delivery to NYCT.
c	Dynamic Post Installation Check Out (PICO)Testing	Contractor shall provide engineering support.	NYCT CPM and the CBTC supplier will perform Dynamic PICO testing on all R211 units at the Contractor’s facility before delivery to NYCT.
5	SAFETY CERTIFICATION		
a	CBTC Safety Certification	None	CBTC equipment, software and database Safety Certification will be done by NYCT CPM and the CBTC supplier.
6	TOOLS AND TRAINING		
a	First Train Installation	The Contractor shop personnel shall perform the installation of CBTC equipment on all Units. The first two Unit installations will serve as the training for the installation of CBTC equipment on the remainder of the R211 cars.	NYCT CPM and the CBTC supplier will support the Contractor for the installation of CBTC equipment on all Units. The installation on the first two R211 Units will serve as a training session for the Contractor’s personnel.
b	Radio Antenna VSWR test unit – Special Tool	The Contractor personnel shall be present as required for training.	NYCT CPM and the CBTC supplier will supply and train Contractor’s personnel.
c	Transponder Antenna Test Unit – Special Tool	The Contractor personnel shall be present as required for training.	NYCT CPM and the CBTC supplier will supply and train Contractor’s personnel.
d	Coax Cable Cleat – Special Tool	The Contractor personnel shall be present as required for training.	NYCT CPM and the CBTC supplier will supply and train Contractor’s personnel.
e	Coax Cable Crimper – Special Tool	The Contractor personnel shall be present as required for training.	NYCT CPM and the CBTC supplier will supply and train Contractor’s personnel.
f	Input/ Output Cable Crimper – Special Tool	The Contractor personnel shall be present as required for training.	NYCT CPM and the CBTC supplier will supply and train Contractor’s personnel.

Notes:

RESPONSIBILITY MATRIX FOR CBTC - R211 CONTRACTOR/ NYCT		
	Description	R211 Contractor
		NYCT

1. All CBTC delivered equipment to the Contractor shall be jointly inspected and accepted by both NYCT/CBTC supplier and the Contractor. The Contractor shall be responsible for any physical damage caused solely by the Contractor, outside of the known manufacturer’s defects, for all such CBTC equipment which are accepted by both NYCT/CBTC supplier and the Contractor. See Article 901B of the Contract Terms and Conditions
2. Tabulated information in the above Responsibility Matrix is provided as reference for Information Only.

Section 15

Carbody Equipment and Interiors

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15. Carbody Equipment and Interiors

15.1. Introduction and General Requirements

15.1.1. Introduction

- 15.1.1.1. This section defines the requirements for the interior and carbody mounted equipment of the R211 cars.
- 15.1.1.2. The design of the car interior shall be carefully coordinated through the Industrial Design activities described in Section 1.2.5, and the general arrangement and features shall be in conformance with the renderings described in Section 1.2.5.2.
- 15.1.1.3. Reference the following sections for car systems and components interfacing with the carbody equipment and interior:
 - a) Design and Performance Criteria – Section 2.
 - b) Carbody Structure – Section 3.
 - c) Cab and Cab Controls – Section 5.
 - d) Side Door System – Section 6.
 - e) Heating, Ventilation, and Air Conditioning – Section 7.
 - f) Lighting Systems – Section 8.
 - g) Auxiliary Electrical and Distribution – Section 9.
 - h) Communications – Section 13.
 - i) Materials, Processes, and Workmanship – Section 19.
 - j) Test Program – Section 24.

15.1.2. General Requirements

- 15.1.2.1. The car design shall comply with all requirements of the Americans with Disabilities Act (ADA), including 36 CFR 1192 (ADA Accessibility Guidelines for Transportation Vehicles) and 49 CFR 38 (ADA Accessibility Specifications for Transportation Vehicles).
- 15.1.2.2. All materials used in the construction of the carbody equipment and interiors shall comply with the flammability, smoke emissions, and toxicity requirements of Section 19.1.10.
- 15.1.2.3. All tamperproof fasteners shall be of pin-in-head TORX design. The Contractor shall minimize the total number of different tool sizes needed.

15.1.3. Accommodation for People with Disabilities

- 15.1.3.1. Accessibility to all cars for persons with disabilities, including persons who use wheelchairs, shall be provided through the side doors closest to the cab in each A Car.
- 15.1.3.2. Two wheelchair parking designated areas shall be provided in the A Car, close to the cab.
- 15.1.3.3. The wheelchair parking designated area shall be placed adjacent to the accessible entrance and shall have a minimum clear floor area of 30 inches (762 mm) by 48 inches (1,219 mm).
- 15.1.3.4. ADA-compliant signage shall be provided to identify priority seating designated by NYCT.

- 15.1.3.5. Pathways to the designated wheelchair area, through the car interior, and between all cars and Units shall be of sufficient width to permit a wheelchair to pass, as defined by the ADA.
- 15.1.3.6. Other accommodations are specified in Section 15.12.2 (Passenger Emergency Intercom), Section 13 (Communications) and Section 15.7 (Inter-car Barriers).

15.2. Insulation - Carbody

15.2.1. General

- 15.2.1.1. The car shall be thermally and acoustically insulated with approved materials to allow the completed cars to withstand the environmental conditions specified in Appendix A (Fixed Facilities Description), and to meet the noise and vibration requirements of Section 2.9 and the heating and cooling requirements specified in Section 7, Heating, Ventilation and Air Conditioning.
- 15.2.1.2. Insulation shall not mold, rot, or sustain vermin, and shall not have an odor or be capable of absorbing odors.
- 15.2.1.3. Insulation shall not corrode any metals used in the construction of the car, or settle (compact) under car vibration.
- 15.2.1.4. Urethane foam insulation shall not be acceptable for use anywhere in the construction of the car.
- 15.2.1.5. Combined thermo-acoustic insulation systems meeting the requirements of Sections 15.2.2, 15.2.3, 19.1.10, and 19.8 may be proposed by the Contractor for NYCT review and approval.

15.2.2. Thermal Insulation

- 15.2.2.1. Thermal insulation shall be installed throughout the roof, floor, side walls, and ends of the carbody.
- 15.2.2.2. Heat transfer through the carbody, using only the car floor-level heaters (or the radiant floor heating system, if used), shall not exceed 12 BTU/hour/°F (22.7 kJ/hour/°C) per foot (305 mm) of carbody length, under the environmental conditions specified in Appendix A (Fixed Facilities Description), with the car stationary.
- 15.2.2.3. Thermal insulation shall be installed such that it will not be compressed beyond the thickness required to provide the required insulation value, and such that it will not shake down in service during the full life of the car.
- 15.2.2.4. Thermal breaks shall be provided as follows:
 - a) Between main conditioned-air supply duct and roof structural members.
 - b) Between interior finish panels and any metal primary or secondary structural members that are thermally grounded to the outside surface of the carbody skin.
 - c) At any other location where it is necessary to interrupt a metal-to-metal path between the interior of the carbody and the outside of the carbody skin.
- 15.2.2.5. If fiberglass insulation is used, it shall be manufactured from long, textile-type or rotary-type glass fibers that are drawn from a calcium borosilicate mixture.
- 15.2.2.6. Fiberglass fibers shall be bonded together with a thermosetting phenolic resin. The thermosetting phenolic resin shall not exceed 6 percent by weight of the fiberglass insulation.
- 15.2.2.7. The fiberglass fibers used as thermal insulation shall be capable of performing to an upper temperature limit of 450°F (232°C).
- 15.2.2.8. See Sections 24.6.5 through 24.6.7 for climate room test requirements.

15.2.3. Acoustic Insulation

- 15.2.3.1. Vibration and sound damping material shall be applied to the inner surfaces of the structural shell, including sub-floor pans, ends, roof, and side frames, and on one side of air duct splitters (if used).
- 15.2.3.2. Vibration and sound damping material shall be resistant to alkalis, greases, gasoline, aliphatic oils, vermin, and dilute acids; shall be unaffected by sunlight or ozone; and shall not become brittle with age.
- 15.2.3.3. Vibration and sound damping materials shall allow the specified noise and vibration requirements of Section 2.9, as applicable, to be met.
- 15.2.3.4. Not used.
- 15.2.3.5. Not used.
- 15.2.3.6. A primer, if required, shall be applied in accordance with the recommendations of the manufacturer of the damping material.
- 15.2.3.7. The damping material shall be a spray-applied, water based, non-asphaltic, silica-free filled polymer in an emulsion form or an NYCT approved alternate material. Application shall be according to the supplier's recommendations, and as follows:
 - a) The inner surface of the car structural shell, except for the end underframe weldments, shall be coated with sound deadening compound. The inside surfaces of structural members shall be sprayed to the maximum extent possible.
 - b) The outside surfaces of the main air duct, any vertical underfloor equipment ventilation ducts that enter the carbody interior through the floor panels, and all other ventilation ducts shall be coated with sound deadening compound.
 - c) Duct splitters shall be coated on one side only.
 - d) The ceiling below the main air duct shall not be coated.

15.3. Floor Covering

15.3.1. Performance

- 15.3.1.1. The floor covering shall have a static coefficient of friction of not less than 0.6 when measured in accordance with ASTM D 2047, using leather and rubber shoe materials. Leather shoe material shall be in accordance with Federal Specification KK-L-165C. Rubber shoe material shall be in accordance with ASTM D 1630.
- 15.3.1.2. Before installing the floor covering, all voids, fastener heads, and gaps between the floor panels shall be filled, and the floor panel installation shall be made smooth and true within 0.063 inch (1.6 mm) in 3.3 feet (1 m) in any direction, using an approved fire-retardant leveling compound.

15.3.2. Design

- 15.3.2.1. The floor covering shall be transit grade smooth rubber, and shall be Noraplan or RCA Rubber terrazzo type flooring or NYCT approved equal.
- 15.3.2.2. The floor covering color and design of inserts shall be as shown on the renderings in Appendix E-1, and shall be approved by NYCT.
- 15.3.2.3. The coloring shall be uniform and shall be distributed completely through the material.
- 15.3.2.4. The color of the speckles will be determined during the Design Review process.
- 15.3.2.5. The floor covering shall be of an approved thickness.

- 15.3.2.6. Floor covering shall consist of long strips or floor tiles, as approved by NYCT.
- 15.3.2.7. The width of floor strips or size of tiles shall be maximized, consistent with the manufacturing process, and graphic design shown in Appendix E-1.

15.3.3. Installation

- 15.3.3.1. No more than three rows of floor covering shall be used, with the widest strip being installed down the center of the aisle.
- 15.3.3.2. At all door openings, the floor covering shall form a positively clamped, watertight seal with threshold plates or equivalent moldings.
- 15.3.3.3. The transition between threshold plate and the finished floor shall be covered by a kickplate.
- 15.3.3.4. The floor covering in the aisle shall be installed to allow replacement without disturbing the flooring under the passenger seats.
- 15.3.3.5. The floor covering shall be prepared and installed in accordance with the manufacturer's recommended practices and approved by NYCT, utilizing adhesive recommended by the floor covering manufacturer. Refer to Section 19.20 for adhesive data submission requirements.
- 15.3.3.6. Procedures for the floor covering installation and repair shall be provided to NYCT. [CDRL]
- 15.3.3.7. Where the floor covering reaches the carbody sidewalls, it shall be applied to the curved cove up to the bottom of the floor heat enclosure (if used) or the sidewall finish panel, where it shall be mechanically retained.
- 15.3.3.8. The cold welding of joints in the floor covering shall not be allowed.
- 15.3.3.9. Reference heat transfer requirements of Section 15.2.1.1 for radiant floor heating output (if used) and related floor covering design impact.

15.4. Door Panels (Side, Cab, Bi-Parting, Cab Storm)

15.4.1. General requirements

- 15.4.1.1. For side door panel requirements reference Section 6, Side Door System.
- 15.4.1.2. Door panels shall be designed and constructed to have a minimum service life of 40 years.
- 15.4.1.3. Installed door panels must be vibration and rattle-free while the train is underway and while opening or closing.
- 15.4.1.4. The door panel skin, structure, and mounting hardware shall sustain a concentrated load of 200 lb. (91 kg) applied perpendicularly to the plane of the door at the center of the front edge over an area not exceeding 16 square inches (10,323 mm²). The maximum load shall be applied for a minimum of five minutes and, upon removal of the load, the door shall exhibit no permanent set or delamination of the skin from the door panel.
- 15.4.1.5. The allowable maximum deflection under concentrated load conditions, with the door simply supported at the top and bottom, shall be limited to 0.375 inch (9.5 mm) with no permanent deformation following removal of the force.
- 15.4.1.6. The upper portion of each cab storm and bi-parting end door shall incorporate a fixed rectangular window as specified in Section 15.6.5.
- 15.4.1.7. One door panel of each type shall be tested to demonstrate compliance with the performance requirements of this section.

15.4.2. Construction

- 15.4.2.1. Door panels shall be constructed such that all hardware, windows, and glazing frames or strips are contained within the width of the door panel to allow the doors to operate freely without obstruction.
- 15.4.2.2. Any fasteners used to attach hardware to the door panel visible to passengers shall be countersunk.
- 15.4.2.3. All door panels shall be constructed solely of stainless steel and joined into an integral welded unit.
- 15.4.2.4. The door panel exterior skin shall be welded to a frame, and internal reinforcement of the door panel shall be provided by a stainless steel honeycomb core, or NYCT approved alternate material, bonded to the skin.
- 15.4.2.5. Window openings shall be blanked out of the inside and outside door skins with the edges formed inward.
- 15.4.2.6. Window cutouts shall have proper radii for glazing and glazing strips.
- 15.4.2.7. All edges and joints shall be thoroughly sealed to prevent the infiltration of moisture.
- 15.4.2.8. Internal cavities, in which condensation may form, shall be provided with appropriate drain holes.
- 15.4.2.9. The exterior and interior skins of the door panel shall have a finish identical to the adjacent exterior areas, or stainless steel as approved by NYCT, and shall be free of dimples, warping, welding depressions, and other deformities.
- 15.4.2.10. Stainless steel reinforcements shall be provided internally for the attachment of all door panel hardware.
- 15.4.2.11. The reinforcements shall be mechanically attached and shall be retained when door panel interface and mounting hardware is being changed.

15.4.3. Environmental Sealing

- 15.4.3.1. The cab storm and bi-parting end door panel(s) and doorways shall be adequately weather-stripped for service speeds up to 60 mi/h (97 km/h) with the worst case possible combination of climatic conditions as described in Appendix A (Fixed Facilities Description).
- 15.4.3.2. Weather seals shall prevent air, rain, and noise from entering the car body at the interface of the cab storm or bi-parting end door and its associated frame with the car traveling at 60 mi/h (97 km/h).
- 15.4.3.3. Cab storm and bi-parting end doors shall be equipped with a NYCT approved weather seal which shall be applied to edges of the doors as required to meet environmental sealing requirements.
- 15.4.3.4. The corners of the weather seal applied to all four edges of the cab storm door shall be continuous to ensure continuity of the seal.
- 15.4.3.5. A secondary weather seal shall be used at the interface of the bottom edge of the cab storm door to the threshold plate if necessary to meet sealing performance requirements.
- 15.4.3.6. Below the threshold plate there shall be a watertight channel member that shall collect the run-off from the end doors and drain it to the outside of the car.
- 15.4.3.7. Once the cab storm doors are closed and latched, the weather seal shall not inhibit door drainage.
- 15.4.3.8. Protective stainless steel plates shall be installed over the interior and exterior bi-parting end door pocket weather seals.
- 15.4.3.9. All elastomeric seals shall be applied in a manner which enables them to be easily replaced with the door panels in place.

15.4.4. Cab Storm Door

- 15.4.4.1. Each A Car shall be equipped with a manually-operated hinged door at the No. 1 End of the car between the collision posts.
- 15.4.4.2. The end door shall be hung on a one-piece stainless steel piano hinge having a stainless steel hinge pin. The ends of the door hinge shall prevent the hinge pin from sliding out of the hinge barrel.
- 15.4.4.3. The No. 1 end door wedge-type jam latches, and latch with an integral lock, shall secure the door to provide a weathertight seal at the front and rear of a train.
- 15.4.4.4. The lock and jam latch shall be operable from both sides of the door.
- 15.4.4.5. If, as determined by NYCT, the threshold plate of the cab storm door presents a tripping hazard, it shall incorporate a reflective material approved by NYCT.

15.4.5. Bi-Parting End Doors

- 15.4.5.1. Each end of the B Car and the No. 2 End of the A Car shall be equipped with a manually operated, lockable, bi-parting, sliding door. The end doors shall move in unison.
- 15.4.5.2. The design of the handle arrangement shall be a single handle design, and shall prevent the door handles of the bi-parting end doors from being secured together, using cable ties or similar methods.
- 15.4.5.3. The end doors shall be hung on co-axial low friction hangers with an enclosed bearing module, as manufactured by Hafco Foundry & Machine Co. Inc. or NYCT approved equal.
- 15.4.5.4. The design of the hangers shall be such that operationally applied lateral loads or door vertical loading shall not act to spread the door track.
- 15.4.5.5. Dual hangers, bolted to the door panel, are considered acceptable. Lightweight hangers are not acceptable.
- 15.4.5.6. The force required to move the doors in the opening direction shall not be less than 4.4 lb. (19.6 N) with the doors in the fully closed (but unlatched) position, and no more than 11 lb. (49 N) at mid-stroke.
- 15.4.5.7. A concealed closing device shall be provided for each sliding doorway, which shall exert sufficient force to hold the door against the weather-stripping.
- 15.4.5.8. The two door leaves shall be mechanically linked by the closing device and shall move in unison. See 15.4.5.1.
- 15.4.5.9. The gap between the end door pocket post and the door shall be designed to prevent injury while opening and closing the door.
- 15.4.5.10. The bi-parting end door design shall include a cushioning feature which shall prevent injury to an individual's hand caught between the closing doors.
- 15.4.5.11. Door panel leading edges shall be faced with deep interlocking (tongue-and-groove) nose rubbers that protect passengers from closing door panel impact.
- 15.4.5.12. Rubber edge interlocking shall not preload and shall provide environmental sealing in accordance with Section 15.4.3 when closed.
- 15.4.5.13. Should any equipment or electric lockers be located in the car end walls, the door arrangement shall include an automatic latch to prevent the end-doors from opening when the electric locker access door is open.
- 15.4.5.14. Bi-parting, sliding doors shall be readily removable.
- 15.4.5.15. Bi-parting, sliding door hangers shall not require lubrication.
- 15.4.5.16. Provisions shall be made for the vertical and transverse adjustment of the bi-parting, sliding door hangers.

15.4.5.17. Nose rubber edges shall be mounted on stainless steel channels, for easy mounting and removal without need to disconnect the door panels from the door hangers.

15.4.6. Cab Partition Door

15.4.6.1. A hinged, vandal resistant door shall be provided in the cab partition, which shall be capable of swinging into the passenger compartment to permit both rapid emergency egress from the cab and access into the cab, and swinging into the cab to permit egress through the cab and storm door (when permitted). The configuration shall be submitted for approval.

15.4.6.2. The cab partition door hinge and latch shall be supported by posts which are continuous from the top of the end sill to the roof.

15.4.6.3. A stop shall be provided in each direction of door travel to prevent the door from striking other structures or equipment.

15.4.6.4. The maximum gap between the closed door and the door frame and floor shall be 0.125 inch (3.2 mm).

15.4.6.5. A fixed window shall be provided in the cab partition door as described in Section 15.6.6.

15.4.6.6. The cab partition door shall be equipped with a full-length, stainless steel, piano hinge having a stainless steel hinge pin. The ends of the door hinge shall prevent the hinge pin from sliding out of the hinge barrel.

15.4.6.7. A handle shall be provided on the cab side of the cab partition door to facilitate opening the door inward towards the cab.

15.4.6.8. The door latch/lock shall be manufactured from nickel bronze or other NYCT approved material.

15.4.6.9. The configuration shall be submitted to NYCT for approval.

15.4.6.10. The cab partition door shall incorporate a third rail shoe paddle holder on the cab side with the capacity to hold five shoe paddles.

15.4.6.11. The cab partition door shall be equipped with a perforated grille in the lower portion to provide ventilation in accordance with Section 7.4.3.14.

15.4.6.12. The cab partition door shall be finished with an approved stainless steel wall on the interior side, and shall incorporate a stainless steel reinforcement beam near the bottom of the door to prevent damage due to vandalism.

15.4.6.13. It shall be possible to latch and lock the cab partition door in a position in line with the cab partition, closing off the entire full-width cab from the passenger area. A latch shall also be furnished to hold the door in either open position.

15.4.6.14. The cab partition door shall automatically latch and lock in the closed position. A key shall not be necessary to lock the cab partition door from inside the cab.

15.4.6.15. It shall be possible to unlock the cab partition door lock from the passenger side with NYCT's Standard Car Key.

15.4.6.16. Each cab partition door lock shall be equipped with a quick-release mechanism, operable only from within the cab, to enable the door to be opened without the use of a door key.

15.4.6.17. The cab partition door posts shall be capable of supporting the loads defined by Section 15.4.1.4 without permanent deformation.

15.4.7. Threshold Plates

15.4.7.1. Threshold plates shall be provided at all side and end doors.

- 15.4.7.2. The height of the side door threshold plate shall be 0.125 inch (3.2 mm) maximum above the top surface of the finished floor, with a maximum slope toward the outside of the car of 10 percent.
- 15.4.7.3. Threshold plates shall be of wear-resistant ductile cast iron with a surface of diamond pattern cross hatches in addition to an abrasive finish. Adhesive backed, non-skid "tape" or sheets are not permitted. Alternate threshold plate materials may be proposed for NYCT review and approval.
- 15.4.7.4. Threshold plates shall be designed and constructed to prevent the entry of water between the threshold plate and door, including entry of water when the car is subject to the horizontal spray jets of the car washing facility.
- 15.4.7.5. Threshold plates and guideways shall be self-cleaning to remove debris.
- 15.4.7.6. Threshold plates shall drain to the outside of the car.
- 15.4.7.7. The threshold plates shall provide support for the leading edge of the door when the door panels are being opened or closed.
- 15.4.7.8. The side door and bi-parting end door threshold plates shall incorporate guides for the sliding doors. The threshold plates shall extend sufficiently into the door pocket and align with the door pocket door guide.
- 15.4.7.9. Door guides in the threshold plate shall accommodate car body deflection as may occur between AW0 and AW3 loads, without resulting in door binding or escape from the guides.
- 15.4.7.10. There shall be no less than 0.25 inch (6.4 mm) engagement between door and threshold plate and no less than 0.125 inch (3.2 mm) clearance between door and threshold plate under all conditions of passenger loading.

Threshold Plate Heaters

- 15.4.7.11. Replaceable side door threshold plate heaters shall be provided to preclude the accumulation of ice and faulty operation of door panels due to freezing conditions. See Section 7.3.2.
- 15.4.7.12. The heaters shall be thermostatically controlled and powered from a 120 Vac, galvanically isolated source, or from the LVDN described in Section 9.4.17.

15.5. Locks and Keys

15.5.1. Locks

- 15.5.1.1. NYCT specified car keys shall be utilized to operate all locks and controls on the cars.
- 15.5.1.2. All car end doors shall be equipped with locks made of satin-finished nickel bronze or other approved material.
- 15.5.1.3. The locks shall be constructed so as to be draft proof.
- 15.5.1.4. The locks shall be able to lock and unlock, shall be spring loaded to automatically latch, and shall be able to be manually unlatched when not locked.
- 15.5.1.5. It shall be possible to unlock the car end doors using the NYCT Standard Car Key from the interior and exterior of the car.
- 15.5.1.6. Cab storm doors and cab partition doors shall incorporate an electrically-operated door lock release device, to unlock the doors. Unlock actuation will be controlled using a switch in the Operator's cab, see Section 5.5.7, and shall function as on the NYCT R188 Cars.

15.5.2. Keys

- 15.5.2.1. Two sets of each of the following type of key shall be provided with each A Car, except where noted otherwise:
- a) Master Controller (MC) Switch Key, required quantity 3,000 (see Section 5.6.4).
 - b) Master Door Controller Key (reference NYCT Commodity No. 19-44-1087), required quantity 3,000: This key will be used for the Master Door Control panel, overhead access panels for side doors, access panels for cutout cocks inside the car, the Passenger Emergency Handle Unit reset, access panel for the Parking Brake Handle, outside and inside crew key switches, cab electric lockers and low voltage circuit breaker panels, and all other locking functions not explicitly identified herein.
 - c) NYCT Standard Car Key (Crew Key - reference NYCT Commodity No. 41-33-2945): The standard car key will be used for all end door locks, the side door cutouts at the door posts, and the inter-car barrier storage compartment.
 - d) Maintenance Key: To open all ceiling panels, cab equipment lockers, and to activate Train Operating Display maintenance screens. The key shall be a 0.25 inch (6.4 mm) Allen key or NYCT approved alternate design.
 - e) Tamperproof pin-in-head TORX tool as described in Section 15.1.2.3.

15.6. Windows

15.6.1. General Requirements

- 15.6.1.1. Window design, construction and installation shall allow the completed cars to withstand the environmental conditions specified in Appendix A (Fixed Facilities Description), and to meet the noise and vibration requirements of Section 2.9 and the heating and cooling requirements specified in Section 7, Heating, Ventilation and Air Conditioning.
- 15.6.1.2. Windows shall be interchangeable with windows of the same size, and their size shall be maximized. The window arrangement and details shall be submitted for approval by NYCT.
- 15.6.1.3. All windows shall be of the single-glazed, fixed type, supported directly by the carbody structure using an approved fastening arrangement.
- 15.6.1.4. Glass shall meet the requirements of Section 19.7.
- 15.6.1.5. Windows may be tinted. The Contractor shall propose various degrees of tint for all glass applications for review and approval by NYCT.
- 15.6.1.6. All car window and windshield panes shall be secured in frames through the use of aluminum retainer strips, or as approved by NYCT.
- 15.6.1.7. The retainer strips shall be inserted into a slot in the frame and shall be secured with a vandal resistant mechanical fastener that penetrates through the retainer strip.
- 15.6.1.8. All sash frames shall have internally rounded corners, both inside and outside the car, to facilitate cleaning.
- 15.6.1.9. Windows shall be installed in the window opening using integral removable seals, without the use of a sealing compound.
- 15.6.1.10. Window seals shall be extruded from black neoprene rubber and shall be of the endless type, with joints formed by hot vulcanization.
- 15.6.1.11. The seals shall be designed specifically for this car, taking into account carbody skin thickness and the configuration of the window and its thickness.

- 15.6.1.12. The interior surfaces of passenger compartment windows shall be covered with a minimum of four layers of an optically clear, distortion-free polyester film manufactured by 3M or NYCT approved equal, installed such that they can be removed and replaced without removing the glass from the window frame or sealing rubber.
- 15.6.1.13. The window arrangement shall be approved by NYCT.
- 15.6.1.14. All window glass shall be readily removable and replaceable from within the passenger compartment without the use of sealing compounds.

15.6.2. Windshields

- 15.6.2.1. A one-piece windshield shall be provided for both the cab storm door window and the right side of the No. 1 End of the A Car.
- 15.6.2.2. The windshield laminate shall include a DuPont Type 307 spall shield, or NYCT approved equal, on the interior-facing surface.
- 15.6.2.3. Bonded-in-place windshields are not permitted unless all validation and maintainability criteria specified in the Specification are met and the design is approved by NYCT.
- 15.6.2.4. Windshield designs shall permit the required field of view as specified in Section 5.1.
- 15.6.2.5. Windshields shall be designed and installed to minimize external glare, as well as reflections from inside the car when being operated at night or in a tunnel with the passenger interior lighting illuminated.
- 15.6.2.6. Windshield installation shall be watertight without the use of any sealants, unless the bonded-in-place method is approved by NYCT.
- 15.6.2.7. Windshields shall be easily replaceable from outside the car.

Windshield Heater

- 15.6.2.8. The right side windshield shall incorporate an electric heating element embedded in the glass assembly for demisting/defogging purposes.
- 15.6.2.9. The heating element shall be applied to the maximum possible window area, consistent with the field of view requirements.
- 15.6.2.10. The windshield heater shall not introduce distortion when viewed from any angle.
- 15.6.2.11. The heating element shall be as transparent as possible.
- 15.6.2.12. The heating element shall prevent the accumulation of ice from freezing rain, snow, or mist under normal operating conditions. The windshield heater shall have the following performance:
 - a) It shall clear a 0.03 inch (0.8 mm) layer of ice from the windshield in 20 minutes or less under the winter conditions specified in Section 7.2.
 - b) It shall clear a minimum of 75 percent of the windshield surface area visible from inside the cab, with the un-cleared area limited to a 2 inch (50.8 mm) band around the perimeter of the windshield.
 - c) It shall be protected against over-temperature. Heated windshield controls are detailed in Section 5.7.10.
- 15.6.2.13. During the climate room testing described in Section 24.6.8, the heated windshield shall be tested to confirm compliance with the requirements of this Section, including the overheat protection function.

15.6.3. Side and Door Windows

- 15.6.3.1. The side windows and door windows in the passenger compartment shall utilize clear, laminated safety glass.
- 15.6.3.2. Side windows and all door windows shall meet the requirements contained within Appendix C-19 (NYCT Specification 3063-MATL-98, "Specification for the Supply of FRA II Laminated Safety Glass for the New Rail Car Passenger Window").
- 15.6.3.3. The passenger compartment side windows located between side entrance doors shall be full-frame, split-vent style, except in locations where a side destination sign is installed.
- 15.6.3.4. Side windows in which a Side Destination Sign (SDS) is installed shall be of the split type.
- 15.6.3.5. Below the split vent, the glazing material shall be installed directly into an extruded aluminum frame.
- 15.6.3.6. In the split vent, the glazing material shall be installed within an NYCT approved, vandal resistant extruded aluminum frame.
- 15.6.3.7. The vent windows shall be equipped with two approved manual locks incorporating stainless steel wear surfaces.
- 15.6.3.8. The split vent shall be inwardly hinged to allow passengers to open the vent for additional ventilation.
- 15.6.3.9. Movement of the split vent window shall be restricted by stainless steel hold-open retainers at the sides. Retainer design shall be submitted for NYCT review and approval.
- 15.6.3.10. Side windows in which a SDS is installed shall be configured to allow replacement of the lower portion without removing the SDS.

15.6.4. Cab Side Windows

- 15.6.4.1. The left and right side windows in the cab shall be a single glazed, two-piece, vertical sliding type.
- 15.6.4.2. The bottom window panel shall be fixed, and the upper window panel shall freely slide up and down.
- 15.6.4.3. With the upper window panel in the fully lowered position, the opening shall provide sufficient clearance for a 5th percentile female and a 95th percentile male operator (as defined in "The Measure of Man and Woman: Human Factors in Design, Revised Edition", Wiley, 2010) to lean out and observe the side of the train, operate yard switches, or operate route selectors.
- 15.6.4.4. The window assembly shall incorporate a counter-balance system to allow the upper window panel to be retained in any position from fully-open to fully-closed during normal operating conditions. Alternative means of achieving incremental open/closed positions may be submitted for NYCT approval.
- 15.6.4.5. The sliding portion of the sash shall be designed to slide freely in either the open or closed direction and to maintain any derived opening during normal operating conditions.
- 15.6.4.6. The force required to move the upper window from any position shall not exceed 10 lb. (45 N).
- 15.6.4.7. A latch, operable from the inside of the cab only, shall be provided on the window to hold the window closed.
- 15.6.4.8. The window shall also be closable from the exterior of the car.
- 15.6.4.9. Window track drains shall allow water to drain to the outside of the car.
- 15.6.4.10. The side window glazing shall be clear, laminated safety glass that meets the requirements of Section 19.7.
- 15.6.4.11. Right side windows shall be equipped with an approved DuPont Mylar, or NYCT approved equal, film to reduce the glare on the Train Operator's Display screens.

- 15.6.4.12. The windows shall be effectively weather-stripped, reinforced for a rugged railway environment, and designed and manufactured to eliminate rattling.
- 15.6.4.13. Weather stripping shall be easily removable and replaceable, and shall not require replacement over a minimum of two SMS cycles (14 years).
- 15.6.4.14. The window frame shall be satin-finished anodized aluminum.
- 15.6.4.15. The window latch engaging and rubbing surfaces and corresponding keeper shall be of stainless steel. Alternate materials may be proposed for NYCT review and approval.
- 15.6.4.16. Grab handles shall be installed adjacent to the cab side window, similar to those on the R160 car class. Reference Sections 15.8.3.5 and 15.8.3.6 for grab handle requirements.
- 15.6.4.17. The cab side window, including operation and maintenance activities, shall be reviewed and approved by NYCT during the evaluation of the mock-up as described in Section 20.6.1.
- 15.6.4.18. The cab side window shall be designed to be easily replaceable and repairable from the inside.
- 15.6.4.19. Working components shall be interchangeable on all cab windows.

15.6.5. Cab Storm Door and Bi-Parting End Door Windows

- 15.6.5.1. Windows shall be provided on each side of the bi-parting end doors, and in the cab storm and bi-parting end doors themselves (see Section 15.4.1.6).
- 15.6.5.2. Windows shall be clear, vandal resistant, laminated safety glass, maximizing clear viewing between cars.
- 15.6.5.3. The top and bottom of each end window shall align with the other end facing windows, and the windows shall be as wide as practicable.

15.6.6. Cab Partition Door Window

- 15.6.6.1. The cab partition door shall be equipped with a single-glazed, laminated safety glass window, which shall incorporate a polarized, zero transmission, black louvered, light controlled film with the louvers oriented vertically, applied on the cab interior facing surface of the window.
- 15.6.6.2. The light control film shall cover the complete cab partition door window and shall prevent reflections on the cab windshield when the passenger compartment lights are illuminated and the car is either in a tunnel or outside at night.
- 15.6.6.3. The light control film design documentation shall be of sufficient detail allow for the sourcing of equivalent material from multiple sources. See Section 19.1.6.7.

Validation

- 15.6.6.4. Maintainability shall be reviewed and approved by NYCT during the evaluation of the Contractor's mock-up (see Section 20.6.1).
- 15.6.6.5. Two windows of each type, selected from a production lot at random by NYCT, shall be tested to demonstrate compliance with the following requirements:
 - a) All windshields and storm door windows, and their frames and glazing strips, attachment hardware, and the carbody elements that directly support the windows shall meet the FRA Type I impact and ballistics requirements.
 - b) All other end facing windows, side facing windows, including bi-parting end door windows, attachment hardware and carbody elements that directly support the windows shall meet the FRA Type II impact and ballistics requirements.

- c) All FRA Type I and II requirements shall be demonstrated by test on the complete window assembly.
- d) The carbody elements are defined as side walls, end and side doors, end frames, and end bonnets. For doors, attachment hardware includes hinges, locks, hangers, and lower guides.
- e) The Contractor may demonstrate the ability of the car body elements to resist the loads developed from the FRA type I and II requirements by testing in conjunction with the window, in separate tests, or by analysis, as approved by NYCT.

15.6.6.6. The Contractor shall demonstrate through the use of the Contractor's mock-up (see Section 20.6.1), that the windshield design and installation minimizes external glare, as well as reflections from inside the car when operated at night or in the tunnel with the passenger interior lighting illuminated.

15.7. Inter-Car Barriers

15.7.1. Functional Requirements

- 15.7.1.1. An inter-car barrier system shall be provided on each side of the car end doors to protect individuals while passing from car to car or Unit to Unit, independent of car speed and relative alignment.
- 15.7.1.2. An inter-car barrier system shall also be provided at each corner of the carbody to warn, deter, and protect individuals from inadvertently walking off the station platform between cars. This system shall also discourage passengers from attempting to enter the car ends directly from the platform.
- 15.7.1.3. Inter-car barrier designs adjacent to the bi-parting end doors shall be stable and easy to grab while considering the effects of carbody motion.
- 15.7.1.4. Open areas between the cars shall be minimized by the inter-car barrier systems while still allowing for access of the train crew to the wayside from between cars, via the bi-parting end doors.
- 15.7.1.5. The overall inter-car gap design shall minimize both the open area/gaps between cars and tripping hazards in the "walkway" between car bi-parting end doors.
- 15.7.1.6. The barrier systems shall be designed to permit coupled cars to negotiate all conditions of vertical and horizontal curvature, turnouts, and crossovers encountered in the NYCT system (reference Appendix A (Fixed Facilities Description)).
- 15.7.1.7. When Units are uncoupled, the inter-car barriers of each A Car shall be returned to a stored and secured position within an approved enclosure on the No. 1 End. The storage method shall not inadvertently open and shall prevent damage to the barrier equipment and the No. 1 End of the carbody during normal car movements.
- 15.7.1.8. Inter-car barriers on A Car No. 1 ends, and all inter-car barriers adjacent to bi-parting end doors, shall be easily separated (locks shall be provided to prevent unauthorized detachment) while the cars are standing on any track configuration from tangent to the minimum radius curve (see Appendix A (Fixed Facilities Description)).
- 15.7.1.9. The aesthetic appearance of the A Car No. 1 end barriers is important, and these should be as unobtrusive as possible when not deployed. The Contractor shall propose alternate designs to those described in Section 15.7.2 for NYCT review.
- 15.7.1.10. If non-cab end car corner barriers are of semi-permanently attached design, a quick disconnect arrangement shall be provided, as approved by NYCT.
- 15.7.1.11. The end barrier design shall not cause entanglement of car washer bristles during washing.
- 15.7.1.12. The Contractor shall present alternatives to the current NYCT inter-car barrier systems during Preliminary Design Review (PDR).

15.7.1.13. The Contractor shall demonstrate the effectiveness, storage, and deployment of barriers on the Contractor's mock-up, reference Section 20.6.1.

15.7.2. Design Requirements

15.7.2.1. All metallic parts of inter-car barriers, and associated hardware shall be constructed of stainless steel.

15.7.2.2. The outboard end barrier assembly between cars shall be the NYCT standard "bologna spring" arrangement with a vertical chain to link the lower and middle spring at the midpoint of the span. Alternate designs may be submitted for NYCT review and approval.

15.7.2.3. For the barriers adjacent to the end doors, removable safety chains similar to the R160 car class (see drawings R160-15063 through R160-15077, in Appendix D-22) have proven successful in the NYCT operating environment. Alternate designs may be submitted for NYCT review and approval.

15.8. Safety Appliances

15.8.1. General Requirements

15.8.1.1. All safety appliances such as climbing steps, grab handles, and walkways shall meet the requirements for support of carbody-mounted equipment, as defined in Section 3.2.14, in addition to the requirements below.

15.8.1.2. Grab handles and their attachment to the carbody shall be designed to withstand, without permanent deformation, a load of 330 lb. (1,468 N) applied in any direction at the midpoint of the grab handle's free span.

15.8.1.3. All safety appliances, including physical space surrounding the appliances, between cars etc. shall accommodate a 5th percentile female and a 95th percentile male operator (as defined in "The Measure of Man and Woman: Human Factors in Design, Revised Edition", Wiley, 2010).

15.8.2. Steps

15.8.2.1. Stainless steel, two-step climbing steps shall be provided at each end of the car to enable entry to the car through the end doors from the roadbed.

15.8.2.2. The steps shall have an 8 inch (203 mm) clear depth and height.

15.8.2.3. The step tread surface shall be slip resistant. Adhesive backed non-skid tape or sheets are not permitted.

15.8.2.4. The steps shall support the load of a 300 lb. (136 kg) crew member with a safety factor of 1.5 against yield.

15.8.2.5. The first step shall be 20 inches (508 mm) above the top of the rail. The second step shall be 10 inches (254 mm) above the top of the first step.

15.8.2.6. The steps shall be within the clearances specified in Appendix D-1 (Memorandum of Understanding Car and Line Equipment Clearances MISC #00-01).

15.8.3. Grab handles

15.8.3.1. Grab handles shall facilitate the entry of personnel into the car from the roadbed.

15.8.3.2. Stainless steel grab handles shall be fastened to the outer face of the car end to facilitate access from the roadbed using the steps defined in Section 15.8.2.

15.8.3.3. The grab handles shall be designed so as to not detract from the cosmetic appeal of the ends of the car.

- 15.8.3.4. The grab handles shall be within the clearances specified in Appendix D-1 (Memorandum of Understanding Car and Line Equipment Clearances MISC #00-01).
- 15.8.3.5. Grab handles shall be a minimum of 0.625 inch (15.9 mm) in diameter.
- 15.8.3.6. A minimum clearance of 2 inches (50.8 mm) shall be provided between each grab handle and any part of the carbody, including doors and latch handles.

15.9. Interior Linings/Panels

15.9.1. Design

- 15.9.1.1. The interior of the car shall be pleasing in appearance, shall be modular in design, and shall be free of sharp corners or edges to eliminate the possibility of injury to passengers, operating personnel and maintenance personnel in either normal usage or emergencies.
- 15.9.1.2. The interior design shall emphasize the integration of components, maintainability, passenger safety, aesthetics, and clean ability.
- 15.9.1.3. Surfaces requiring paint are not permitted.
- 15.9.1.4. Interior linings/panels shall be lightweight, shall be vandal resistant (impact, graffiti, etc.), non-glare, and shall have a proven record in rail transit service.
- 15.9.1.5. The texture and color of linings/panels shall be unaffected by common liquids with which they may come into contact, such as coffee, soda, fruit juices, nail varnish, acetone, etc.
- 15.9.1.6. Also, the linings/panels shall be unaffected by aerosol paints and felt tip pens, and by the cleaning agents used to remove their effects.
- 15.9.1.7. The interior finish linings/panels shall not fade nor discolor over time.
- 15.9.1.8. Glass Reinforced Plastic (GRP) linings/panels shall be covered with DuPont Tedlar® polyvinyl fluoride laminate, or NYCT approved equal to provide an anti-graffiti finish, and shall be Schneller GT series, or NYCT approved equal.
- 15.9.1.9. The Contractor shall provide samples of the materials to be used for NYCT's approval. [CDRL]
- 15.9.1.10. All interior linings/panels shall be approved by NYCT.
- 15.9.1.11. Melamine-faced aluminum linings/panels shall be constructed in accordance with the requirements of Section 19.10.
- 15.9.1.12. Melamine-faced plymetal linings/panels shall be constructed using aluminum sheet, unless specified as stainless steel, and the melamine shall be laminated to the metal sheet in accordance with Section 19.10.7 prior to laminating the metal sheet to the core.

15.9.2. Performance

- 15.9.2.1. A centrally applied load of 50 lb. (222 N) on a contact area of not more than 4 square inches (2,581 mm²) shall not deflect a lining/panel more than 1 percent of the short span length.
- 15.9.2.2. A uniform pressure of 30 lb./ft² (1.44 kPa) shall not deflect a lining/panel more than 1 percent of the short span.
- 15.9.2.3. Linings/panels shall be capable of withstanding 20 ft.-lb. (27 J) of impact energy applied uniformly over an area of 2 square inches (1,290 mm²) without permanent deformation or cracking.
- 15.9.2.4. Lining/panel mountings shall be designed to accommodate the dynamics of car movement without transmitting undue stress to the liners.

- 15.9.2.5. The interior linings/panels and moldings shall be free of all undulations, and the maximum permitted variation from a designed contour on all interior surfaces shall be 0.125 inch (3.2 mm) over 3.3 feet (1 m) in any direction.

15.9.3. Installation

- 15.9.3.1. Interior linings/panels shall be applied and mechanically fastened to their supporting surfaces.
- 15.9.3.2. Exposed fasteners will not be permitted, unless specified or approved for a specific application.
- 15.9.3.3. "Anti-squeak" tape shall be used between linings/panels and any structure to which they are attached or with which they come into contact.
- 15.9.3.4. Interior linings/panels shall be designed to have a radius cove at intersecting adjacent surfaces to facilitate cleaning.
- 15.9.3.5. The design and layout of the interior linings/panels shall minimize the size and number of seams and moldings.
- 15.9.3.6. If threaded fasteners are inserted into the lining/panels, nut inserts must be used.
- 15.9.3.7. Lighting fixtures shall be supported from the car structure and not the linings/panels.

15.9.4. Finish

- 15.9.4.1. The color scheme for the interior shall be as shown in Appendix E-1.
- 15.9.4.2. Samples of all colors, patterns and finishes used in the interior of the car shall be approved by NYCT. **[CDRL]**
- 15.9.4.3. Embossed pattern textured stainless steel shall be used on interior panels as noted in Sections 15.9.5.5 and 15.9.5.9.
- 15.9.4.4. All other exposed stainless steel, except for floor moldings, side doors, bi-parting end doors, cab doors and cab storm doors, shall be given a 180 grit finish using a belt sander or NYCT approved equal.
- 15.9.4.5. The finish for the side doors, bi-parting end doors, cab doors and cab storm doors shall be proposed by the Contractor and shall be optimized for appearance and minimal surface dirt retention, and the grain direction shall be arranged to suit the decorative scheme.
- 15.9.4.6. The Contractor shall submit to NYCT at least three different samples of each of the finishes to be applied to interior trim and to interior sheets, demonstrating the range of surface finish of a worn, partially worn, and a new belt. **[CDRL]**
- 15.9.4.7. All interior stainless steel panels shall undergo a chemical passivation treatment to ensure no incidence of rust formation.
- 15.9.4.8. The efficacy of the chemical passivation treatment of stainless steel interior panels shall be verified by testing performed per ASTM A967 Practice "A" High Humidity Testing or Practice "C" - Salt Spraying.
- 15.9.4.9. All melamine surfaces shall have a low-glare finish with a gloss meter reading between 4 and 14, per ASTM D 523, machine direction, using a 60 degree glossometer.
- 15.9.4.10. All composite surfaces on the ceiling shall be low-gloss and all composite surfaces on the side and end walls shall have a high-gloss finish with a minimum gloss meter reading of 85 degrees, per ASTM D 523, machine direction, using a 60 degree gloss meter with no appreciable orange peel or print-through.
- 15.9.4.11. Except for melamine, powder coated parts, and Glass Reinforced Plastic (GRP), the color shall extend all the way through all lining/panel materials.

- 15.9.4.12. Interior lining/panel finishes shall be readily cleaned using NYCT's standard cleaning practices contained within Appendix C-3 ("Cleaners and Other Products Approved for Use on Railcars and Railcar Parts).

15.9.5. Side and End Wall Linings/Panels

- 15.9.5.1. Side linings/panels below the window masks and above the floor heater grilles (wainscot) shall be melamine faced panels, or as otherwise approved.
- 15.9.5.2. End linings/panels below the window masks (wainscot) shall be covered with integrally colored, unbalanced Fire Retardant (FR) grade melamine, or as otherwise approved.
- 15.9.5.3. The number of joints in the wainscot panels shall be minimized, and shall be hidden from view by the passenger seats.
- 15.9.5.4. Corner joints between linings/panels shall have a radius to facilitate cleaning and prevent pointed edges.
- 15.9.5.5. The interior side and end finish above the wainscot panels at all side windows shall be constructed of GRP panels with recessed flush-mounted, embossed textured pattern stainless steel inserts, or NYCT approved equal.
- 15.9.5.6. The fastening method and number of linings/panels per window shall be approved by NYCT.
- 15.9.5.7. The window masks shall be sloped to eliminate dirt collection.
- 15.9.5.8. All joints shall be supported and covered with moldings.
- 15.9.5.9. Interior end linings/panels shall be faced with recessed and embossed textured patterned stainless steel or NYCT approved equal.
- 15.9.5.10. The side linings/panels at the door pockets shall be melamine-faced panels with a plymetal, stainless steel honeycomb, or NYCT approved equal, core.
- 15.9.5.11. Consideration will be given to a modular construction of the door pocket, window mask and curved ceiling panel if the Contractor can provide a panel with a surface that is cleanable, and resistant to marking and scratching.
- 15.9.5.12. The colors of moldings on all exposed surfaces shall be compatible with the colors of the other materials in the car.

15.9.6. Cab Partition

- 15.9.6.1. The Train Operator's cab shall be located at the No. 1 End of the A Car.
- 15.9.6.2. The cab shall be full width and fully enclosed to prevent unauthorized access.
- 15.9.6.3. The enclosure shall be designed so that the Train Operator's forward view is not obstructed.
- 15.9.6.4. A hinged, vandal resistant, single leaf door shall provide access to the cab from the passenger area, as described in Section 15.4.6.
- 15.9.6.5. The cab partition shall be enclosed by a panel constructed from a rigid, durable, mar-resistant material such as melamine-faced plymetal, melamine-faced stainless steel honeycomb, or NYCT approved equal.
- 15.9.6.6. A window, as described in Section 15.6.6, shall be provided in the partition door to permit viewing into the passenger area.
- 15.9.6.7. The partition shall be attached to the car structure, not to wall panels or ceiling panels.
- 15.9.6.8. The cab partition may include electric lockers, if required, and shall complement the appearance of the interior lining of the side walls.

15.9.7. Moldings

- 15.9.7.1. The use of moldings is to be minimized; however, where necessary, moldings shall be used to cover all joints.
- 15.9.7.2. Snap-on, H-Type, plastic inserts, or other approved types of molding having no exposed fasteners shall be used.
- 15.9.7.3. Moldings shall be hard-surfaced plastic, plastic-coated aluminum or steel, or powder coated aluminum or steel, in a color and gloss matching the adjacent lining/panel.
- 15.9.7.4. Moldings shall be mechanically attached to the interior linings/panels.

15.9.8. Ceiling Panels

- 15.9.8.1. The portion of the ceiling between air diffusers shall be constructed of integrally colored, melamine-faced panels with an aluminum honeycomb core, or NYCT approved equal.
- 15.9.8.2. Transverse joints shall be spaced no closer than 4 inches (102 mm).
- 15.9.8.3. The curved ceiling panels, outboard of the light fixtures and door transoms, shall be constructed of integrally colored melamine-faced aluminum, powder coated aluminum, molded GRP, or NYCT approved equal.
- 15.9.8.4. Alternatively, the curved ceiling panels may be formed by extensions of the window masks or door pocket panels.
- 15.9.8.5. Curved ceiling panels shall be designed to support Flexible Ceiling Strip Displays (FCSD). Should NYCT decide to not use FCSDs, provisions shall be made to use standard rectangular advertising cards (see Section 15.12.1).
- 15.9.8.6. The low ceiling panels under the overhead HVAC units shall be comprised of the minimum number of components consistent with the need for access to equipment.
- 15.9.8.7. Longitudinal joints in the low ceiling area are permissible only at light fixtures.
- 15.9.8.8. Spring safety clips shall be applied to access panels allowing the access panels to open a minimum of 2 inches (51 mm) before the clips engage the frame of the access opening.
- 15.9.8.9. All ceiling panels and air diffusers shall be adequately supported by hangers to prevent sagging and drumming, with hangers spaced no greater than 40 inches (1,016 mm) apart.
- 15.9.8.10. The hangers shall be secured to the roof structure either by welding or by an NYCT approved mechanical fastening arrangement.
- 15.9.8.11. Panels or grilles under the overhead HVAC units, for access to and removal of the apparatus, shall be hinged longitudinally and equipped with jacketed safety chains and spring clips.
- 15.9.8.12. Access panels shall be provided to ensure ready access to equipment, such as door panels and door tracks, for inspection, service, and repair.
- 15.9.8.13. Exposed, but inconspicuous, approved quick-release fasteners shall be used for regularly required access to side door operator and control equipment, and HVAC filters.
- 15.9.8.14. Where linings/panels cover apparatus requiring replacement, or even infrequent maintenance, they shall be fastened with captive, tamperproof machine screws, designed to allow ready access for removal and replacement of such apparatus.

15.9.9. Floor Heater Grilles

- 15.9.9.1. Floor heater grilles shall be fabricated of rigidized stainless steel, suitably perforated to facilitate air flow over the heater elements, and rigidly supported.
- 15.9.9.2. Floor heater grilles shall be designed to prevent the collection of any materials on its outer surface and to prevent litter and debris from entering the heating element side of the grille from any side (no gaps).
- 15.9.9.3. The grilles shall be secured at all edges with accessible fasteners.
- 15.9.9.4. Heater element access shall determine the panel length and attachment method.
- 15.9.9.5. Heater grilles shall conform to the requirements of Section 7.3.2.
- 15.9.9.6. Perforation size and shape shall preclude insertion of ballpoint pen-size instruments.
- 15.9.9.7. Material shall be of sufficient thickness to resist denting as a result of kicking impacts.

15.10. Passenger Seats

15.10.1. Design

- 15.10.1.1. The arrangement and color scheme for the seats shall be as shown in Appendix E-1.
- 15.10.1.2. Passenger seats shall be installed longitudinally along the sides of the car, and shall be cantilevered from the carbody side structure, with no support from the carbody floor structure. Alternate seat design and arrangement configurations may be proposed by the Contractor for review and approval by NYCT.
- 15.10.1.3. Passenger seats shall be modular in design and shall be free of sharp corners or edges to eliminate the possibility of injury to passengers, operating personnel and maintenance personnel in either normal usage or emergencies.
- 15.10.1.4. The passenger seat design shall emphasize the integration of components, maintainability, passenger safety and circulation, aesthetics, and clean ability.
- 15.10.1.5. The passenger seats shall be manufactured in appropriate groupings, and the maximum gap between seats shall not be greater than 0.0625 inch (1.59 mm).
- 15.10.1.6. Passenger seats shall be interchangeable with like seats.
- 15.10.1.7. Passenger seats shall meet the material and strength requirements of Section 15.10.3.
- 15.10.1.8. The passenger seat design shall be finalized during the review of the Contractor's mock-up, reference Section 20.6.1.
- 15.10.1.9. Passenger seats shall be readily installed and removed using common hand tools.
- 15.10.1.10. Passenger seat shell attachment to the frame shall permit ready replacement.
- 15.10.1.11. Not used.

15.10.2. Construction

- 15.10.2.1. The passenger seats and backs shall be one-piece, molded Fiberglass Reinforced Plastic (FRP) shells meeting the requirements of Section 19.12.
- 15.10.2.2. The passenger seat shell shape shall be as illustrated in Appendix E-1, unless otherwise approved by NYCT.
- 15.10.2.3. The composite passenger seat shall be reinforced by a structural frame.
- 15.10.2.4. A stainless steel pan shall be provided on the bottom of the passenger seat shell to protect the shell and frame from vandalism. Alternate pan materials may be proposed for NYCT review and approval.

- 15.10.2.5. Passenger seat frames shall be of a welded, painted steel construction.
- 15.10.2.6. Passenger seat frame tubing shall have the ends plugged where exposed.
- 15.10.2.7. Alternate seat designs and materials meeting the strength requirements of 15.10.3 may be proposed for NYCT review and approval.

15.10.3. Passenger Seat Loading

- 15.10.3.1. With a longitudinal force (acting from front of seat to back) of 300 lb. (1334 N) per seating position (600 lb. (2,669 N) for a two passenger seat), passenger seat deflections everywhere shall be less than 0.75 inch (19 mm) with no failure of the tubular frame or composite shell. A permanent set of up to 0.0625 inch (1.59 mm) maximum will be permitted under these conditions.
- 15.10.3.2. With a downward vertical load applied uniformly along the front edge of each sitting position of 200 lb. (890 N), a permanent set of up to 0.0625 inch (1.59 mm) maximum will be permitted.
- 15.10.3.3. With a vertical downward load of 400 lb. (1,779 N) applied to a 4 inch by 10 inch (102 mm by 254 mm) area at the front of the passenger seat or an area of the same size in the middle of the seat bottom no failures shall occur.
- 15.10.3.4. The passenger seat shall allow for a 40 lb. (18 kg) weight dropped from heights of 6 inches (152 mm), 8 inches (203 mm), 10 inches (254 mm), and 12 inches (305 mm), for 10,000 drops from each height with no failures of the shell or frame.
- 15.10.3.5. The passenger seats shall allow for a swinging impact load applied with a 40 lb. (18 kg) weight to the seat back from the front of the seat. The seat shall withstand impacts from a distance of 6 inches (152 mm), 8 inches (203 mm), 10 inches (254 mm), and 12 inches (305 mm), for 10,000 strokes from each distance with no failures of the shell or frame.
- 15.10.3.6. The edge of each installed passenger seat shell shall be capable of resisting a 100 lb. (445 N) force in any direction without any visible deformation.
- 15.10.3.7. The Contractor shall consider the effect of out of plane bending moments applied to the carbody side wall structure if cantilevered seats are supplied.
- 15.10.3.8. Tests shall be performed in the presence of NYCT on a sample passenger seat of each type to be selected by NYCT to verify compliance with the strength requirements of this section. The seats shall be completely assembled and fastened to a rigid fixture simulating the car interface and attachment. The weight for the drop and swing impact tests shall consist of sand contained snugly in a tightly closed sturdy leather bag.
- 15.10.3.9. The Contractor shall furnish to NYCT one complete passenger seat of each type, constructed in accordance with the design provisions specified above prior to placing quantity orders. The seats will be used by NYCT for evaluation of the comfort, interchangeability, and aesthetic aspects of the seats. [CDRL]

15.11. Stanchions, Grab Rails, Windscreens

15.11.1. General Requirements

- 15.11.1.1. Stanchions and grab rails shall be provided to permit passengers to safely board the car, to permit on-board circulation, and to provide assistance to standees.
- 15.11.1.2. The arrangement shall be generally as shown in Appendix E-1.
- 15.11.1.3. Generally, every standee shall have a handhold within a reach of 24 inches (60 cm).

- 15.11.1.4. The final stanchion, grab rail and stanchion arrangement shall be determined during the design review process and approved by NYCT on the Contractor's mock-up, reference Section 20.6.1.
- 15.11.1.5. Unfinished stanchions, grab rails, and associated fittings shall be made of stainless steel with an approved circumferential grit finish.
- 15.11.1.6. Finished stanchions, grab rails, and associated fittings, as shown in Appendix E-1 shall be made of stainless steel with an approved deep, scratch resistant powder coated finish, see Section 19.22.6.
- 15.11.1.7. Stanchions and grab rails shall have a diameter of 1.25 inch (32 mm). The full vertical stanchions from floor to ceiling shall have a diameter of 1.50 inch (38 mm).
- 15.11.1.8. All surfaces shall be smooth and free of sharp edges which might injure passengers.
- 15.11.1.9. Knuckle clearance shall be a minimum of 1.50 inches (38 mm).
- 15.11.1.10. All fasteners shall be tamper-resistant, and of stainless steel.
- 15.11.1.11. Each vertical stanchion and its carbody attachment shall withstand, without permanent deformation, a horizontal load of 330 lb. (1,468 N) applied in any direction at the midpoint of the stanchion's free span.
- 15.11.1.12. Additionally, the double-tube vertical stanchions and their carbody attachments shall sustain a horizontal load of 300 lb. (1,334 N) applied equally in opposite directions (as a force couple) simultaneously on each of the tubes without permanent deformation and without rotation.
- 15.11.1.13. Each horizontal and diagonal grab rail and its carbody attachment shall withstand, without permanent deformation, a distributed load of 10 lb./inch (1.75 kN/m) applied at any angle.

15.11.2. Stanchions

- 15.11.2.1. Vertical stanchions shall be located on the inboard edge of each windscreen, attached to the passenger seats, and on the longitudinal center line of the car in each doorway.
- 15.11.2.2. Branching vertical stanchions, as shown in Appendix E-1, shall be installed along the longitudinal center line of the car in the area of each doorway.

15.11.3. Grab Rails

- 15.11.3.1. A longitudinal grab rail shall be mounted to the ceiling along the longitudinal centerline of the car.
- 15.11.3.2. Additionally, reaction bars (finger-tip grab rail) shall be installed in the low ceiling area.
- 15.11.3.3. Longitudinal grab rails shall be provided over the passenger seating areas.
- 15.11.3.4. A grab rail shall be provided at the designated wheelchair area at a location determined during the design review process and approved on the Contractor's mock-up, reference Section 20.6.1.
- 15.11.3.5. The grab rails over the passenger seats shall be positioned 69 inches (1,753 mm) above the finished floor, and the grab rails along the centerline of the car shall be positioned 79.5 inches (2,019 mm) above the finished floor to assist passengers standing in the aisles.
- 15.11.3.6. The grab rails shall be designed without the need for any lateral supports.

15.11.4. Windscreens

- 15.11.4.1. Windscreens shall be provided adjacent to all side doorways, except at the designated wheelchair areas.
- 15.11.4.2. The windscreen design and finish shall be as shown in the initial renderings in Appendix E-1.

- 15.11.4.3. The windscreens and grab rails shall be secured to the vertical stanchion, and interior wall, in an approved manner.

15.12. Interior Accessories

15.12.1. Ceiling Cove Advertising Card Frames

- 15.12.1.1. Each car shall be designed with provisions for the mounting of advertising cards with clear Lexan covers or NYCT approved equal.
- 15.12.1.2. The advertising cards shall be 11 inches (279 mm) high mounted on curved ceiling panels above the sidewalls, where Flexible Ceiling Strips are not installed prior to car delivery.
- 15.12.1.3. The frames shall be designed to be an integral feature of the curved ceiling panels.
- 15.12.1.4. The design of the curved ceiling panels shall ensure that the advertising cards and curved covers do not sag.
- 15.12.1.5. Securement devices identical to that provided on NYCT's existing cars (Lexan-type clip) shall be provided to secure the ends of the advertising cards.
- 15.12.1.6. All frames shall be hinged on one side.
- 15.12.1.7. All hardware used for the access of all frames shall be captive.

15.12.2. Passenger Emergency Intercom

- 15.12.2.1. Two Passenger Emergency Intercom (PEI) stations shall be provided per B Car, and three per A Car.
- 15.12.2.2. The PEI stations shall be located at diagonally opposite sides of the cars adjacent to the Number L2 and R7 doors. See Section 13.4.6 for specific PEI requirements.
- 15.12.2.3. The third PEI station for the A Car shall be flush mounted in the wheelchair area and shall be located within ADA height requirements.

15.12.3. Other Accessories

- 15.12.3.1. Convenience outlets shall be provided as described in Section 9.4.20.
- 15.12.3.2. Not used.
- 15.12.3.3. The necessary air ventilation ducting and piping shall be as described in Section 7.3.4. The Contractor shall satisfy these requirements when configuring walls and ceilings.
- 15.12.3.4. Access panels shall be provided to allow access to door control equipment including Door Operators, Door Control Relay Panels, and Door Monitoring and Control Units. All access panel joints shall be supported and covered with moldings.

15.12.4. Advertising Card and System Map Frame

- 15.12.4.1. A vandal resistant advertising card frame, identical to that used on the R160 cars, shall be provided on each door pocket panel that does not contain Flexible Wall Display provision, or other equipment, and, on A Cars, one on each side of the cab partition wall.
- 15.12.4.2. In the event Flexible Wall Displays are not installed at car delivery, advertising card frames shall be provided at all door pocket locations except where a system map frame, or other equipment, is installed.
- 15.12.4.3. The advertising card frame shall contain a protective, clear, Lexan cover or approved equal and shall accommodate a standard 22 by 21 inches (559 by 533 mm) advertising card.

- 15.12.4.4. In the event Flexible Wall Displays are not installed at car delivery, each car shall include a minimum of two, vandal resistant 23 by 28 inches (584 by 711 mm), system map frames with clear Lexan covers or approved equal.
- 15.12.4.5. All frames shall be hinged on one side.
- 15.12.4.6. All hardware used for the access of all frames shall be captive.

15.13. Information Signs

15.13.1. General

- 15.13.1.1. An information sign system shall be installed, consisting of side destination signs viewed from the exterior of the car, interior information signs, flexible ceiling strip displays, flexible wall displays and end route signs viewed from the exterior of the car. See also Section 13.5.

15.13.2. Side Destination Signs

- 15.13.2.1. Two SDSs, viewed from the car exterior, shall be furnished per car.
- 15.13.2.2. The signs shall be located in the car interior, one per side, at diagonally opposite ends of the car, against the upper portion of the side window.
- 15.13.2.3. The SDS display shall not be obscured by the frame.
- 15.13.2.4. A cover shall be provided over the SDS, which shall hide the sign from internal passenger view.
- 15.13.2.5. The cover shall be manufactured from the same material as the side lining/panel surrounding the window.
- 15.13.2.6. Detailed SDS requirements are contained in Section 13.5.2.

15.13.3. Ceiling Interior Information Signs

- 15.13.3.1. Two high definition type Ceiling Interior Information Signs (CIIS), using flexible content displays to show the desired information, shall be furnished in the car interior, mounted at each end of the car.
- 15.13.3.2. Detailed CIIS requirements are contained in Section 13.5.3.

15.13.4. End Route Signs

- 15.13.4.1. One End Route Sign (ERS) shall be furnished on the No. 1 End of each A Car.
- 15.13.4.2. The ERS shall be located on the interior of the car's front end, to the left of the storm door, and shall be readable from the outside of the car.
- 15.13.4.3. Detailed ERS requirements are contained in Section 13.5.4.
- 15.13.4.4. ERSs shall be easily accessible from inside the car.

15.13.5. Flexible Ceiling Strip and Flexible Wall Displays

- 15.13.5.1. Dynamic information displays shall be furnished as shown on the renderings in Appendix E-1 and shall be provided with a protective, clear Lexan cover or NYCT approved equal.
- 15.13.5.2. Detailed requirements are contained in Sections 13.5.5 and 13.5.6.

15.14. Graphics

15.14.1. General Requirements

- 15.14.1.1. The location, layout, size, text, color and application of graphics shall be as shown in the renderings in Appendix E-1 and approved by NYCT.
- 15.14.1.2. Text shall be Helvetica medium and in accordance with 49 CFR Part 38.55.
- 15.14.1.3. Unless otherwise specified, interior cab decals used for information/identification of cabinets and/or equipment shall have rounded edges using the following criteria: decals with a length or width of 1 inch (25 mm) or less shall have a corner radius of 0.125 inch (3.2 mm), and decals with a length and width greater than 1 inch (25 mm) shall have a corner radius of 0.25 inch (6.4 mm).
- 15.14.1.4. The Contractor shall define a common format, subject to NYCT approval, for safety and equipment identification signs for use by the Contractor and all sub-suppliers.
 - a) The format shall define overall nameplate size, font sizes, and colors.
 - b) All lettering and graphics, exclusive of manufacturer's logos, shall use the defined common font size and color.

15.14.2. Exterior Graphics

- 15.14.2.1. Exterior graphics shall be as shown in Appendix E-1 and constructed from an approved adhesive backed, Tedlar® or 3M Controltac film, applied and edge sealed in accordance with the manufacturer's instructions, unless otherwise approved by NYCT.
- 15.14.2.2. Where logotype is applied to Tedlar® film, it shall be protected by a final lamination of clear Tedlar® film.
- 15.14.2.3. Each car shall be provided with four car number plates located at the same height and near the ends of the outside of the car. The plates shall be applied to the car as approved by NYCT.
 - a) Plates shall be manufactured from 18 gauge (1.27 mm) steel, Grade III, ingot iron, or 0.090 inch (2.3 mm) thick fiberglass reinforced composite material.
 - b) If steel plates are provided, the finish shall be an acid and alkaline-resistant, smooth, porcelain, vitreous enamel fused to the plates by an approved process and free from cracks, chips, scales, flaws, bubbles, holes, pits, and other imperfections.
 - c) Numerals shall be properly spaced standard Helvetica medium type face, white on a black background, in accordance with Appendix D-24 (Body Number Plate Details, NYCT graphic standards drawing 604-5001). The car numbers will be assigned by NYCT.
- 15.14.2.4. A logo type design shall be applied to the car exterior in areas to be selected by NYCT. Logo design will be furnished by NYCT.
- 15.14.2.5. A small stainless steel or cast aluminum ownership plate shall be attached to the body side sill, right side, No. 2 end of the car over the center of the bolster; and to each truck at the corner toward the center of the car, left side. The ownership plate shall include the words "Property of NYCTA" and serial numbers which agree with the carbody and truck numbers.
- 15.14.2.6. The following items of undercar equipment shall be stenciled. Color as noted with high visibility paint:
 - a) "MR" in 4 inch (102 mm) letters on both sides of the main reservoir - red.
 - b) "S" in 4 inch (102 mm) letters on both sides of the supply reservoir - yellow.
- 15.14.2.7. Underfloor apparatus shall be marked by means of engraved metal plates, welded, or mechanically fastened to the apparatus being identified and with the background and lettering in a contrasting color.

- a) Each air brake reservoir and all cutout cocks, parking brake isolation valve, switches, fuses, and junction boxes shall be marked as previously stated.
 - b) The cover of each apparatus box shall list each major item of apparatus contained therein. An additional label, readable from the side of the car, is required if the box cover label is not readable in the installed position.
- 15.14.2.8. The application status of the Parking Brake Isolation Valve (PBIV), Brake Cutout (BCO), and Service Brake Cutout (SBCO) (or equivalent) are to be clearly defined by mechanically fastened labels as follows:
- a) PBIV – Cut In, Cut Out.
 - b) BCO - Cut In, Cut Out.
 - c) SBCO - Cut In, Cut Out.
- 15.14.2.9. Warning advice, including the normal maximum voltage of circuits therein, shall be provided on the outside of boxes containing electrical apparatus energized at greater-than-battery potential. Identifying labels with black characters on a white background shall be provided for switches, circuit breakers, terminal strips, and indicating lamps.

15.14.3. Interior Graphics

- 15.14.3.1. Interior passenger assistance and general information graphics shall be ADA compliant.
- 15.14.3.2. All graphics applied to the car interior shall be in accordance with Appendix C-21 (NYCT Specification 3061-MATL-87, "Interior Railcar Self-Adhesive Stickers").
- 15.14.3.3. Passenger assistance and general information signs shall be applied to the interior of the car; others may be required.
- 15.14.3.4. Decals on certain passenger seats indicating priority for the disabled shall be as follows:
- a) For the A Car only, the international wheelchair symbol decal shall be located in the area between the cab bulkhead and the side doors on the No. 1 End.
 - b) For A Cars, "Priority Seating" decals shall be provided, as approved by NYCT.
 - c) For the B Car, "Priority Seating" decals shall be located over the two-person seats located at the diagonal ends of the car.
 - d) The lower edge of the "Priority Seating" decals shall be located at a height of 55 inch (1397 mm) above the finished floor.
 - e) The international wheelchair symbol decals shall be located 0.5 inch (12.7 mm) below the Priority Seating decals.
- 15.14.3.5. On the cover of the Passenger Emergency Handle Unit, the label shall read as follows, arranged horizontally on four separate rows:
- "Emergency Brake"
 - "Open this cover"
 - "Alarm will sound"
 - "Pull handle down".
- 15.14.3.6. Door numbers in figures shall be applied at the top of the inside door post nearest the door panel, numbered starting from the No. 1 End in consecutive order toward the No. 2 End of the car, as R1, R2, R3, R4, etc., L1, L2, L3, L4, etc.

- 15.14.3.7. The car number shall be displayed at each end of the passenger compartment on the end wall, and the exact location shall be approved by NYCT.
- 15.14.3.8. The car class and the car number, which shall be in agreement with the exterior-mounted car number, shall be placed on the cab bulkhead and inside the Train Operator's cab.
- 15.14.3.9. The style for the car number plate shall be consistent with the decals required by this section, subject to NYCT approval.
- 15.14.3.10. Car ends shall be numbered "1" and "2".
- 15.14.3.11. For A Cars, the cab end shall be marked "1" and the non-cab end shall be marked "2," and the exact location shall be approved by NYCT.
- 15.14.3.12. The identification numbers for car ends shall not be combined with the aforementioned car number plates.
- 15.14.3.13. For B Cars, the No. 1 end of the car shall be defined by the Contractor based on a unique design feature.
- 15.14.3.14. Signs including, but not limited to those depicting Evacuation Instructions; "Do Not Hold Doors"; "Do Not Lean On Door"; "No Exit"; "No Smoking, Littering, Radio"; and "Do Not Ride Between Cars", shall be provided and shall be located as directed by NYCT.
- 15.14.3.15. Each car shall have a video surveillance decal to alert passengers that they are being videotaped. Number, locations, and exact wording of decals shall be approved by NYCT.
- 15.14.3.16. A pictogram of an approved design depicting the use of a PEI unit, consisting of a four-color, engraved and paint filled, stainless steel plate, shall be provided for each A Car bulkhead equipped with a vandal resistant, texturized stainless steel covering.
- 15.14.3.17. The PEI pictogram plate shall be located immediately above, and centered on, the PEI and shall be installed using stainless steel rivets.
- 15.14.3.18. A star, black on a clear film, shall be placed at an approved location over the location of a brake cutout cock handle.
- 15.14.3.19. A triangle, black on a clear film, shall be placed at an approved location over the location of a selector cock handle
- 15.14.3.20. A "V," black on a clear film, shall be placed in an approved location over each High Voltage circuit breaker.
- 15.14.3.21. Name plates, trade mark insignias or other identifying markings will not be permitted on any equipment inside the car visible to the public, except that an NYCT-approved builder's plate may be furnished by the Contractor and attached to the inside of the car in an approved location.
- 15.14.3.22. Builder's plates shall be unpainted and have a finish to match other interior hardware.

15.14.4. Safety Signs

- 15.14.4.1. All warning or safety signs shall meet the requirements of ISO 3864 "Graphical Symbols -- Safety Colors and Safety Signs" and shall be distinguished by using the word "warning" for personnel safety and "caution" for damage to equipment.
- a) "Warning" signs will be used in case of operating or maintenance procedures, practices, conditions, statements, etc., which, if not strictly observed, could result in injury or death.
 - b) "Caution" signs will be used in case of operating or maintenance procedures, practices conditions, statements, etc., which, if not strictly observed, could result in damage to or destruction of Equipment.
- 15.14.4.2. Signs shall be permanently affixed with proper adhesive, screws, or rivets, on all equipment enclosures to alert maintenance personnel to exercise caution when working on or near this equipment.

15.14.4.3. All exterior safety signs and undercar signs shall be made of stainless steel with a mirror finish background. Appropriate messages shall be engraved as approved by NYCT.

15.14.5. Equipment Identification Signs

15.14.5.1. All equipment identification signs shall be made of stainless steel with a mirror finish background and shall be permanently affixed with screws or rivets.

15.14.5.2. Lettering and graphics shall be engraved and paint filled.

15.15. Equipment Enclosures

15.15.1. General

15.15.1.1. The Contractor shall develop a general equipment design specification that is consistent with the details below and all relevant sections of this Specification. The general equipment design specification shall be used to ensure a common equipment design philosophy for the Contractor and its subcontractors. The specification shall be submitted to NYCT for approval [CDRL]. The specification shall standardize details including, but not limited to the following:

- a) Access doors, seal designs, panels, hinge design.
- b) Mounting method/details.
- c) Latches, hold-open devices, and safety catches.
- d) Labeling.
- e) Equipment/LRU arrangement.
- f) All materials and finishes.
- g) Grounding scheme, where appropriate.

15.15.1.2. Exterior equipment enclosures, except the battery box, shall be constructed of stainless steel, LAHT, mild carbon steel or, where approved, FRP.

15.15.1.3. The battery box shall comply with the requirements of this section and the design requirements in Section 9, Auxiliary Electrical Equipment and Distribution.

15.15.1.4. Enclosures constructed of steel shall have continuous welds along all seams.

15.15.1.5. When FRP or other potentially combustible materials are proposed and approved by NYCT, they shall conform to the flammability and smoke emission requirements defined in Section 19.1.10. FRP strength and impact resistance shall not be compromised by flame-retardant additives.

15.15.1.6. Equipment enclosures, unless specifically stated otherwise within this Specification, shall be mounted underfloor.

15.15.1.7. Exterior mounted equipment enclosures shall be hung in accordance with the requirements in Section 3.4.18.

15.15.1.8. Undercar equipment with a direct line of sight to a wheel for any possible truck orientation shall be protected from water splash, flying rock ballast, or other objects thrown by the wheel.

15.15.1.9. Shields, if used to protect equipment, shall not obstruct the flow of air from or to the underfloor to an extent that overheating of wiring or apparatus could occur.

15.15.1.10. All car equipment that must be operated by NYCT personnel in case of propulsion or brake system malfunction shall be accessible from the interior or the ends of the car, unless otherwise approved by NYCT.

- 15.15.1.11. Equipment shall be arranged to ensure sufficient ventilation. Forced ventilation is not permitted.
- 15.15.1.12. All underfloor and roof equipment shall be arranged to allow access from the side of the car, from the maintenance pits, or scaffolding, and when the car is on lifts or jacks.
- 15.15.1.13. Clearances for all handholds, latches, and related items shall be provided so that a person wearing gloves is not hindered from operating them.
- 15.15.1.14. Materials and workmanship of the exterior equipment box assemblies shall conform to the applicable requirements of Section 19, Materials, Workmanship and Processes.
- 15.15.1.15. Exterior equipment enclosures shall contain drain holes fitted with cotter pins or other approved, simple drain clearing mechanisms for discharge of condensation and leakage.
- 15.15.1.16. All equipment, and equipment enclosures and their contents, shall conform to the structural requirements of Section 3.2.14.
- 15.15.1.17. Labels and warning indicators shall be applied as required by Section 15.14.
- 15.15.1.18. Equipment installed in boxes shall not be attached directly to the box by fasteners through the enclosure skin. Equipment shall be attached to standoffs or sub-plates welded to the box.
- 15.15.1.19. Minimum clearance of 0.5 inch (12.7 mm) shall be provided between the exposed sides and covers of the equipment enclosure and the internal equipment to protect the internal equipment from damage.
- 15.15.1.20. All underfloor enclosures, with the exception of the battery box, shall be grounded to the carbody, as specified in Section 9.4.7.
- 15.15.1.21. Design of the equipment enclosure seals shall allow for ease of replacement.

15.15.2. Access Covers

- 15.15.2.1. Underfloor equipment enclosures shall be provided with top-hinged access covers on the outboard side and, if required, the inboard side.
- 15.15.2.2. Openings provided upon opening of covers shall be of sufficient size to permit removal and replacement of any component in the box and access to equipment in the box for inspection and maintenance.
- 15.15.2.3. Equipment box access covers shall not be removable, unless approved by NYCT, and shall be self-closing when the "hold open" feature is released.
- 15.15.2.4. The covers shall be arranged so that only one person is required to easily open, close, and latch any cover, regardless of size.
- 15.15.2.5. Latches and latch catches shall be arranged so that they do not protrude beyond the bottom of the box or cover in the latched position, except as approved.
- 15.15.2.6. Latches shall not violate the car dynamic clearance outline as described in Appendix D-1 (NYCT Document MISC #00-01, "Memorandum of Understanding Car and Line Equipment Clearances") if not engaged.
- 15.15.2.7. Latches shall be spring loaded to compensate for seal relaxation, up to the worst case condition of hard contact between the cover and box, unless otherwise approved. In all cases, the latch shall hold the cover to the box without rattling.
- 15.15.2.8. Cover safety pins shall retain the cover within the car dynamic clearance envelope described in Appendix D-1 (NYCT Document MISC #00-01, "Memorandum of Understanding Car and Line Equipment Clearances"), at all operating speeds without the cover latches engaged.
- 15.15.2.9. Outboard covers shall swing open a minimum of 120 degrees for quick examination of the interior without removing the covers, except as approved by NYCT.

- 15.15.2.10. Inboard covers shall swing open to the maximum extent possible, but in no case less than 60 degrees, except as approved by NYCT.
- 15.15.2.11. All outward facing covers shall have an internal "hold open" feature, unless approved by NYCT.
- 15.15.2.12. The "hold open" feature shall automatically lock in the open position when the cover is opened fully and shall be easily unlocked when reclosing the door or panel.
- 15.15.2.13. The "hold open" feature shall not automatically open the cover and shall not interfere with or impede the opening of the cover.
- 15.15.2.14. The "hold open" mechanism shall not present the possibility of shorting or grounding internal electrical parts when the cover is opened or closed.
- 15.15.2.15. The "hold open" device shall be the B-1450 series as made by Takigen Manufacturing Company or NYCT approved alternative. The use of gas-filled struts or spring loaded hold open devices are prohibited.
- 15.15.2.16. Equipment box access covers shall be constructed of stainless steel, LAHT, or mild carbon steel.
- 15.15.2.17. Interior surfaces of covers shall be coated with an arc-protecting, high-dielectric powder coating or NYCT approved alternate material. FRP covers, where approved for use by NYCT, shall meet all requirements in Section 19.12.
- 15.15.2.18. All hardware, including hinges, used to secure access covers or access plates on equipment enclosures shall be made of stainless steel.
- 15.15.2.19. All mounting hardware for access covers shall have captive nuts or bolts.
- 15.15.2.20. All access covers shall be provided with quick-release, spring-loaded, latches that operate with a toggling-type action. Other latches may be used, subject to NYCT approval.
- 15.15.2.21. The latch and all its components shall be fabricated from stainless steel.
- 15.15.2.22. The latches shall not have separable or non-retained parts.
- 15.15.2.23. Prior to delivery, cover latches shall be checked to ensure that the cover seals are compressed no more than 50 percent of the compressible height of the seal. Water tightness shall be tested (see Section 24.9.2).
- 15.15.2.24. A spring-loaded safety pin, Alstom part no. CX63CH-001 or NYCT approved equal, shall be provided for each underfloor box cover.
- 15.15.2.25. Latches, safety catch, and "hold open" devices shall be identical on all undercar equipment boxes except as approved by NYCT.

15.15.3. Environmental Sealing

- 15.15.3.1. Environmental sealing of equipment boxes shall be equivalent to a NEMA Standard No. 250 "Enclosures for Electrical Equipment (1000 Volts Maximum)", Type 4 enclosure. Seals shall be of a material that will ensure water tightness and remain resilient for a period of at least 10 years with proper maintenance.
- 15.15.3.2. Closed-cell foam tube or similar design shall be used for all cover seals. The seals shall have a minimum free compression range (hollow tube inside diameter) of 0.375 inch (9.5 mm).
- 15.15.3.3. Flat foam strips or glue-on attachments shall not be permitted.
- 15.15.3.4. Alternative gasket arrangements may be used as approved by NYCT.

15.15.4. Conduit and Cable Interfaces

- 15.15.4.1. The arrangement of conduit, cable, wire routing, connections to equipment enclosures, and equipment contained in enclosures shall ensure that structural, electrical, and environmental integrity is maintained,

and shall permit the removal and replacement of the equipment enclosure. The arrangement shall be approved by NYCT.

- 15.15.4.2. All control and power cable terminations shall be made internal to the enclosures or in waterproof junction boxes (with gaskets installed) meeting NEMA 4-type requirements or using connectors as specified in Section 19.25.5.
- 15.15.4.3. Cable entry shall be by means of watertight sealing glands. Glands and cable terminations shall provide for cable replacement without removal of lugs, terminals, or connectors from the wires. Other configurations may be used upon NYCT approval on a case-by-case basis.
- 15.15.4.4. Conduit shall be connected to underfloor equipment groups using watertight connectors as specified in Section 19.25.5. The entrance of conduit or cables in the top and bottom of equipment boxes will not be permitted.

15.15.5. Interior Enclosures

- 15.15.5.1. Electrical or electronic equipment located within the cars shall be mounted within dust-proof equipment enclosures subject to NYCT approval.
- 15.15.5.2. The design and finish of such equipment shall be consistent with the general interior, but shall prevent access by passengers.
- 15.15.5.3. Electrical lockers may be provided in the cab partition, accessible only from the cab area, except where approved by NYCT.
- 15.15.5.4. Locker depth shall be minimized and shall be approved by NYCT.
- 15.15.5.5. The locker panels shall be of the same construction as the cab partition.
- 15.15.5.6. Access doors shall be hung on stainless steel piano hinges and secured with locks as specified in Section 15.5.1.
- 15.15.5.7. Electric lockers shall be free of sharp corners or edges to eliminate the possibility of injury to passengers, operating personnel and maintenance personnel in either normal usage or emergencies.
- 15.15.5.8. Electric locker design shall allow ready access to maintenance personnel.
- 15.15.5.9. Electric lockers shall contain sufficient access doors to allow free access for monitoring and maintenance of the enclosed equipment.
- 15.15.5.10. All interior equipment enclosures shall be readily accessible.
- 15.15.5.11. Equipment weighing more than 5 lb. (2.3 kg) shall be mounted in a way that permits ease of installation by a single person, e.g., guide pins or key-hole mounting slots.
- 15.15.5.12. All equipment, and equipment enclosures and their contents, shall conform to the applicable structural requirements of Section 3.2.14.
- 15.15.5.13. Fasteners used on the design of the interior enclosures and securement of equipment shall meet the requirements of Section 19.19.

15.16. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

<u>CDRL</u>	<u>Ref</u>	<u>Deliverable</u>	<u>Timing</u>
15-1	15.3.3.6	Flooring installation and repair procedures.	Acceptance of first unit
15-2	Not used	Not used	Not used
15-3	Not used	Not used	Not used
15-4	15.9.1.9	Interior lining/panel material samples.	CDR
15-5	15.9.4.2	Samples of colors, patterns and finishes used in the interior lining.	CDR
15-6	15.9.4.6	Interior stainless steel finish samples with worn, partially worn, and a new belt applied finishes.	CDR
15-7	15.10.3.9	Sample passenger seat of each type.	CDR
15-8	15.15.1.1	General equipment enclosure design specification	CDR

Section 16

Trainline and Car Control Architecture

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16. Trainline and Car Architecture

16.1. Introduction

16.1.1. General Requirements

- 16.1.1.1. This section defines the requirements for trainlines, networks, and the mechanism by which commands and other data are communicated from the active cab to the whole train or Unit. The requirements are divided into Performance, Function, Design, Maintainability, and Validation sections. Refer to the following sections for car systems and components interfacing with the trainlines and car control networks and other applicable requirements:
- a) Design and Performance Criteria – Section 2.
 - b) Coupler Systems - Section 4.
 - c) Cab and Cab Controls – Section 5.
 - d) Side Door System – Section 6.
 - e) HVAC – Section 7
 - f) Propulsion System – Section 10.
 - g) Friction Brake and Air Supply Systems – Section 12.
 - h) Communications – Section 13.
 - i) Train Control System – Section 14.
 - j) Monitoring and Diagnostics – Section 17.
 - k) Software Systems – Section 18.
 - l) Materials, Processes, and Workmanship – Section 19.
 - m) Reliability, Maintainability, and System Assurance - Section 21.
 - n) System Support - Section 22.
- 16.1.1.2. The train control design shall fully integrate the crew controls and Communications Based Train Control (CBTC) referenced in Section 14 – Train Control System, or the Cab Signaling requirements referenced in Section 25 – Staten Island Railway (SIR) Cars, as applicable.
- 16.1.1.3. Trainlines and networks shall be co-designed with the coupler pin connections to provide both high availability and full functionality of the required information between Units. See also Section 4 – Coupler Systems.
- 16.1.1.4. The coupler pin arrangement and connection to the trainlines and networks shall allow for Unit coupling in either orientation.
- 16.1.1.5. Spare coupler pins shall be provided for additional trainlines and a spare network. See also Section 4.4.3.11.
- 16.1.1.6. Network application software, and its documentation, developed for NYCT shall become the property of NYCT. The Contractor shall provide licenses to NYCT as required by Section 18.2.5 for Commercial Off-The-Shelf (COTS) network software.
- 16.1.1.7. All device interfaces (ports, protocols, ranges, fixings, etc.) shall be fully open, discernable, and fully described so as to permit modification, enhancement, upgrade, addition or removal by NYCT without the need for additional or proprietary information.

16.1.1.8. The network systems shall maintain an open design plan that utilizes network components and switches/routers that are either non-proprietary, or demonstrated to be available from multiple independent manufacturing sources, compatible with a rapid transit environment similar to NYCT.

16.1.2. Train Control Architecture

16.1.2.1. The graphical depiction in Figure 16-1 illustrates the basic requirements for the A Car train and car control architecture. The trainlines and the train network(s) traverse the train connecting to propulsion, doors, and friction brake equipment on each car.

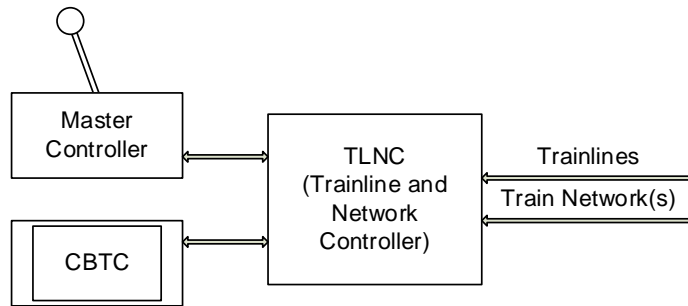


Figure 16-1 - Train Control A Car Cab Block Architecture

16.1.2.2. Safety and reliability critical signals shall be transmitted by discrete wires and coupler pins. These signals shall be justified by the Contractor and shall be subject to approval by NYCT.

16.1.2.3. Table 16-1 identifies the trainline signals used on the R179 car design as a baseline. Sections 14.4.6.3, and 25.14 provide the unitline requirements for CBTC and SIR ATC respectively. These tables are provided for information only.

Table 16-1 - Estimate of Hard-Wired Trainline Signals

Signal / Function	Trainlines	Coupler pins
Emergency Brake, Section 16.4.3	1	2
Train Operator Indication, Section 6.4	1	2
Conductor Indication	1	2
Brake Release Interlock, Section 10.3.8	1	2
Door Enable (Left & Right), Section 6.4	2	2
Door Unlock (Left & Right)	2	2
Door Open (Left & Right)	2	2
HVAC Control	1	2
Coupler Control	6	8
Buzzer, Section 13.7	1	2
CBTC Data Radio Network: 4 x RS-485 twisted twin	8	8
CBTC EMV Bypass: Discrete signals that enable bypass of the CBTC EMV control circuit.	2	4
Networks: 6 including redundancy and a spare	8	32
Battery zero volt reference	1	2
CBTC Spares: Discrete Signals	4	8
No. of Spares: Discrete Signals	4	8

16.2. Performance Requirements

16.2.1. General

16.2.1.1. The performance of the trainlines shall not noticeably change over the range of battery voltage (see Section 2.5.4) and train configuration (see Section 2.2.1).

16.2.2. Response Times

16.2.2.1. The response time for all controls from the Operator's (T/O or C/R) cab or the CBTC commands to each controlled system shall be:

- a) Less than two seconds, such that it is consistent with normal operator and crew expectation.
- b) Uniform for the whole train, such that the train operates in unison, particularly to changes of tractive or brake effort.

16.2.3. Network Margins

16.2.3.1. The Contractor shall submit detailed calculations of the average data traffic levels and operating margin for each network, including CBTC traffic and a budget for the communication media, for approval by NYCT. [CDRL]

16.2.3.2. The Contractor shall also submit the estimated/anticipated peak data traffic levels, which shall not exceed 60 percent of the protocol supplier's recommended maximum peak traffic levels.

16.3. Functional Requirements

16.3.1. Train Controls

16.3.1.1. The train controls shall be designed for the following operation:

- a) The Train Operator will select any A Car in the train from which to operate the train. (Lead-cab operation is normal, otherwise the operation is under special NYCT operating rules.)
- b) The crew will select any A Car in the train from which to operate the doors and perform related functions.
- c) The CBTC equipment shall be able to perform its train control functions from any A Car in the train, working in conjunction with an Operator in the lead car and a Conductor, if present, in another A Car. See Section 14.2.4.

16.3.1.2. Means shall be provided to automatically and continuously determine the sequence of cars in a Unit and sequence of Units in a train.

- a) Any physical change to the makeup of the train shall be directly determined when the train is assembled or reassembled and is keyed-up.
- b) The information shall be made available to the Monitoring and Diagnostics System (MDS).

16.3.1.3. Each A Car shall contain a Master Controller which shall be connected to the Trainline and Network Controller (TLNC) using only a minimum number of robust connections. See also Section 5.6.2.

16.3.1.4. The number of discrete trainlines shall be minimized but consistent with safe normal operation and unequivocal operation in Emergency Braking.

16.3.2. Trainlines

16.3.2.1. Trainlines shall consist of wires for:

- a) Conventional discrete trainlines for selected signals. These trainlines and unitlines shall use LVPS/battery level signals.
- b) Battery zero volt reference.
- c) Networks; these are expected to be either autonomous Ethernets, or an Ethernet + Train Control Network (TCN).
- d) 4 x RS-485 CBTC Radio network.

16.3.2.2. A table of trainlines, unitlines, and coupler pin requirements, including spares and redundancy shall be submitted for approval. The table shall include the locations for secure maintenance ports to access the trainlines to facilitate signal confirmation along the train, in both the A Car and the B Car. **[CDRL]**

16.3.3. Trainline Control

16.3.3.1. A Cars shall contain redundant devices to receive train crew and CBTC commands, and provide appropriate information and commands to the trainlines and network, such that the functionality described in Section 14.4.6, and the reliability and availability described in Section 2.13 shall be achieved.

16.3.3.2. Where feedback and indication to the cab equipment and to the CBTC system (via the CIU) is necessary, the TLNC shall receive and provide this information back from the trainlines and networks.

16.3.3.3. The TLNC shall include diagnostic functionality that reports failures and events to the MDS.

16.3.4. Networks - Overview

16.3.4.1. Trainlined networks shall be provided for:

- a) The Protected Control of the Propulsion and Brake systems for both manual and CBTC operation, and may also include Door system controls, HVAC system controls and other system controls.
- b) Passenger Information and Communications,
- c) MDS. Used to monitor all systems throughout the connected Units, and the transportation of events, PTE logs, and diagnostic data.
- d) The Contractor shall provide the wireless data link as specified in Section 16.3.8.

16.3.4.2. All trainlined networks shall be configured to ensure high system availability.

16.3.4.3. When Units are coupled and uncoupled, and when cars are connected and disconnected, the network shall automatically reconfigure itself for the new train configuration.

16.3.4.4. Network switches shall continuously detect and manage added or removed networked devices and automatically and dynamically reconfigure their network database.

16.3.4.5. Networks and their associated processors in operational service shall be inherently protected and made secure from unauthorized access or malicious intent.

- a) Connections and Information between different networks (such as the MDS) shall follow the Principle of Least Privilege so that only the minimum necessary information needs to be exchanged. Preferably, the information shall be transferred via an intermediate channel.
- b) Cyber security, network devices, communication protocols, connectivity and all software shall be compliant with Section 18 - Software Systems.

16.3.4.6. Networks shall be designed such that end stations, open ports, and coupler terminations do not cause reflection, add noise, or otherwise degrade network performance.

16.3.4.7. Network cable connectors shall be appropriately robust and secure with the contacts appropriately gold plated for their anticipated duty, including periodic disconnection for maintenance.

16.3.5. Protected Control Network

16.3.5.1. Train control shall be a fully integrated system of crew controls and CBTC signal controls, using dedicated parts of the TLNC. Refer to Section 14 – Train Control System.

16.3.5.2. Means shall be provided to prevent the operation of the train propulsion systems with more than one TLNC in control.

16.3.5.3. The TLNC shall use components in hot redundancy configuration, where the parallel components are both powered, active and capable of an immediate transfer of the duty with no noticeable transient condition. This is to maximize the availability of the transmitted and received information.

16.3.5.4. The type and topology of this network shall ensure its security and integrity.

16.3.5.5. Refer to Section 16.4.3 for the independent control of the Emergency Brake.

16.3.5.6. Refer to Section 14 for CBTC information and Section 25 for SIR Cab Signaling.

16.3.6. Passenger Information and Communication Network

16.3.6.1. The Communication Controller (CMC) shall carry location and route information, and voice communications. This network may also carry video; refer to Section 13.9.

16.3.6.2. There shall be no connectivity from this network to the Protected Control Network.

16.3.7. Monitoring and Diagnostics Network

16.3.7.1. The MDS shall log an appropriate maintenance requirement action in the MDS maintenance file, to the appropriate Unit (or Units), whenever a malfunction of a device on the network, or an abnormally high error rate, has occurred. The log shall detail the car time of the malfunction, the error code, and the location of the device(s) involved.

16.3.7.2. The MDS network shall provide car (global) time for the synchronization of each subsystem. Refer to Section 17.3.6.

16.3.7.3. The MDS network manager shall periodically poll the processors within the trainline and networked devices for their status and events. Refer to Section 17.4.1.

16.3.7.4. The MDS shall only be capable of a limited and directional set of requests and responses, whenever communicating with a device that serves another network.

16.3.7.5. The MDS network shall facilitate the transportation and downloading of logs for the PTE. These shall include logs for devices that receive commands from another network, such as the Propulsion and Brake PTE logs.

16.3.8. Wireless Data Link

16.3.8.1. Each A Car shall provide a wireless data link to form the redundant wireless links on the Unit. The Contractor may propose to use separate wireless data links for some selected tasks, subject to NYCT approval. It shall support the following functions, at a minimum.

- a) CCTV Remote Video Request System (RVRS) (see Section 13.9.7)
- b) Wireless MDS download and editing (see Section 17.3.1.3)
- c) Not used

- d) Wireless Passenger Information System (PIS) data upload (see Section 13.6.4)
- e) Platform Edge CCTV (see Section 13.10)
- f) Platform Screen Door (PSD) interface (see Section 13.11)

16.3.8.2. The Contractor shall provide surveys and a system consisting of the following items, at a minimum, to support the wireless link specified in Section 16.3.8.1:

- a) A comprehensive design of car-borne and wayside equipment required.
- b) A survey of NYCT selected yards to confirm the wayside equipment needed for an optimal wireless coverage in the yards. Provide the design and instruction with recommended infrastructure and shop requirements that NYCT would need for the full implementation.
- c) All necessary on-board equipment (for example, network switches, transceivers, etc.) for the train wireless interface.
- d) The workstations and servers required to retrieve and store data from the train, and upload data to the train.
- e) All software needed to perform the tasks identified in Section 16.3.8.1.
- f) Not used.
- g) Cyber security aspects of the wireless data link.

16.3.8.3. The data transferring using the wireless data link shall include, as a minimum, the signals listed below, subject to NYCT's approval.

- a) Download from train to wayside:
 - i. Selected MDS and event recorder data, including the signals identified in Section 17.3.7.8.
 - ii. Selected period of the stored video images from onboard Digital Video Recorder (DVR). (see Section 13.9.7)
 - iii. Data required for the provisional Platform Edge CCTV interface.
 - iv. Data required for the provisional PSD interface.
- b) Upload from wayside to train:
 - i. Data required to update the stopping pattern files and audio files for Automatic Announcement System (AAS). (see Section 13.6.3)
 - ii. Media data to update the messages and display information in PIS. (see Section 13.6.4)
 - iii. Data required for the provisional Platform Edge CCTV interface.
 - iv. Data required for the provisional PSD interface.

16.4. Design Requirements

16.4.1. Standards

16.4.1.1. Trainlines, Networks and their protocols shall conform to the applicable parts of the following standards:

- a) IEEE Std. 1473-E, "Standard for Communications Protocol aboard Passenger Trains".
- b) IEC 61375-1, "Train Communication Network (TCN)".
- c) IEC 61375-2-5, "Ethernet Train Backbone".

d) IEC 61375-3-4, "Ethernet Consist Network".

16.4.1.2. Control equipment shall conform to the requirements of this Specification and IEEE Std. 1475 "Standard for the Functioning of and Interfaces Among Propulsion, Friction Brake, and Train-borne Master Control on Rail Rapid Transit Vehicles".

- a) In the event of conflict between this Specification and IEEE Std. 1475, the Contractor shall notify NYCT of the conflict and shall accept NYCT's determination of which provisions are to be applied.
- b) Specific deviations from IEEE Std. 1475 shall be submitted for NYCT approval.

16.4.2. Network Backbones

16.4.2.1. Within each network backbone, the train switches shall use parallel network interfaces with hot redundancy. Hot standby with automatic transfer shall not be offered. The failure of a network component shall result in the immediate transfer of signal to an alternative component, without any loss of information.

16.4.2.2. The MDS shall log an appropriate maintenance requirement whenever a transfer of a network signal path, such as the active use of a redundant component or path, has occurred. See also Section 16.3.7.1.

16.4.2.3. Each Unit shall have its own sub-networks. Their topology shall:

- a) Be appropriate for its application and associated security.
- b) Provide high availability.
- c) Be aware of the static and dynamic differences in the ground voltage level between Units, cars and equipment packages.
- d) Be justified by the Contractor.
- e) Be approved by NYCT.

16.4.2.4. Network backbones shall communicate commands to the Unit networks via dedicated train switches/routers.

16.4.2.5. For device commissioning, diagnostics, and maintenance, each Unit shall have its own dedicated network manager/router. It shall:

- a) Maintain a database of all network nodes under its domain.
- b) Facilitate and simplify trainline communications and minimize network traffic.
- c) Automatically identify a replacement networked component and automatically include it into the Unit network operation without the need for special tools.
- d) Facilitate the appropriate limited and secure interface to the MDS and to the PTE.
- e) Periodically check each network node to verify its health and report relevant incidents to the MDS.
- f) Synchronize to car time via the MDS.
- g) Permit any device (existing or future) on the network to appropriately communicate to any other device on the same network.

16.4.2.6. Network interconnections across cars and within each Unit shall be hard wired using dedicated connectors as specified in IEC 61375-2-5. Network wiring shall be segregated, protected, and positioned away from other cables and trainlines and all likely sources of Electromagnetic Interference (EMI).

16.4.3. Emergency Brake Control

- 16.4.3.1. The Emergency Brake trainline shall be configured as follows:
- a) Each car shall have a local emergency circuit that breaks both positive and negative feeds to the Emergency Magnet Valve (EMV) on that car, as specified in Section 12.3.3.
 - b) The Emergency Brake trainline shall pass through every car in the train.
 - c) Emergency activation devices in each car shall locally cause the brake pipe to be vented via the car EMV and energize the Emergency Brake trainline.
 - d) On each car, when the Emergency Brake trainline has been energized, the brake pipe shall be exhausted via the car EMV.
 - e) On each car, when the brake pipe pressure falls below 90 psi, the Emergency Brake trainline shall be energized. Conditions c) and d) shall prevail until appropriate reset/recharge conditions have been met. Refer to Section 12.3.3.
 - f) On each A Car, the local EMV control circuit shall include contacts set by the CBTC system. Refer to Section 14.4.6.5.
- 16.4.3.2. The CBTC equipment in a train shall be interconnected via the CBTC emergency trainline to allow control of the CBTC relay, the contacts of which are in the local EMV control circuitry on the A cars:
- a) Interconnecting wiring shall be installed according to Section 14 - Train Control System.
 - b) Final CBTC emergency circuit design may result in other interfaces to car circuits that shall be provided by the Contractor.
- 16.4.3.3. The entire emergency braking system is subject to review and approval, and may be affected by the CBTC design coordination process.

16.4.4. Audio and Video Signals

- 16.4.4.1. The audio signals consist of Public Address, Passenger Emergency Intercom and Crew Intercom operation. All audio signals shall be carried on the communications network, refer to Sections 13 and 16.3.6.

16.5. Maintainability Requirements

16.5.1. General

- 16.5.1.1. All equipment shall meet the maintainability design requirements in Section 2.14.4, and all hardware shall comply with the requirements of Section 19 - Materials, Processes and Workmanship.

16.5.2. Portable Test Equipment

- 16.5.2.1. The Contractor shall provide PTE software to support the operation, maintenance, analysis, diagnostics, and repair of car's trainline and network system, in compliance with Section 22 - System Support.
- 16.5.2.2. The PTE connection to the Protected Control network shall be wired. A wireless connection shall not be possible. The PTE port shall be in a location accessible only to authorized personnel.

16.5.3. Bench Test Equipment

- 16.5.3.1. The Contractor shall provide Bench Test Equipment (BTE) in compliance with the requirements specified in Section 22 - System Support.

16.5.4. Not Used

16.5.5. Network Training

- 16.5.5.1. The Contractor shall provide comprehensive, student paced, "hands-on" network training classes complete with full documentation, in compliance with requirements of Section 22 - System Support.
- 16.5.5.2. The Contractor shall deliver two series of classes following the delivery of the first production cars as per schedule specified in Section 22 - System Support:
- a) The first series shall cover basic network theory, operation, function, and standard networking techniques for monitoring and diagnostics of the R211 train and Unit networks.
 - b) The second series shall be a custom class developed by the Contractor specifically to train NYCT engineering staff on how to modify, upgrade, and add new network devices to the R211 train and Unit networks.

16.6. Validation Requirements

16.6.1. Control System Response Times

- 16.6.1.1. The train control system design shall include a response time budget analysis associated with the various commands and data. The response time budget shall include source and destination processing time, and the transmission time to each destination. The response time budget shall be submitted for approval.
[CDRL]
- 16.6.1.2. Compliance of the actual response time shall be demonstrated on the first two-Unit train.
- 16.6.1.3. The Network Response shall include the maximum response time for the change to be effective, and the maximum difference in reaction time, for the same operation, across all the cars and Units in a train.
- 16.6.1.4. The response analysis shall include a statement of acceptability by the Propulsion and the Brake supplier(s), and the Door supplier(s).

16.6.2. Network Combination Test

- 16.6.2.1. The Contractor shall develop a comprehensive laboratory mockup of the Unit network system to simulate and demonstrate the performance of networks.
- 16.6.2.2. The laboratory mockup shall include, at a minimum, all the network components and interfaces necessary to simulate a full network across two A Cars and three B Cars simultaneously, and the wireless data link specified in Section 16.3.8. The actual hardware, correct length of cable and all the connectors as specified for the cars shall be deployed to demonstrate normal network and degraded network performance.
- 16.6.2.3. Each and every failure mode shall be properly simulated and its effect fully documented.
- 16.6.2.4. The test shall include, at a minimum:
- a) Proper point-to-point addressing.
 - b) Error rate versus data rate.
 - c) Replacement of nodes.
 - d) Replacement of management computers.
 - e) Reversing coupled Units.
 - f) Direction and side determination.

g) Proper priority for real time control.

h) Response to faults.

16.6.2.5. The contractor shall submit for approval, the combined network demonstration plan, the detailed test procedures, and an actual failure modes and effects report. [CDRL]

16.6.2.6. The Network Combination test equipment shall remain intact and available for additional testing until at least one year after acceptance of the first car. Upon successful completion of these tests, the Network Combination test equipment shall become the property of NYCT.

16.6.2.7. The number of B Cars simulated shall be varied to confirm that the tests outlined in Section 16.6.2.4 work correctly with all Unit configurations. Refer to Section 2.2.1.3.

16.6.3. Network Verification on a Complete Train

16.6.3.1. The Contractor shall submit network verification procedures on a complete (two Unit) train for approval, followed by the completed report. These shall include: [CDRL]

a) Comprehensive EMC tests specific to the networks and their devices.

b) Error Rate Quantification with train speed, with a comparison made to error rates recorded during the Network Combination Test.

c) Confirmation that no Network Device or Connection is subject to shocks and vibration on the running train beyond its capability.

16.6.4. Control System Interface Analysis

16.6.4.1. For each interface listed in IEEE 1475, the Contractor shall document the Type of interface (I, II or III), signal origin, signal destination, and signal characterization.

16.6.4.2. The connectors, the pins, and the connections between devices, between cars, and within the coupler, that transfer the trainlines, network signals and high frequency information shall be justified by qualification test, fully described and subject to approval.

16.6.5. Control Signal Identification Plan

16.6.5.1. The Contractor shall submit a detailed plan regarding the identification and manner of transmission of all control signals. [CDRL].

16.6.5.2. This plan shall be submitted prior at the Preliminary Design Review, and then updated and resubmitted at subsequent design reviews.

16.6.5.3. The Control Signal Identification Plan shall include a Safety and Hazard Analysis, as defined by Section 21.3. All vital and safety related functions shall be analyzed and proven to be appropriately safe.

16.6.6. Open Architecture Information

16.6.6.1. To ensure interoperability with existing and future network interfaces, the following documentation shall be provided: [CDRL]

a) The interfaces to the network devices shall be fully described using a System Functional Description and Interface Control Documents.

b) The Contractor shall provide a complete list and comprehensive description of all network interconnections, including all application software, databases and/or configuration files as necessary to reproduce the network connections.

16.6.7. Network Analysis

- 16.6.7.1. The Contractor shall submit a detailed mitigation plan to each of the cyber security and network vulnerability requirements set in Section 18, Software Systems. [CDRL].
- 16.6.7.2. The Contractor shall submit complete, comprehensive, and detailed compatibility and interoperability documentation for each network. As a minimum, such network documentation reports shall include a glossary of terms, references, system description, system operation, system architecture, node object description, and node installation.
- 16.6.7.3. The Contractor shall submit a System Functional Description (SFD) to provide an outline of all networks and their interfaces, an overview of the train control architecture, including the proposed type of network for the propulsion, doors and friction brake to ensure their security and integrity. The Contractor shall evaluate what network type and arrangement is best for the R211 car and justify this choice of network to NYCT. [CDRL]
- 16.6.7.4. The train control architecture description document shall be updated to include all probable degraded modes and their effects. It shall first be submitted for approval for PDR.

16.7. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
16-1	16.2.3.1	Average and Peak data traffic levels and operating margins for each network	IPDR
16-2	16.3.2.2	Table of trainlines, unitlines, and coupler pin requirements, including spares and redundancy	PDR
16-3	16.6.1.1	Control System Response Time Budget Analysis	IPDR
16-4	16.6.2.5	Combined network demonstration plan, detailed test procedures, and failure modes and effects report	Prior to car FAI
16-5	16.6.3.1	Network verification procedures	CDR
16-6	16.6.5.1	Control Signal Identification Plan	PDR
16-7	16.6.6.1	Open architecture information	CDR
16-8	16.6.7.1	Cyber Security and network vulnerability	CDR
16-9	16.6.7.3	Train control architecture SFD	PDR

Section 17

Monitoring and Diagnostics

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17. Monitoring and Diagnostics

17.1. General

- 17.1.1. The Monitoring and Diagnostics System (MDS) section defines requirements related to hardware, software, and NYCT maintenance philosophy. The requirements are divided into Performance, Function, Design, Maintainability, and Validation sections. Refer to the following sections for car systems and components interfacing with the Monitoring and Diagnostics System and other applicable requirements
- a) Design and Performance Criteria – Section 2.
 - b) Cab and Cab Controls – Section 5.
 - c) Side Door System – Section 6.
 - d) Heating, Ventilation, and Air Conditioning– Section 7.
 - e) Auxiliary Electrical Equipment and Distribution – Section 9.
 - f) Propulsion System – Section 10.
 - g) Friction Brake and Air Supply Systems – Section 12.
 - h) Communications – Section 13.
 - i) Train Control System (CBTC) – Section 14.
 - j) Trainline and Car Control Architecture – Section 16.
 - k) Software Systems – Section 18.
 - l) Materials, Processes, and Workmanship – Section 19.
 - m) Reliability, Maintainability, and System Assurance - Section 21.
 - n) System Support - Section 22.
 - o) Test Program – Section 24.
- 17.1.2. The maintenance philosophy upon which the hardware and software depend shall be based on Sections 2.14 and 21.2.
- 17.1.3. Each Unit shall be provided with an on-board Monitoring and Diagnostic system.
- 17.1.4. The MDS shall collect a wide variety of accurate operating information, and current and historical fault data from all car subsystems, whether or not they utilize microprocessor controls.
- 17.1.5. The MDS shall store, analyze, and report to the crew and maintenance personnel information regarding the Unit subsystems.
- 17.1.6. The MDS in a Unit shall be capable of accessing the data collected by the MDS in any other Unit coupled into the same train.
- 17.1.7. The MDS shall include sufficient redundancy to capture and store faults and events (including those of the MDS) such that a single failure within the MDS will not cause a loss of Unit data.

17.2. Performance Requirements

- 17.2.1. The MDS shall have sufficient non-volatile storage to save fault data for 72 days between periodic maintenance without losing data to over-writes.

- 17.2.2. The time from power-up until the MDS system is fully operational, with the complete consist is displayed correctly on the Train Operator's Display (TOD), shall not exceed 60 seconds. The display shall indicate its progress towards full operation.
- 17.2.3. The time from a change in train configuration (due to coupling, uncoupling) until recognition of the new train configuration and the correct display of the new configuration on the TOD shall not exceed 30 seconds. The TOD shall indicate its progress.

17.3. Functional Requirements

17.3.1. General

- 17.3.1.1. MDS shall report information on the MDS TOD located in the cab console of each cab. Refer to Section 5.4.3 for the overall TOD screen hierarchy and formatting requirements.
- 17.3.1.2. Additional interface points, as described in Section 17.3.7.1 and 17.3.7.2, shall be provided to permit downloading of stored diagnostic data.
- 17.3.1.3. A wireless data link (see Section 16.3.8) shall be provided to transfer selected MDS system data to the wayside and to the handheld device specified in Section 22.3.6.

17.3.2. MDS Functions

- 17.3.2.1. The system shall provide information to allow the Train Crew or Road Car Inspector to immediately determine the cause of an existing or impending problem and take corrective or preventive action.
- 17.3.2.2. The system shall provide information to allow maintenance personnel to troubleshoot any problems to the Line Replaceable Unit (LRU) without the need to use external test equipment.
- 17.3.2.3. The MDS shall use the data networks described in Section 16, Trainline and Car Architecture, to efficiently, rapidly, and accurately collect information and to relay information to the TOD.
- 17.3.2.4. Network data rates shall be sufficient to support the data transfer requirements of the MDS without exceeding the bandwidth requirements specified in Section 16.
- 17.3.2.5. Not used.
- 17.3.2.6. Not used.
- 17.3.2.7. A display window on the MDS TOD Operating Screen (see Section 5.4.3) shall appear to time the period whenever the side doors are open during passenger service. The count shall show each second up to 99 seconds in clear numerals.

17.3.3. Interface with Train Operator Display

General

- 17.3.3.1. The Trouble Screen and the Maintenance Screens described in Section 5.4.3 shall obtain the information to be displayed from the MDS. Each screen may employ one or more levels of subsidiary screens that present more extensive information.
- 17.3.3.2. The interface for screen selection shall be consistent among all of the screens described in Section 5, Cab and Cab Controls.

Trouble Screen

- 17.3.3.3. The purpose of the Trouble Screen is to provide pertinent information to the Train Crew or Road Car Inspector concerning conditions that affect the immediate operation of the train.

- 17.3.3.4. Information provided on the Trouble Screen shall be a subset of information collected from the car and Unit subsystems and analog sensors.
- 17.3.3.5. Providing trouble information to the TOD shall have priority over other activities of the Monitoring and Diagnostics System.
- 17.3.3.6. A more detailed subset of trouble information shall be provided, as approved by NYCT, which shall only be accessed by use of a maintenance key (see Section 5.4.2.11).
- 17.3.3.7. The trouble information shall make it possible for maintenance personnel to isolate the fault to the LRU or Lowest Level Replaceable Unit (LLRU).
- 17.3.3.8. If corrective action must be taken immediately by the Train Operator the suggested action shall be listed on the screen.
- 17.3.3.9. The Trouble Screen shall present, as a minimum, the following train information and function, with the proposed arrangement submitted for approval **[CDRL]**:
- a) Passenger Emergency Handle Unit activation and location.
 - b) Door Not Closed, location and door leaf.
 - c) Door Open EnRoute.
 - d) Both door leafs in one doorway fail to open when commanded (annunciated after an approved number of occurrences).
 - e) All doors on one side of a car fail to open simultaneously when commanded.
 - f) Stuck Brake, location - car, truck.
 - g) Brake In Emergency (BIE), cause and location.
 - h) Trip Cock activation, location.
 - i) Insufficient Propulsion, location.
 - j) Axle lockout, location – car, truck.
 - k) Circuit Breaker Tripped, location - breaker ID.
 - l) Auxiliary Power fault.
 - m) Air Supply fault – insufficient air supply.
 - n) Hot Car (see Section 7.2.1.2).
 - o) Network Fault, location and ID.
 - p) Passenger Emergency Intercom activation, location.
 - q) CCTV fault, location.
- 17.3.3.10. The following Trouble information, as a minimum, shall only be accessed by using a maintenance key:
- a) Reduced Propulsion.
 - b) Reduced Air Brake.
 - c) Air supply fault – 1 (meaning a lesser Air Supply Fault than identified above)

d) LVPS fault – 1.

17.3.3.11. "Location" information shall be graphical to show which car in the train is affected, supplemented by text including car number and sufficient additional detail to isolate the fault to the subsystem or component.

Automatic Consist Configuration

17.3.3.12. The system shall automatically detect and provide a correctly oriented display of cars by car number as they are added or removed from the train consist, as specified in Section 17.2.3.

17.3.3.13. The train display shall include, at a minimum, the following information:

- a) Car numbers, in order.
- b) Car orientation.
- c) Lead car and active cab end.
- d) Direction of travel.

17.3.4. Maintenance Screens

General

17.3.4.1. There shall be a selection of maintenance screens, as approved by NYCT, arranged to provide access to all MDS functions and capabilities.

17.3.4.2. Access to the functions shall require the Maintenance Key (see Section 5.4.2.11).

17.3.4.3. Status screens shall display real time status information from systems, subsystems, and sensors at the train, Unit, and car level. For propulsion and service brakes see Sections 10.5.4 and 12.5.

17.3.4.4. The real-time status information shall include faults that are still active.

Fault Log Displays

17.3.4.5. The Contractor shall provide fault logs of all subsystems of all cars in the train on a separate fault logging screen.

17.3.4.6. Fault data shall include the time, car number, system, and a brief description of the fault.

17.3.4.7. Provision shall be made to edit, via a menu of options, the description of the trouble information described in Sections 17.3.3.9 and 17.3.3.10, and fault data displayed, using the wireless data link (see Section 16.3.8.1).

17.3.4.8. The format of the individual subsystem fault logs shall be consistent, regardless of the source of the fault data.

17.3.4.9. Maintenance Screens shall allow scrolling through all logged faults by subsystem or by time.

17.3.4.10. All fault logs shall be available to the maintenance personnel for review on the screen, or to be downloaded to the PTE, USB flash drive or wireless link to wayside (see Section 16.3.8).

Fault Log Memory Management

17.3.4.11. A message "Fault Log Full" shall indicate when newer faults began to overwrite faults in any fault log that are less than 72 days old.

17.3.4.12. Download of fault information to the PTE or to a flash memory card shall not automatically clear the log.

17.3.4.13. A separate action using the PTE in the password protected mode shall be required to clear the log and reset faults.

17.3.4.14. Provision shall be made to allow the MDS to temporarily suspend logging of faults, using the PTE in the password protected mode, during active troubleshooting on a subsystem. The MDS shall automatically resume normal operation when the PTE is disconnected.

17.3.4.15. Provision shall be made within the MDS and any other data storage device to take advantage of higher capacity media as it becomes available to prevent obsolescence constraints.

Access to Fault Data

17.3.4.16. The Maintenance Screens shall allow access to the fault logs of every subsystem of every Unit in an existing train, without the need to move from car to car.

17.3.4.17. A maintainer shall be able to select customized subsets of historical or status data, such as a time frame of interest or specific data from different subsystems for display on the same screen.

Access to the Event Recorder Data

17.3.4.18. Provision shall be made to allow access to the Event Recorder data on the Maintenance Screen, without the need to physically access the Event Recorder. Event Recorder data shall not be manipulated through this access.

Self-Test

17.3.4.19. A maintainer shall be able to initiate self-tests of all intelligent subsystems and view the results without changing screens.

17.3.4.20. Execution of self-tests shall be possible only when the car is stopped with brakes applied across the Unit.

17.3.4.21. Self-tests shall not create any hazards of Category I, II or III severity (see Section 21.3.3).

17.3.5. Testing Capability

17.3.5.1. It shall be possible to set up data gathering parameters in advance for a specific test run or revenue service run. Such parameters include selecting signals and display rates to be captured.

17.3.5.2. The MDS shall capture and store the system level and subsystem operating status data in case of a major fault.

17.3.5.3. Provision shall be made for adding 10 (per Unit) temporary networked sensors for use in troubleshooting. The MDS shall be capable of handling these additional inputs in the same way it handles any other data. The provisions for connection shall be determined during design review with input from NYCT.

17.3.5.4. When Units are uncoupled, the fault information of each Unit shall be resident in the Unit of origin.

17.3.5.5. Each Unit's MDS shall retain a record of other Units, including time and coupled car numbers, to which it has been coupled in its fault log.

17.3.6. Time Clock Management

17.3.6.1. The MDS master clock shall provide a master real time clock signal for the purpose of synchronizing all microprocessor based systems in the train.

17.3.6.2. The MDS master clock shall be changed through the use of a PTE and by trainline command when the Unit is operating in non-CBTC mode (see Section 18.2.3).

17.3.6.3. Provision shall be made to periodically synchronize the MDS master clock to the CBTC system. The synchronization period chosen shall prevent a drift of more than 0.1 (one tenth) seconds between MDS time and CBTC time.

17.3.6.4. Daylight savings time corrections shall be made automatically. The MDS shall allow a suspension of daylight savings time corrections by the PTE (See Section 18.2.3).

17.3.7. Monitoring and Diagnostics Data Collection and Management

- 17.3.7.1. There shall be a conveniently located connector in the cab for PTE to fully test the MDS, to download faults and to make any needed changes to user settings. The connector type shall be approved by NYCT. Refer Section 22, System Support, for PTE connector requirements.
- 17.3.7.2. The MDS shall have an integrated USB connection or other NYCT approved connection to allow user-selected downloads of fault logs without the use of PTE. The location of the connection shall be approved by NYCT.
- 17.3.7.3. The PTE shall comply with all of the requirements specified in Section 22.8.
- 17.3.7.4. The MDS shall use the wireless data link (see Section 16.3.8) for the purpose of transmitting MDS data to the wayside and the handheld device (see Section 22.3.6).
- 17.3.7.5. Communications on the wireless data link shall be secure and encrypted to prevent unauthorized users from accessing the data or system.
- 17.3.7.6. The transmission (broadcast) technique shall not interfere with or be interfered with by any other system on the train or wayside. Non-MDS functions shall not be allowed on the MDS network.
- 17.3.7.7. Separate workstations shall be provided in the maintenance facility and storage yard or other locations as defined by NYCT (see Section 22.9). The workstation shall perform the following tasks:
- a) Retrieve data from various PTEs used to download car data.
 - b) Retrieve data from USB drives used to download car data.
 - c) Retrieve data from cars through the wireless data link as described in Section 16.3.8.
 - d) Store and analyze the collected data.
 - e) Provide custom reports including multiple variable sorting based on time, car, number, specific fault, failed system, and other relevant parameters.
 - f) Provide procedures for archiving and retrieving older data.
- 17.3.7.8. The data retrieved, as described in 17.3.7.7 a), b) and c), shall include, as a minimum, the signals listed below.
- a) All event recorder signals specified in Section 17.5.2.
 - b) Train location.
 - c) Passenger area temperature.
 - d) Dwell time (doors open to doors close).
 - e) Load weigh signal, in respect of time, the route, train location and car number.

17.4. Interface Requirements

17.4.1. MDS Subsystem Diagnostics

- 17.4.1.1. The MDS shall be designed and suitably buffered such that a failure of the MDS does not adversely affect the systems it is monitoring, and failures of monitored systems and sensors do not adversely affect the MDS.
- 17.4.1.2. The Supplier shall identify heartbeat signals to be included in network monitoring. A prioritized message from a dying network device with its self-diagnostics shall be included in monitoring.
- 17.4.1.3. Wherever possible, the MDS shall be capable of distinguishing between a complete failure of a specific system and a failure to communicate with it.

- 17.4.1.4. The MDS shall communicate with other parts of itself, and with other systems and sensors through the networks described in Section 16, Trainline and Car Architecture.
- 17.4.1.5. Fault information shall not be transmitted as text messages from car subsystems to MDS.
- 17.4.1.6. The following interfaces with other subsystems are required:
- a) Time Stamp Synchronization: The Monitoring System clock shall provide the official time stamp for information from all subsystems.
 - b) Exception Reporting: Conditions outside of specified parameters shall be reported to the Monitoring and Diagnostics System.
 - c) Failure Indications: All system failures during operation or during self-tests shall be reported.
 - d) Diagnosis Documentation: All parameters associated with failure indications and exception reporting shall be clearly documented. This includes the identification of the parameters, the relationship(s) among parameters, filtering, time delays, levels, counting, and reset requirements.
 - e) Historical Data Storage: All subsystem reports shall be stored in a non-volatile memory for diagnostic use. Records shall include time stamp, condition and associated data.
 - f) Test on Demand: Each system shall respond to Monitoring System commands for controlled self-test and report the results to the Monitoring System.
 - g) Real Time Data: Each system shall provide specific pre-determined operating (status) data to the Monitoring and Diagnostics System at sampling rates appropriate to the rate of change and priority of the sampled signal and also respond to Monitoring System requests for updated data. Sampling rates shall be established during design reviews. Transmission time delays shall be defined and identifiable.
- 17.4.1.7. Identical log formats shall be used for all car systems. These data shall be accessible locally at the system, using the PTE or through the MDS.

17.5. Event Recorder

17.5.1. General

- 17.5.1.1. There shall be a physically separate Event Recorder that is independent of the MDS.
- 17.5.1.2. Each Unit shall have two Event Recorders, one per A Car, located above floor, in a secure location, inaccessible to unauthorized personnel. The location shall be approved by NYCT.
- 17.5.1.3. Event Recorders shall conform to the requirements of IEEE Std. 1482.1, "IEEE Standard for Rail Transit Event Recorders".
- 17.5.1.4. Data retrieved from the Event Recorder for use in safety related investigations by authorized personnel shall be readily presented in report format without the use of screen shots.

17.5.2. Signals to be Monitored

- 17.5.2.1. The Event Recorder shall record the Train Operator's actions, the resulting trainline commands, and various system responses.
- 17.5.2.2. The following signals are additions to, and clarifications of, the required event recorder signals from IEEE Standard 1482.1-2013, and shall be recorded:
- a) Cab Status (Train Operator (T/O), Conductor (C/R), Non-Active).
 - b) Trip Cock Activation.

- c) Contact Rail voltage.
- d) Restricted Manual (RM) Interlock Bypass Switch Status.
- e) Door Open Trainline (Left/Right).
- f) Door Enable Trainline (Left/Right).
- g) Zero speed detection (Section 10.3.7).
- h) Door interlock bypass switch status (Section 6.4.17).
- i) Three Spares.

17.5.2.3. The signals shown in Table 17-1 from the CBTC System shall be recorded.

Table 17-1; CBTC signal list

Signal	Description	Source
CBTC Operating Mode	ATO, ATPM, AWP, Yard and WSP.	Train Network
CBTC Emergency Brake Application	Indicates the signal being output by the OBCU. The CBTC supplier has stated they will configure their emergency circuits such that both OBCUs must call for emergency in order for the CBTC contacts of the local EMV control circuit to open.	
Tractive Effort Level Command	The encoded, desired Master Controller handle position.	
CBTC Measured Speed	The train speed calculated by the CBTC.	
CBTC Door Enable Left	Network indication of the discrete output from the CBTC.	
CBTC Door Enable Right	Network indication of the discrete output from the CBTC.	
Trainline and Network Controller Operating Mode	ATO, Manual, Restricted Manual, CBTC Bypass, Special Charge, Emergency Brake and Idle mode.	
CBTC Bypass Switch	CBTC, Bypass.	CBTC Bypass Switch, discrete input
Mode Switch	Normal (including AWP), Restricted Manual.	Mode Switch, discrete input
RM Release Switch	Normal, Release.	RM Release Switch, discrete input
High Performance Trainline	Indication present on the High Performance Trainline.	High Performance Trainline, discrete input
Door Open Trainline (Left/Right)	Indication the Door Open Command is active on the Trainline.	Door Open Trainline, discrete input
In ATO Mode Unitline	Indication on the Unitline when CBTC is in ATO Mode.	CBTC, discrete input

17.6. Maintainability Requirements

- 17.6.1. All equipment shall meet the maintainability design requirements in Section 2.14.4.
- 17.6.2. MDS system hardware shall comply with the requirements of Section 19, Materials, Processes, and Workmanship.
- 17.6.3. MDS system software shall comply with the requirements of Section 18, Software Systems.

17.7. Validation Requirements

MDS

- 17.7.1. The Contractor shall submit a calculation of memory use and capacity, using worst case scenarios, to demonstrate compliance with Section 17.2.1 for NYCT review and approval. **[CDRL]**
- 17.7.2. The Contractor shall submit a comprehensive Fault Management Plan for the MDS for NYCT review and approval. **[CDRL]**
- 17.7.3. The Fault Management Plan shall include but not be limited to the following:
 - a) Fault listing.
 - b) Detailed description of each fault, including fault severity level, as assigned by the subsystem.
 - c) Detailed description of the triggering conditions for each fault, including time delays and event counts.
 - d) Conditions required for fault reset.
 - e) Detailed description of the triggering conditions for subsystem lockout, including time delays and event counts.
 - f) Conditions required for lockout reset.
- 17.7.4. The layouts of Maintenance Screen and Trouble Screen shall be included in of the Screen Specification submittal as described in Section 5.8.1.4 for NYCT review and approval.
- 17.7.5. A validation program of testing shall be undertaken to demonstrate compliance this Section. See Section 24, Testing Program, for specific requirements.
- 17.7.6. The Contractor shall perform comprehensive laboratory testing to demonstrate the full performance of the MDS with all real subsystem interfaces and full functionality of the TOD. Four, five and six car Units shall be modelled. The Contractor shall simulate all fault and event conditions to complete this test requirement. This test may be performed in conjunction with the network testing required in Section 16.6.2. The testing shall be demonstrated to NYCT.

Event Recorder

- 17.7.7. Details of the event recorder design, operation, and functionality, including a list of recorded parameters, shall be submitted to NYCT for approval. **[CDRL]**.
- 17.7.8. The Contractor shall demonstrate via test that the event recording memory module meets the crashworthiness requirements listed in Table 4 of IEEE-1482.1-2013.

17.8. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL #	Clause	Title	Due
17-1	17.3.3.9	Trouble Screen arrangement	CDR
17-2	17.7.1	Calculation of memory use and capacity	CDR
17-3	17.7.2	Fault Management Plan	PDR

17-4	17.7.7	Details of the Event Recorder design, operation, and functionality	PDR
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Section 18

Software Systems

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18. Software Systems

18.1. Introduction and General Requirements

- 18.1.1.1. This section defines the requirements for all software for the R211 project. All software, whether resident within a microprocessor-controlled intelligent subsystem, provided as part of test equipment, for the purpose of post-download fault log processing, or incorporated within training technology, shall be subject to the same requirements, except as stated within this Specification.
- 18.1.1.2. The requirements of this section apply to programming of all programmable devices, including microprocessors and microcontrollers (both termed “processors” in this section), Programmable Logic Devices (PLD), Application-Specific Integrated Circuit (ASIC), or Field-Programmable Gate Array (FPGA).
- 18.1.1.3. All software for this project, whether supplied by the Contractor or a subcontractor, shall be subject to the requirements of this section.
- 18.1.1.4. The requirements for design for obsolescence management specified in Section 2.14.7 shall apply to all processor based systems. The software associated with processor based systems that are identified as being likely to be affected by obsolescence over the life of the car shall include provisions to support future portability. These provisions shall be included in the applicable Software Requirements Specification (SRS).

18.2. Functional Requirements

18.2.1. General

- 18.2.1.1. The software shall monitor all inputs for unsafe, erroneous, unknown conditions, or combinations of these conditions.
- 18.2.1.2. The software shall sample all input conditions at cycle rates fast enough to detect and remedy unsafe or irregular conditions, and so implement protective or warning measures.
- 18.2.1.3. The software shall limit all output commands to prevent equipment damage and hazards to personnel.
- 18.2.1.4. The software shall respond predictably and safely when the system is powering up and recovering from power interruptions or system resets.
- 18.2.1.5. The software shall perform system self-diagnostics and respond safely and predictably to all detected faults.
- 18.2.1.6. Software self-diagnostic routines shall include tests for program corruption and integrity in read and write memories.
- 18.2.1.7. The software shall permit interrogation of subsystems for faults using external diagnostic equipment.
- 18.2.1.8. Software programs shall be modular in design, using separate executable or operating software modules to call software routines.
- 18.2.1.9. The Contractor shall be responsible for the complete car software design, the partitioning of the requirements for subsystems, and the integration of the subsystems into the complete car.
- 18.2.1.10. The Contractor shall be responsible for ensuring the allocation of the requirements to the subsystem suppliers.

- 18.2.1.11. The Contractor supplied Software Verification and Validation Plan (SVVP) shall describe the integration of the subsystems to address the requirements of the entire car, Unit, or train.
- 18.2.1.12. After power interruption, the Software shall ensure that all corrupted routines and data stored in memory are re-initialized to a safe operating condition. After an interruption of power, any calculated operational state (such as grid temperature) shall be restarted in a system-safe condition, which may include a calculated value allowance for the interruption interval.
- 18.2.1.13. Processor based system parameters shall be structured as intuitive tables and adjustable via Portable Test Equipment (PTE) by authorized personnel.
- 18.2.1.14. Parameter ranges shall be included in the appropriate subsystem SRS.
- 18.2.1.15. Processor based systems that perform vital functions shall comply with Section 21.3 System Assurance.

18.2.2. Hardware Platform

- 18.2.2.1. Car-borne and custom designed hardware shall be designed and constructed in accordance with the general electronic design principles of Section 19, Materials, Processes and Workmanship.
- 18.2.2.2. Microprocessor-based systems shall be based on an established family of microprocessors and controllers with prior revenue service in the rail transit industry.
- 18.2.2.3. Any use of commercially available hardware shall be approved by NYCT prior to implementation. The use of commercially available hardware shall be optimized by the suppliers and the Contractor.
- 18.2.2.4. Microprocessor controllers shall be powered by isolated power supplies and shall operate across the full voltage range of the car's battery and low voltage power supply.
- 18.2.2.5. These isolated power supplies for microprocessor systems shall be multiple sourced, readily available, interchangeable, and approved by NYCT.
- 18.2.2.6. All car-borne control system inputs and outputs shall be electrically isolated.
- 18.2.2.7. All control system hardware shall meet IEC60571 Ed.3: "Railway Applications – Electronic Equipment Used on Rolling Stock".
- 18.2.2.8. The use of voltage divider circuits that utilize car ground as a reference are not preferred and shall be subject to NYCT approval.
- 18.2.2.9. Program code and fixed (constant) parameters shall be stored in protected non-volatile memory.
- 18.2.2.10. The use of a uniform multi-level password for all PTE functions shall be required to enable any monitoring, troubleshooting, or reprogramming of car-borne hardware.
- 18.2.2.11. Circuit board mounted batteries (one per system) shall be restricted to maintaining a clock and calendar (see also Section 18.2.3).
- 18.2.2.12. Circuit board mounted batteries shall have a life expectancy under normal car operating conditions of at least eight years.
- 18.2.2.13. The system shall annunciate the need for battery replacement via the Monitoring and Diagnostic System (MDS).
- 18.2.2.14. The processor shall store control data in non-volatile memory upon detection of loss of power.
- 18.2.2.15. For all processor systems, the working margins for the spare capacity of the memory and their normal and peak processor cycle time shall be subject to NYCT approval.
- 18.2.2.16. Peak memory usage in any system shall be not greater than 70 percent of the installed capacity in that system, to allow for future changes.

18.2.2.17. In any case, the peak processor cycle time shall not be more than 50 percent of the available processor time.

18.2.3. Time and Date Management

- 18.2.3.1. A master real time clock signal shall be provided by the MDS for the purpose of synchronizing the Unit time and date to all processor-based subsystems.
- 18.2.3.2. The time and date software for all systems shall allow for the time to be adjusted across the entire car (or for any part of the system), forward or back, without incorrect operation or loss of data.
- 18.2.3.3. All time displayed to the train crew, maintenance personnel, or passengers shall be adjusted to the current local time, in accordance with daylight savings time policies. Any manual adjustments shall be made via PTE or the MDS. This shall include a convenient PTE facility to turn off the daylight saving mode.
- 18.2.3.4. The display shall be in 12-hour format for the passengers and 24-hour format for the train crew and for all maintenance use.
- 18.2.3.5. All recorded data within any car or test software shall be time-stamped with Unit time including a four-digit year format.
- 18.2.3.6. The subsystem clock or time function shall not be used for internal timers or any other function.
- 18.2.3.7. Time setting operations shall be fully recorded in the MDS and indicated in the Event Recorder.
- 18.2.3.8. The Contractor shall identify all real-time clocks in the system including test equipment.
- 18.2.3.9. All software and hardware delivered or developed under this Contract shall be capable of handling all times and dates in the range from 1990 through 2100.
- 18.2.3.10. The date processing shall not experience abnormal ending and/or invalid or incorrect results from the hardware, software, data repository, or firmware.
- 18.2.3.11. Proper time and date processing requirements shall be included in the SRS for all relevant subsystems.
- 18.2.3.12. There shall be no "Y2K" or "year 2036" or "year 2038" type problems with the software.
- 18.2.3.13. The MDS clock shall be accurate such that, when periodically updated to global time, the correction should be minimal. At most, updates shall affect the indication of seconds.
- 18.2.3.14. Periodic synchronization of MDS time with global time shall occur when the Communication Based Train Control (CBTC) system is active or in restricted mode.

18.2.4. Operating Systems and Programming Languages

- 18.2.4.1. Software shall be written in a high level programming language appropriate for its device or application.
- 18.2.4.2. The software language and its implementation shall be commercially available in English. All comments embedded or accompanying the Source Code shall be in English.
- 18.2.4.3. No proprietary software language shall be used for software development.
- 18.2.4.4. All software languages shall have a prior installation history in rail applications and shall be approved by NYCT.
- 18.2.4.5. Each software supplier shall include methods and procedures to prevent unauthorized changes to their Basic Input /Output System (BIOS) and other firmware. The software supplier shall document

these methods, procedures and mitigation recommendations in their System Functional Description (SFD).

18.2.5. Software Supplier Qualifications

- 18.2.5.1. All software suppliers shall have a well-established formal mature software developmental process.
- 18.2.5.2. The Contractor shall submit a list of any commercially available software used in the development, assembly, or maintenance of the R211 cars to NYCT for approval. The list shall be resubmitted whenever it is updated, or at the request of NYCT. [CDRL]
- 18.2.5.3. Commercially available software documentation requirements shall not be limited to the original data/transfer media, functional and usage details, manuals, and any required licenses.
- 18.2.5.4. For commercial software, the Contractor shall supply NYCT with the same complete software package with licenses as NYCT would receive as an original purchaser, including the proven installation.
- 18.2.5.5. All non-commercial software suppliers shall demonstrate operation at the maturity level 2 for the Capability Maturity Model Integration (CMMI) for Software and System Engineering, as defined by the Software Engineering Institute at Carnegie Mellon University in Pittsburgh, PA.
- 18.2.5.6. To confirm a software supplier's capability, the Contractor shall submit either an independent software capability evaluation, or an independent standard CMMI appraisal method for process improvement. [CDRL]
- 18.2.5.7. If any software provider cannot demonstrate CMMI capability, the software supplier shall be subject to NYCT approval.
- 18.2.5.8. The Contractor shall incorporate training on how the software is to be used in the specific situation for which it was provided, as part of the Training Program.
- 18.2.5.9. Training shall include the use of all workstations and their software, including all commercial and custom software used for the development and maintenance of every software application.

18.2.6. Cyber Security

- 18.2.6.1. Each software supplier shall be responsible for removal of all software features/modules that are not required for the on-going operation and/or maintenance of their systems within the R211 cars. If removal is not technically feasible, the software supplier shall disable that software function/module. This removal or disabling shall not impede any R211 required functionality.
- 18.2.6.2. The Contractor shall document those functions and modules that are not required or disabled, including their method of removal or disablement. If software that is not required per 18.2.6.1 cannot be removed or disabled, the software supplier shall explain the reason for this classification, and estimate any associated risk as well as how each risk is mitigated in the SFD.
- 18.2.6.3. Each software supplier shall employ the Principle of Least Privilege to configure their system, where information requested for transfer between processes and systems is only that necessary for their legitimate purpose. Each software supplier shall document what information its software makes available to other systems or processes and what information it obtains from other systems or processes.
- 18.2.6.4. The Contractor shall declare to NYCT the country (or countries) of origin of each procured hardware and software product associated with any system to be used on or with the R211 cars.
- 18.2.6.5. Each software supplier shall identify all the countries where the development, assembly, and maintenance for their product are provided.

- 18.2.6.6. NYCT shall have the right to review and disapprove of any software supplier.
- 18.2.6.7. The Contractor shall notify NYCT of changes in the list of countries where services are provided in support of their product.
- 18.2.6.8. Each software supplier shall provide a Contingency Plan for sustaining the security of the procured product in the event they leave the transit business. This plan shall be delivered to NYCT prior to their software delivery, as an appendix to the Software Project Management Plan (SPMP).
- 18.2.6.9. NYCT shall have the right to request documentation of each software supplier's implemented cybersecurity program, including recent assessment results.
- 18.2.6.10. NYCT shall have the right to conduct onsite or penetration security assessments of the software supplier's facilities. These security assessments may be conducted by an independent specialist third party, at the discretion of NYCT.
- 18.2.6.11. Each software supplier shall provide summary documentation to attest to its workforce receiving position-appropriate cybersecurity training and awareness. This includes specialized training for those involved in the design, development, manufacture, testing, shipping, installation, operation, and maintenance of products procured by NYCT as part of the software supplier's cyber security program. [CDRL]
- 18.2.6.12. The software supplier shall follow the NYS Information Technology Policies, Standards, and Best Practice Guidelines found at <https://www.its.ny.gov/tables/technologypolicyindex>, in particular Information Classification (NYS-S14-002), Encryption (NYS-S14-007) and Wireless (NYS-S15-003) standards.
- 18.2.6.13. The software supplier shall demonstrate a capability for detecting unauthorized access throughout the delivery process to any part of their product.
- 18.2.6.14. The associated hardware supplier shall use trusted channels to ship processor(s), memory hardware, and firmware.
- 18.2.6.15. The software provider shall list and provide NYCT all the Commercial off the Shelf (COTS) hardware or systems used within or to develop or assemble its product. The list shall be resubmitted whenever it is updated, or at the request of NYCT. [CDRL]

18.3. Maintainability Requirements

- 18.3.1.1. The Contractor shall provide all of the software documentation listed in Sections 18.4.1.4 and 18.5, as required by Attachment 18-1 and at the correct version associated with their use. The Contractor shall also provide all the associated documentation that is referenced within a submitted document.
- 18.3.1.2. NYCT shall be granted a license, valid for the life of the cars, to use all the software, present and updated, that is resident in all Computers, Workstations, PTEs, and Bench Test Equipment (BTE). (Refer to Contract Terms and Conditions; Article 105 Authority's Rights in Property).
- 18.3.1.3. NYCT shall be granted the use of these licenses to be used in any non-production rolling stock test environment to conduct feasibility analysis and system review of current or upgraded software code.
- 18.3.1.4. All changes to software shall be rigorously reflected in the software's version number, its associated documentation and configuration records.
- 18.3.1.5. The software shall permit access to the software version number via the PTE and the MDS.

- 18.3.1.6. The Contractor shall develop and maintain a Software Configuration Management Plan (SCMP) of all the Software Configurable Item (SCI)'s used, developed, and purchased for traceability purposes. The SCMP shall be updated whenever a SCI changes, including its version.
- 18.3.1.7. The SCMP, including content and format, shall be submitted for NYCT approval, and resubmitted whenever it is updated or at the request of NYCT. [CDRL]
- 18.3.1.8. The Contractor shall submit a final software configuration report, in an electronic format for all SCIs for each car at the time of acceptance or conditional acceptance.
- 18.3.1.9. All software shall be identified by name and version number; the name selected shall identify the equipment into which the software is installed.
- 18.3.1.10. Workstation and PTE equipment shall demonstrate proper functionality that may include but not be limited to event analysis, software examination, changes, compilations, verification, configuration, etc.
- 18.3.1.11. For all software associated with the R211 project (other than commercial software defined in 18.3.1.12), NYCT requires that its source code, a fully annotated source file listing, data/parameter files, and development/application package, including workstation(s) be delivered to NYCT. NYCT will keep the source code files and its development/application information secure and make conditional nondisclosure agreements with the software suppliers. (Refer to Contract Terms and Conditions; Article 105 Authority's Rights in Property).
- 18.3.1.12. For commercially available software, or software which has previously been developed and previously successfully employed on at least three other completely separate applications, then the executable file(s), data/parameter files, and complete functional, licensing, and usage documentation shall be provided on readily available contemporary electronic media.
- 18.3.1.13. Prior to end of the Contract warranty period, all the software installed on all systems directly associated with the R211, including all car systems and their maintenance software (PTE and BTE), shall be installed from workstations within NYCT. This to verify the process of supplying and uploading the latest approved version of all the software directly associated with the R211 from the code types delivered to NYCT. All or part of this software installation shall be either made by or witnessed by NYCT. Any keys, codes, dongles, cards, etc. necessary to enable the reprogramming of the application shall be provided to NYCT no later than this time.
- 18.3.1.14. For all software that uses parameter files, NYCT shall be provided with sufficient information in English to allow authorized personnel with a basic understanding of the software and the system to change parameters without the need to involve the original supplier. This information, and any appropriate warnings, shall be included with the parameter files, and/or separately in an application-specific Software Design Description (SDD) or similar document.
- 18.3.1.15. Contractor-supplied workstations shall include all software development tools including associated manuals. These software development tools and associated manuals shall be those used by the original software developers.
- 18.3.1.16. During the design, testing and warranty periods, any software security flaws identified in Contractor-supplied workstations and PTEs shall be patched by the Contractor in a timely fashion in accordance with the New York State Information Technology Policies, Standards, and Best Practice Guidelines which can be found at <https://www.its.ny.gov/tables/technologypolicyindex>.

18.4. Validation and Documentation Requirements

- 18.4.1.1. Software code (programs) and data shall have error detection based on a designated Cyclic Redundancy Check. This utility shall be included in the PTE, Software Workstations, and the MDS and used to confirm the integrity of the software item.

- 18.4.1.2. Software version and checksum shall be included in code and readable using the PTE, Software Workstations, and the MDS.
- 18.4.1.3. All custom application software developed shall be in accordance with IEEE Standard 1558, "Standard for Software Documentation for Rail Equipment and Systems" and the requirements stated within this Specification.
- 18.4.1.4. The Contractor and each software supplier shall develop and submit the following documents, and comply with the documentation requirements in IEEE Standard 1558 for a type 5 development, in a common format per the requirements of that Standard, to NYCT for approval:
- a) System Functional Description (SFD).
 - b) Software Project Management Plan (SPMP) per IEEE 1058, "IEEE Standard for Software Project Management Plans".
 - c) Software Quality Assurance Plan (SQAP) per IEEE 730, "IEEE Standard for Software Quality Assurance Processes".
 - d) Software Configuration Management Plan (SCMP) per IEEE 828, "IEEE Standard for Configuration Management in Systems and Software Engineering".
 - e) Software Verification and Validation Plan (SVVP) per IEEE 1012, "IEEE Standard for System and Software Verification and Validation".
 - f) Software Verification and Validation Report (SVVR) per IEEE 1012, "IEEE Standard for System and Software Verification and Validation" and IEEE 1558.
 - g) Software Requirements Specification (SRS) per IEEE 830, "IEEE Recommended Practice for Software Requirements Specifications".
 - h) Interface Control Document (ICD) per the ICD requirements of this Specification and IEEE 1558.
 - i) Software Design Description (SDD) per IEEE 1016, "IEEE Standard for Information Technology - Systems Design - Software Design Descriptions".
 - j) Software Requirements Traceability Matrix (SRTM) per IEEE 1558.
 - k) Software Test Plan (STP) per IEEE 829, "IEEE Standard for Software and System Test Documentation".
 - l) Software Test Procedure (STPr) per IEEE 829, IEEE Standard for Software and System Test Documentation".
 - m) Software Test Report (STR) per IEEE 829, "IEEE Standard for Software and System Test Documentation".
 - n) Software User Manual (SUM) per Section 22.3.11.
 - o) Software Maintenance Manual (SMM) per Section 22.3.12.
 - p) Cybersecurity Training and Awareness Documentation per Section 18.2.6.11.
- 18.4.1.5. A waiver to the IEEE Standard 1558 requirements may only be granted by NYCT if the software provided will never require modification or customization for this application and has prior revenue service in rail transit.
- 18.4.1.6. All documents shall be in compliance with all referenced standards as defined in IEEE Standard 1558.

- 18.4.1.7. The Contractor shall submit, as part of the Preliminary Design Review (PDR) package, the Software Quality Assurance Plan (SQAP) that specifically includes all its subsystem vendors and the overall SPMP used to manage all the software suppliers. [CDRL]
- 18.4.1.8. The Contractor shall ensure that all software suppliers are identified and shall submit for approval, as part of the PDR package, their SQAP, SPMP, SCMP, SFD, SRS, STP, SVVP, and SRTM. [CDRL]
- 18.4.1.9. The Contractor shall ensure that each software developer provides an updated SRTM with each of the following submittals SFD, SRS, SDD, STP, and STPr.
- 18.4.1.10. The Contractor and software suppliers shall submit, as part of the In-Process Design Review (IPDR) package, updates of the SFD, SRS, SVVP, and updated SRTM.
- 18.4.1.11. The Contractor and software suppliers shall submit, as part of the Critical Design Review package, completed versions of the SFD, SRS, SDD, STPr, SVVP, and SRTM.
- 18.4.1.12. Each software developer shall submit test reports for approval. These shall include a report for each STPr and a SVVR for the complete system, along with an updated SRTM prior to commissioning of the first car. The SVVR shall be a compilation of the results of the Verification and Validation activities, as planned in the SVVP, and shall conform to IEEE Std 1012. The mapping of SVVR results to corresponding SVVP activities shall be clear and precise. The SVVR shall include a statement indicating whether the Validation Process provides evidence that the products satisfy system requirements for functionality, safety, and reliability, and satisfy intended use and end user needs
- 18.4.1.13. Each subsystem supplier shall develop a software test plan and test procedures that provide a clear understanding of the processes and ensure correctness, function, and safety of the software contained within the subsystem equipment.
- 18.4.1.14. The Contractor shall submit all software test plans and test procedures to NYCT for review and approval prior to their testing.
- 18.4.1.15. All features and functions of the software systems shall be testable on a system level. Test plans and procedures shall include tests of all available software features and functions.
- 18.4.1.16. Any special test equipment required shall be supplied by the Contractor and shall become the property of NYCT.
- 18.4.1.17. Type tests of all processor based systems shall verify the proper operation of all software features, including system diagnostics.
- 18.4.1.18. The Contractor shall witness all software verification and validation testing prior to the release of any software. NYCT reserves the right to attend these tests.
- 18.4.1.19. NYCT shall have the right to conduct its own cyber-security vulnerability and penetration testing, and/or require a cyber-security status report prior to the release of any software. See Section 18.2.3.9 for additional details.
- 18.4.1.20. Any cyber-security vulnerability found must be directly corrected or must have compensating controls approved by NYCT.
- 18.4.1.21. The Contractor shall demonstrate through analysis and test, that times and dates will be correctly provided through the required span of years on all systems.
- 18.4.1.22. The Contractor shall provide analysis of the design impact as it pertains to correct processing of train time, see also Section 18.2.3. The analysis shall contain the following, and shall be submitted for approval: [CDRL]
 - a) Identification of all clocks in the system both on the car and off.

- b) Definition of the internal representation for the time and year and the algorithms used.
 - c) Identification of all critical times requiring special processes, describing how processing will execute without creating errors.
 - d) Definition of the interfaces between subsystems (networking).
 - e) Provision of a test procedure based on the above requirements that demonstrates the correct handling of dates by the individual subsystems and by the processor systems, including COTS software.
- 18.4.1.23. The supplier shall document all "software accounts" (background processes) within the R211 Contract (including, but not limited to, generic and/or default) that are active, prior to its delivery.
- 18.4.1.24. Upon request, the supplier shall return or document the secure disposal of all NYCT data and NYCT-owned hardware that is no longer needed by the software supplier per National Institute of Standards and Technology (NIST - an agency of the U.S. Department of Commerce) Special Publication [SP] 800-80.
- 18.4.1.25. A summary schedule for software documentation is provided in Attachment 18-1.

18.5. Control of Software Modifications

- 18.5.1.1. Following qualification of a system containing software, the Contractor shall submit a Software Modification Request (SMR) (see Sections 20.2.7.10 through 20.2.7.12) for any change to any software within the car or on the PTE. All supplier requests and information submittals shall be approved by, and submitted through, the Contractor.
- 18.5.1.2. The Contractor shall follow the process described in Section 20.2.7.12.
- 18.5.1.3. The software supplier shall implement an approach for collecting and storing (e.g., transfer or log forwarding) security log files. The software supplier shall time stamp audit trails and log files, as specified.
- 18.5.1.4. If required, the software supplier shall provide confidentiality and integrity security protection of log files.
- 18.5.1.5. Following successful implementation of the SMR, any affected documentation (refer to Section 18.4.1.4) shall be amended and resubmitted.

18.6. Software Operational Adjustments

- 18.6.1.1. Operational adjustments to be made by stored parameters in software shall reside in non-volatile memory. The number of adjustments which can be made directly via the PTE shall be kept to a minimum, and shall be listed in the SUM.
- 18.6.1.2. Location in the user interface and scaling of all operational adjustment parameters shall be clear and obvious to authorized personnel. The procedure and the effect of changing an available parameter shall be fully explained in the SUM.
- 18.6.1.3. Numeric parameter values shall be in decimal notation and expressed in customary U.S. units of measure, as stated in Section 1.5.4.
- 18.6.1.4. The use of a PTE incorporating user access restrictions, as specified in Section 22.8.5 shall be required in order to initiate parameter changes.
- 18.6.1.5. Parameter adjustment features shall not allow adjustment beyond safe and reasonable limits. If it is not possible for the software to determine if a parameter value is safe, both the user interface and the SUM shall warn the user that it is their responsibility to enter safe values.

18.7. Software Modification and Upgrade Support

- 18.7.1.1. The Contractor shall support five software upgrade-cycles within a 20-year period, to the car subsystems defined in Table 18-1. This period shall start after the end of warranty of the last car.

Table 18-1: Software Support Matrix

Car Subsystem
Propulsion System
Auxiliary Power Supply System including Low Voltage Power Supply
Friction Braking and Air Supply System
Master Controller
Trainline / Network Control system including logic control unit
Automatic Train Control System for R211S

- 18.7.1.2. Software upgrades may be requested by NYCT to change the existing version of the respective subsystem’s software by adding minor new features and/or improvements; or by adding significant new features and/or enhancements.
- 18.7.1.3. The scope of the software upgrades shall be capped as described in the Contract Terms and Conditions.
- 18.7.1.4. The scope of the upgrade shall include all design, documentation and lab testing work needed to confirm the change, and support for a trial installation, including testing, on a single Unit, car or piece of equipment, as applicable. It shall not include fleet installation or NYCT testing.
- 18.7.1.5. Emergency software patches, intended to rectify software defects/ bugs otherwise found to be related to product development or quality, shall not be counted as part of the upgrade cycles noted in Section 18.7.1.

18.8. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement

CDRL	Ref	Deliverable	Timing
18-1	18.2.5.2	List of any commercially available software	CDR
18-2	18.2.5.6	Independent software capability evaluation	CDR
18-3	18.2.6.11	Cybersecurity training and awareness documentation	CDR
18-4	18.2.6.15	List of COTS hardware or systems	CDR
18-5	18.3.1.7	Software Configuration Management Plan	IPDR
18-6	18.4.1.7	Software Quality Assurance Plan	PDR
18-7	18.4.1.8	SQAP, SPMP, SCMP, SFD, SRS, STP, SVVP, SRTM.	CDR
18-8	18.4.1.22	Analysis of the design impact of processing train time	CDR

	PDR	IPDR	CDR	Following Test	Delivery
Contractor	Cyber-security training				Cyber-security
	SQAP	CMMI appraisal			
		SCMP	SCMP update	SCMP update	SCMP final
	SPMP	Commercial list			
	STP				
	SVVP			SVVR	STR
					SUM
				SMM	
Each Software Supplier	Cyber-security training				Cyber-security
			Vehicle time		
			COTS list		
			Power supplies	Processor margin	
	SQAP				
	SCMP	SCMP update	SCMP update	SCMP update	SCMP final
	SPMP				SPMP+Contingency Plan
	STP				
	SFD	SFD update	SFD complete		
	SRS	SRS update	SRS complete		
	SVVP	SVVP update	SVVP complete	SVVR	STR
	SRTM	SRTM update	SRTM complete	SRTM redline	SRTM final
			ICD complete	ICD redline	ICD final
			SDD complete	SDD redline	SDD final
		STPr complete	STPr redline	STPr final	

Attachment 18-1 Summary Schedule for Software Documentation.

Section 19

**Materials, Processes, and
Workmanship**

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19. Materials, Processes, and Workmanship

19.1 General Requirements

19.1.1 Applicability

- 19.1.1.1 Materials and workmanship shall be in accordance with the requirements of this section, unless otherwise approved by NYCT via the Specification Approval Request (SAR) process. See Section 20.2.7.
- 19.1.1.2 This section is applicable to all parts of the car, whether furnished by the Contractor or by any suppliers, including the internal component design and construction of equipment furnished by all suppliers.
- 19.1.1.3 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 the appropriate R211 Technical Specification sections take precedence over this section.

19.1.2 Quality

- 19.1.2.1 In accordance with Section 23.3, the Contractor's Quality Assurance (QA) Program shall assure that all aspects of the Contract are in conformance with the design, materials, and workmanship requirements provided in this Specification.

19.1.3 Workmanship

- 19.1.3.1 Workmanship and quality shall conform to the best manufacturing practices in all respects. All work shall be performed by qualified personnel who are properly trained and skilled in the tasks they will be performing, using the correct application of tooling and procedures, based upon NYCT approved design documentation, and the material manufacturer's recommendations and instructions.
- 19.1.3.2 Surfaces exposed to passengers, crew, or maintainers shall be smooth and free of burrs, sharp edges or corners, and dangerous protrusions. The car design shall avoid pinch points, tripping hazards, snagging points, water traps, and debris accumulation points.
- 19.1.3.3 Uncovered edges on equipment exposed to passengers or maintenance personnel shall be smoothed to comply with UL 1439.
- 19.1.3.4 Foreign matter, such as packaging, protective plugs, caps, shavings, chips, trimmed materials, etc., shall be completely removed from all parts of the car, its components, assemblies, and subassemblies, whether hidden or exposed.

19.1.4 Standards

- 19.1.4.1 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 (AA), Association of American Railroads (AAR), American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), ASTM International (ASTM), Federal Railroad Administration (FRA), Insulated Cable Engineers Association (ICEA), Institute of Electrical and Electronics Engineers (IEEE), National Electric Code (NEC), Society of Automotive Engineers (SAE), and additional requirements, as specified herein. See Section 1, General Requirements and Scope for descriptions of the abbreviations noted in this requirement.

19.1.4.2 The reference standards listed herein are provided for convenience. It is the responsibility of the Contractor to implement all applicable standards.

19.1.5 Storage of Material

19.1.5.1 All materials intended for use in the car construction, either as permanent application, or for use in the manufacturing process, shall be marked or stored so as to be readily identifiable.

19.1.5.2 All stored material subject to corrosion, loss of coatings or lubrication (including fasteners), degradation or contamination from airborne dirt, debris, or other environmental conditions in the storage area shall be adequately protected by waterproof covers, coatings, or packaging to prevent damage and debris accumulation. Equipment covers, cable entrances, and openings shall be suitably closed with caps, plugs, or seals, to prevent ingress of water or dirt.

19.1.5.3 All dated material shall have the expiration date clearly marked on the individual container and on the external packaging such that it may be viewed as stored. Material that has expired, or is beyond the stated shelf life, shall not be used.

19.1.5.4 Material or components that require maintenance during storage shall be clearly identified on the exterior of the packaging, and be properly maintained per the component(s) manufacturer's instructions. The Contractor shall document such maintenance, and provide these records as requested by NYCT.

19.1.5.5 No equipment shall be stored with batteries installed, except for circuit boards containing batteries soldered to the printed circuit board.

19.1.5.6 Rejected or damaged material shall be clearly marked, dispositioned, and stored separately from all other material. Materials that are modified or re-worked, and dispositioned for re-use shall be clearly identified as modified or re-worked. The use of modified or re-worked material shall be subject to NYCT review and approval.

19.1.5.7 Materials, such as rubber, whose properties are altered by long-term storage, temperature variations, and environmental exposure shall be marked with date of manufacture and shelf life expiration date. Where appropriate, the drawings shall specify the required storage conditions, the required material properties, and the maximum storage duration. If affected by storage, the condition and material properties at the time of installation shall be verified prior to use.

19.1.6 Materials

19.1.6.1 All materials utilized in the construction of the car shall be subject to the approval of NYCT. The Contractor shall keep a running list of all materials used in the car in matrix format. The matrix shall contain the material name, material ID number, applicable specifications, application, approval status, correspondence number, etc. The Contractor shall submit this matrix along with material certifications and material property test reports to NYCT for review. [CDRL]

19.1.6.2 All materials used shall be readily available in the United States.

19.1.6.3 The Contractor shall submit any plans, procedures, test reports, and certificates requested by NYCT.

19.1.6.4 All materials selected by the Contractor shall be suitable for their intended purpose and function, and shall perform safely and satisfactorily within their operating environment at NYCT, including maintenance operations.

- 19.1.6.5 Whenever a commercial material is not covered by a specification or standard, the Contractor shall identify the material by the commercial trademark, name, material identification number, and address of the supplier. For any material not covered by published specification or standard, the Contractor shall submit a description and the technical data specifications and characteristics of the material composition for approval by NYCT. [CDRL]
- 19.1.6.6 The Contractor shall maintain records that trace all materials to their manufacturers, and shall allow verification of material compliance with quality standards specified or cited in these provisions.
- 19.1.6.7 Sole-source materials (e.g., materials available from a single manufacturer only) shall not be permitted unless approved by NYCT. Approval shall be determined on a case-by-case basis. Specification equivalency and benefit data for any substitution to a cited standard shall be submitted to NYCT for review and approval. [CDRL]
- 19.1.6.8 The Contractor shall submit, for NYCT review and approval, a copy of all Material Safety Data Sheets (MSDS) and Technical Data and Specification Sheets (TDSS), for all chemical and/or non-metallic materials (paints, solvents, adhesives, caulking, etc.) used in the manufacture of the car. [CDRL]
- 19.1.6.9 MSDS and TDSS shall also be provided for all lubricants used in the completed car. The Contractor shall also provide MSDS and TDSS information as requested by NYCT for any additional material in question. Information shall be in a form compliant with the requirements of ANSI Z400.1. The list of approved lubricants for NYCT is located in Appendix C-12 (Lubricants Approved for Car Equipment Use).
- 19.1.6.10 All materials shall be new and of recent manufacture. Material found to be defective and subsequently repaired cannot be used unless specific approval is granted by NYCT. See Section 19.1.5.6.
- 19.1.6.11 All materials used shall be inherently corrosion resistant, or be suitably finished or treated with a corrosion resistant finish to minimize corrosion and degradation of appearance and/or function.
- 19.1.6.12 All non-metals shall comply with the Flammability, Smoke Emission, and Toxicity requirements of Section 19.1.10.

19.1.7 Prohibited Materials

- 19.1.7.1 The following materials are prohibited from use on the cars, in addition, reference Appendix C-22 (General Requirements-Restricted Chemical Substances):
- a) PVC.
 - b) Asbestos.
 - c) Cadmium (except for battery).
 - d) Lead (excluding electrical solder on printed circuit boards).
 - e) Polychlorinated Biphenyl (PCB) compounds.
 - f) Materials that, in their normal, installed state, emit products that are known to be toxic, carcinogenic, or irritants.
 - g) All Chlorinated fluorocarbon (CFC and HCFC) compounds classified as ozone depleting substances per 40 CFR 82.
 - h) Air Contaminant materials listed in 29 CFR Sec. 1910.19.
- 19.1.7.2 The Contractor shall provide a statement of compliance certifying these materials are not present. [CDRL]

19.1.8 Corrosion Control

- 19.1.8.1 All materials used shall be either inherently corrosion resistant, or suitably treated or coated to resist corrosion. Equipment located in areas highly susceptible to corrosion shall be made from inherently corrosion resistant materials.
- 19.1.8.2 Areas exposed to corrosive fluids or cleaning solutions shall be protected with coatings resistant to those fluids. The Contractor shall be responsible for verifying that all such areas are protected.
- 19.1.8.3 The Contractor shall prepare a Corrosion Control Plan, which shall locate all materials that require treatment to prevent corrosion due to atmospheric exposure, treatment of faying metallic surfaces, and areas of dissimilar metal or other material joining that could result in galvanic action and material deterioration. This plan shall document the methods used to preclude failure due to corrosion for any of the above conditions. The Contractor shall update this document as materials and treatments change. The Corrosion Control Plan shall be submitted to NYCT for review and comment. [CDRL]
- 19.1.8.4 The recommendations contained in UMTA-DC-06-0152-83-1, "A Corrosion Control Manual for Rail Rapid Transit," shall be used, except as otherwise directed by NYCT.
- 19.1.8.5 Procedures shall be provided for removal of temporary coatings, packing, protective films, and corrosion protection materials for materials delivered under this Contract as separate items, such as individual components.
- 19.1.8.6 Except as otherwise indicated, all aluminum exposed to view in finished work in the interior of the car shall have a protective anodized coating.

19.1.9 Dissimilar Metal Treatment

- 19.1.9.1 Direct contact between galvanically dissimilar metals is prohibited, except allowed herein, in Section 3, Carbody Structure, and for electrical connections between copper and aluminum where appropriate joint compounds are used as specified in this Section.
- 19.1.9.2 Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be used at all times.
- 19.1.9.3 All metals used in the fabrication process shall be surface treated with corrosion-resistant materials prior to assembly, with consideration being given to the severity of exposure to which the surface shall be subjected.
- 19.1.9.4 The joining of incompatible metals and materials shall be minimized as much as possible. When such metals must be joined, provision shall be made in accordance with MIL-STD-889 to prevent chemical reactions between the metals. The influence of coating materials on the mechanical performance of treated joints shall be considered in the design, where appropriate.
- 19.1.9.5 Surfaces of aluminum alloy parts secured to ferrous parts shall be protected with gaskets, or coatings such as one-part polysulfide, or silicone sealant used as joint compound, or with joint material that is non-hygroscopic and is free from chlorides and heavy metal ions.
- 19.1.9.6 Fibrous joint material, if used, shall be impregnated with a water-proof, water-repellant substance, which shall completely cover interfacing surfaces.
- 19.1.9.7 All ferrous metal surfaces, other than stainless steel, shall be protected by painting or zinc plating as defined in this specification, unless otherwise specified.
- 19.1.9.8 Steel surfaces not requiring specific protection types, shall be galvanized by the methods and requirements described in ASTM A123. Minor damage to galvanized coatings shall be repaired with an approved zinc rich paint.

19.1.9.9 The Corrosion Control Plan submitted by the Contractor shall include a description of the procedures and processes employed to prevent corrosion, including those arising from the use of dissimilar metals, for NYCT approval.

19.1.10 Flammability and Smoke Emission Requirements

General

- 19.1.10.1 All combustible material used in the construction of the car shall satisfy the flammability and smoke emission requirements cited in this section.
- 19.1.10.2 Materials used in the construction of the car shall meet the requirements contained in this section, 49 CFR 238.103, Appendix B to Part 238, and NFPA 130-2014.
- 19.1.10.3 Should a conflict exist between the NFPA and Federal requirements and the requirements listed elsewhere in these provisions, the more restrictive shall govern. Note: the Fiberglass-Reinforced Plastic (FRP) smoke requirement has been modified to a more restrictive value to improve smoke characteristics for tunnel operation.
- 19.1.10.4 The Contractor shall furnish a comprehensive listing of materials used in the cars in matrix form (flammability matrix). [CDRL]
- 19.1.10.5 The flammability matrix shall include the following information as a minimum:
- a) Material application (component description, part/drawing number, and location).
 - b) Material supplier (full name of material manufacturer).
 - c) Material description (actual material name and trade name).
 - d) Material part number, formula number, or compound number.
 - e) Material weight (both density and total weight in car).
 - f) Flammability data as applicable:
 - Flame spread / flammability.
 - Smoke generation.
 - Heat value per pound.
 - Heat release rate.
 - Total heat released.
 - Flashpoint / auto ignition temperature.
 - Toxic content in combustion products.
 - g) Testing laboratory (full name of independent testing entity).
 - h) Date of test(s).
 - i) Submittal letter (from contractor) (letter number(s) submitting test reports and material specifications).
 - j) Response Letter (letter(s) from NYCT dispositioning the latest submission of data).
 - k) Approval status (current approval status by NYCT of the specific material).
- 19.1.10.6 The Contractor shall submit laboratory test results, certified by an independent testing laboratory, for all materials for all tests specified, including a technical data sheet, for NYCT approval. The flammability matrix shall contain sufficient information to positively identify each material listed.
- 19.1.10.7 The material description used by the contractor shall be identical in every place it appears, such as in test report documentation, technical data sheet, drawings, Bill of Materials, flammability matrix, and other related references. This documentation must be directly

traceable between the technical documentation, test reports, and flammability matrix, to the applicable Contractor drawings without ambiguity.

- 19.1.10.8 For all materials, independent laboratory test results indicating successful compliance to these requirements shall be made available to NYCT. Testing must be conducted within the Contract duration period, and preferably on a production batch of material.
- 19.1.10.9 Each laboratory must have tested a standard test sample no greater than 30 days prior to performing the tests that will be submitted to NYCT.
- 19.1.10.10 The Contractor shall be responsible for complete conformance with these standards for itself and its subcontractors and suppliers.
- 19.1.10.11 NYCT may, at its discretion, require that the current batch of material being provided for this contract be retested for conformance with these standards at the Contractor's expense.
- 19.1.10.12 The Contractor may request a waiver from testing for this material if the quantity of a particular material is such that it would not contribute significantly to a fire.
- 19.1.10.13 The waiver shall be submitted in writing to NYCT and shall include the total weight of the material to be used, the location and the distribution of the material in the car, technical data and specification sheets, and any previous test reports available.
- 19.1.10.14 Waivers shall be accompanied by proper justification and will be reviewed by NYCT on a case-by-case basis.

Combustible Content

- 19.1.10.15 The design of the car shall minimize the total combustible material content.

Flammability and Smoke Emission

- 19.1.10.16 Materials used in the cars shall be tested to demonstrate compliance with the requirements set forth in this section, as defined in Attachment 19-A.

Floor Assembly Fire Resistance Testing Criteria

- 19.1.10.17 The Contractor shall test the floor assembly in accordance with ASTM E119 to demonstrate a 30-minute endurance rating. The test procedure, test facility, and test results shall be approved by NYCT prior to the Contractor's procurement of any flooring material necessary for car production. [CDRL]
- 19.1.10.18 The following test criteria shall be met:
- a) The test specimen shall be a full width car section including side sills or that portion of the wall which extends below the floor, by 12 feet (3.7 m) in length. 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 supported at the ends to simulate the actual support configuration that would occur in the finished car. The sample shall be loaded to simulate "crush" passenger loading conditions. Concentrated loads shall be applied to simulate underfloor equipment. A partial sidewall structure may be incorporated if necessary to simulate actual carbody support.
 - c) Test specimen shall include at least three typical transverse supports.
 - d) Test specimen shall represent the actual construction, and materials, 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.

Toxicity

- 19.1.10.19 Those materials and products generally recognized to have highly toxic products of combustion shall not be used.
- 19.1.10.20 All materials used in the car construction, except for materials used in small parts (such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that would not contribute significantly to fire propagation or to smoke or toxic gas generation, shall be tested for toxicity using Boeing Specification Support Standard BSS 7239. Materials shall meet the maximum toxic gas release limits (ppm) as determined per BSS 7239, as defined in Table 19-1.

Table 19-1 – Toxic Gas Emission Limits

Toxic Gas	Maximum Concentration
Carbon Monoxide (CO)	3500 ppm
Hydrogen Fluoride (HF)	200 ppm
Nitrogen Dioxide (NO ₂)	100 ppm
Hydrogen Chloride (HCl)	500 ppm
Hydrogen Cyanide (HCN)	150 ppm
Sulfur Dioxide (SO ₂)	100 ppm

- 19.1.10.21 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.

Electrical Fire Safety

- 19.1.10.22 Electrical equipment shall conform to NFPA 130 - 2014, Section 8.6, except where more restrictive requirements are imposed by this Specification.

19.2 Stainless Steel

19.2.1 General

- 19.2.1.1 Permitted uses of structural stainless steels are specified throughout this Specification. Ferritic stainless steels shall be painted where exposed to passengers or the weather except when used in external sheeting.
- 19.2.1.2 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.

19.2.2 Austenitic Stainless Steel

- 19.2.2.1 Austenitic stainless steel sheets, strips, plates, and flat bars shall comply with ASTM A666, except that the carbon content shall not exceed 0.03 percent. An exception is ASTM A666

- standard material for applications where stainless steel is arc welded, and resistance to sensitization can be proven by an approved test.
- 19.2.2.2 Stainless steel shall be SAE 201, 201L, 201LN, 301, 301L, 301LN, 302, 304, 304L, 316, 316L, or 347, in accordance with the intended function. Low carbon "L" grades shall have a carbon content below 0.03 percent.
- 19.2.2.3 Stainless steel used in structural applications shall conform to APTA PR-CS-S-004-98, "Standard for Austenitic Stainless Steel for Railroad Passenger Equipment".
- 19.2.2.4 Buffing, polishing, and surface finishing ("graining" or "brushing") of stainless steel, where required, beyond mill finishes, shall be applied in an approved manner and without the use of any composition containing iron or iron oxide.
- 19.2.2.5 Stainless steel skin components that have an applied finished or that are re-finished, other than at the mill, shall be chemically passivated using any approved method in accordance with ASTM A967, excluding citric acid cleaning.
- 19.2.2.6 Stainless steel shall be tested for free iron presence in accordance with the water-wetting and drying test per ASTM A380 Section 7.2.5.1. Mechanical or other chemical cleaning of stainless steel, if used, shall be in accordance with ASTM A380.
- 19.2.2.7 General requirements for delivery of stainless steel shall be as required by the Certification Provisions of ASTM A666, and stainless steel to be used in structural applications shall be tested for susceptibility to intergranular corrosion in accordance with ASTM A262, latest revision. Practice "A" of ASTM A262 can be used to accept material only; Practice "E" is required for final determination of acceptance or rejection of material that is not acceptable by Practice "A".

19.2.3 Ferritic Stainless Steel

- 19.2.3.1 When specified, ferritic stainless steel conforming to ASTM A240 may be used for sheeting up to 0.2 inch (5.1 mm) thickness.
- 19.2.3.2 Ferritic stainless steel sheet shall have a Ductile-to-Brittle Transition Temperature (DBTT) or Nil-Ductility Temperature (NDT) below 0°F (-18°C). Weld heat-affected-zones shall also have a DBTT or NDT below 0°F (-18°C).
- 19.2.3.3 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 car body, inhibit formation of martensite, and limit chromium depletion in weld-heat-affected zones so that material shall meet ASTM A763 requirements for resistance to intergranular corrosion.
- 19.2.3.4 General requirements for delivery of stainless steel shall be as required by ASTM A480.
- 19.2.3.5 Where ferritic stainless steels are welded to other structural steels, the less-noble steel shall be painted with weld-through primer.

19.2.4 Testing

- 19.2.4.1 The Contractor shall prepare, 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] The tests and inspections shall verify that the stainless steel conforms to specified requirements. For austenitic stainless steel with tempers of half-hard (HT temper) or greater used in structural applications, the test and inspection plan shall include verification of material hardness on a representative sample of finished structural profiles, including edges.

19.2.4.2 For austenitic stainless steels, the test and inspection plan shall include frequency of submittal of certifications in accordance with Certification Provision of ASTM A666 and frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A262.

19.2.4.3 For ferritic stainless steels, the test and inspection plan shall include frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A763.

19.3 Steel

19.3.1 Low-alloy, High-tensile Steel

19.3.1.1 Low-alloy, high tensile (LAHT) steel for carbody applications shall comply with the applicable ASTM standard, i.e., ASTM A242 or ASTM A588 for structural shapes, plates, and bars.

19.3.1.2 Cold and hot rolled LAHT steel sheets and strips shall, as a minimum, conform to the requirements of ASTM A606, Type 4. General requirements for delivery of these products shall be as required by ASTM A568.

19.3.1.3 LAHT steel shall comply with APTA PR-CS-S-034-99, Rev. 2, "Standard for the Design and Construction of Passenger Railroad Rolling Stock" (subsection; "High-Strength Low-Alloy Steel [HSLA]").

19.3.1.4 LAHT (or HSLA) steels used for carbody and truck applications shall comply with the applicable ASTM standard and shall be applied in accordance with their intended use.

19.3.1.5 Chemical deviations or customized chemistries from these standards are not permitted.

19.3.2 Heat-Treated Alloy Steel

19.3.2.1 Heat-treated alloy steel suitable for welding and other structural purposes shall comply with ASTM A514, Grade F.

19.3.3 Testing

19.3.3.1 The Contractor shall prepare, 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]

19.3.3.2 The test and inspection plan shall include provisions for submission of reports and certification to NYCT for each shipment in accordance with the applicable requirements of the Contractor's material purchase specification and specified Coarse Grain Heat-Affected-Zone (CGHAZ) impact tests. See Section 19.21.10.

19.4 Castings

19.4.1 General

19.4.1.1 The Contractor is responsible for selecting casting grade, composition, strength, and finishing. However, steel castings used in the car body structure and truck assemblies shall meet AAR Specification M-201 latest revision, Grade "B", plus 2 percent nickel, minimum.

19.4.1.2 These castings shall be heat treated to develop a minimum tensile strength of 75,000 psi (517 MPa), a minimum yield strength of 48,000 psi (331 MPa), elongation of not less than 25 percent in 2 inches (50.8 mm), and reduction of area of not less than 50 percent.

19.4.1.3 Steel castings used for coupler, drawbars, and anchors shall meet AAR Specification M 201, latest revision, Grade "C" quenched and tempered.

- 19.4.1.4 Where cast steel of superior properties is required for a specific application, the Contractor shall propose such castings for NYCT review and approval.
- 19.4.1.5 Cast iron materials shall meet ASTM A874/A874M "Standard Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service", or ASTM A48/A48M "Standard Specification for Grey Iron Castings", or equivalent requirements with NYCT approval.

19.4.2 Design Qualification of Structural Castings

- 19.4.2.1 One casting, selected by NYCT 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 E446 and any mechanical testing.
- 19.4.2.2 Acceptance levels for the design qualification radiographic examinations shall be selected by the Contractor as appropriate for the service intended, subject to the approval of NYCT before any castings are produced. Radiographs shall meet the requirements of ASTM E94 and the quality level in the area of inspection shall be at least 2 percent (2-2T).
- 19.4.2.3 A qualification test report shall be prepared and submitted to NYCT for approval. The production of any castings before receipt of NYCT's approval of this report shall be at the Contractor's risk. [CDRL]
- 19.4.2.4 All radiographs that resulted from the qualification test shall be made available to NYCT for review.
- 19.4.2.5 In case the casting selected for qualification fails to qualify, an action plan including details of how failed material will be handled shall be included in the qualification test report.
- 19.4.2.6 Once a design is qualified and accepted by NYCT, 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.

19.4.3 Quality of Structural Castings

- 19.4.3.1 All structural castings supplied shall be equal to or better than the design qualification castings in all respects. The casting supplier or Contractor shall test, inspect, and accept castings in accordance with procedures described in AAR Specification M-201. The production quality of the structural castings shall be shown to be consistent with the performance and quality levels assumed in the static and fatigue design assumptions and calculations. The Contract shall submit Casting Quality Plan for Approval. [CDRL]
- 19.4.3.2 In addition, the inspections below shall be performed and a written report of the results of the tests and inspections shall be furnished for each lot of castings produced.

Magnetic Particle Inspection

- 19.4.3.3 Magnetic particle inspections of all surfaces of each casting shall be conducted according to ASTM E709, by personnel certified to National Aerospace Standard AIA/NAS-410, Level 1 minimum.
- 19.4.3.4 With respect to structural castings, including coupler castings, the maximum permissible magnetic particle indications shall be 0.25 inch (6.4 mm) in the direction transverse to the usual direction of loading, and 0.75 inch (19.1 mm) in the direction parallel to the usual direction of loading.

Radiographic Inspection

- 19.4.3.5 Radiographic inspection shall be conducted according to the requirements of ASTM Standards E-94 using reference radiographs to ASTM E446. A sampling frequency plan shall be proposed by the Contractor and submitted for NYCT approval. [CDRL]
- 19.4.3.6 As a minimum, structural castings shall not exceed severity level 3 of ASTM E446 in all critical areas of such castings and shall not exceed level 5 in all other areas of the castings. Critical areas are areas of high stress, mounting areas, or direct interface to related components. Where required by the structural calculations, the Contractor shall stipulate high quality levels in the Casting Quality Plan.
- 19.4.3.7 To demonstrate that the stated severity level requirements of ASTM E446 have been met, successively-produced castings shall be re-inspected by radiography in the defective areas shown in the prior radiographic inspection.
- 19.4.3.8 After such severity levels have been proven, the sampling frequency for structural castings shall be one casting out of each ten produced. If no castings are rejected by radiographic inspection, this frequency may be extended to one casting in twenty-five.

19.4.4 Repair Welding and Cast-Weld Design

- 19.4.4.1 Repair welding of castings is permitted, provided the casting supplier performs all repair welds according to the structural welding requirements of Section 19.21.
- 19.4.4.2 Castings requiring repair or modification by welding shall be stress relieved per American Welding Society (AWS) D11.2 criteria after completion of the weld. Manual torch stress relief shall not be permitted.
- 19.4.4.3 For cast-weld designs, the entire length of all assembly welds on any welded assembly of separate castings selected for design qualification shall be radiographically inspected to ASTM E94 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. The quantity of inspected casting shall be proposed by the Contractor for NYCT approval.

19.4.5 Disposal of Non-Conforming Castings

- 19.4.5.1 If castings are found to be non-conforming to requirements determined by the design qualification castings, the material shall be repaired, retested, and re-inspected or destroyed at the Contractor's expense.

19.5 Aluminum

19.5.1 General

- 19.5.1.1 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" AA ASD-1.
- 19.5.1.2 Aluminum alloy forgings shall conform to ASTM B247.
- 19.5.1.3 Copies of all test reports for sheet, extrusion, and forgings used in the car structure shall be submitted to NYCT.
- 19.5.1.4 Aluminum shall not be used for structural applications nor be part of the Crash Energy Management design for the cars.

19.5.2 Design Stresses

- 19.5.2.1 All aluminum members shall be designed so that calculated stresses under the specified AW3 passenger load do not exceed the allowable stresses listed in the Aluminum Association of America's "Specification for Aluminum Structures" for bridge and similar type structures and "Engineering Data for Aluminum Structures".
- 19.5.2.2 Proper allowance shall be made for the effects of fatigue, for column and plate stability effects, and for strength reduction at welded regions.
- 19.5.2.3 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.

19.5.3 Fabrication and Fastening

- 19.5.3.1 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 (ALCOA) Technical Report No. 524, "Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles," except as otherwise specified herein.
- 19.5.3.2 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.

19.5.4 Protection of Contact Surfaces (see also Sections 19.1.8 and 19.1.9)

- 19.5.4.1 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 by NYCT and shall depend upon the determination of the most suitable method which can be adapted to the design involved. The following requirements provide the minimum acceptable level of protection at contact surfaces.
- 19.5.4.2 The contact surfaces of aluminum alloy with aluminum alloy shall be painted with zinc chromate primer or approved equal before securing.
- 19.5.4.3 After driving, steel fasteners in aluminum alloy shall be primed and painted with red oxide or aluminum paint. The joint design shall consider the curing requirements of the sealants and coating utilized.
- 19.5.4.4 Stainless steel and carbon steel fasteners plated with zinc, shall be coated with zinc chromate paste or approved equal before installation. Where possible, only the head and the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used in place of the zinc-chromate paste.

19.5.5 Interior Trim

- 19.5.5.1 Where unpainted aluminum is exposed to contact by passengers, unless otherwise specified, it shall be finished with an anodic coating conforming to Aluminum Association Standards, AA DAF-45, Architectural Class II finish: AA-M10 C12 C22 A31, or approved equal process.

NON-METALLIC MATERIALS

19.6 Elastomers

19.6.1 General

- 19.6.1.1 Material physical properties, chemical composition, curing method details, and specifications (Technical Data and Specification Sheets) for all non-metal materials (including non-elastomeric materials) used in the car shall be submitted to NYCT for review and approval. [CDRL]
- 19.6.1.2 Elastomers shall be compounded and cured to perform as intended for the NYCT environment specified in Section 2.5.1 and Appendix A (Fixed Facilities Description).
- 19.6.1.3 Elastomers shall have high resistance to ultraviolet (UV) and other solar radiation, weather, and to all NYCT car-washing and cleaning fluids.
- 19.6.1.4 All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease, and acid, and shall have the longest possible life, consistent with the other characteristics specified. The minimum replacement life shall coincide with the regular maintenance and SMS intervals, as appropriate.
- 19.6.1.5 Elastomeric components shall not be electrically conductive.
- 19.6.1.6 Elastomeric parts shall be suitably sized for the intended application such that the fit is correct (e.g., no gaps, bulges, stress tears, etc.). Gaskets or sealing extrusions shall not bulge, kink, or spread when installed. Seams in joined, extruded gaskets shall be oriented to minimize the possibility of leakage.
- 19.6.1.7 The following elastomeric parts shall be of neoprene unless otherwise specified or approved:
- a) Glazing Rubber.
 - b) Door Seals.
 - c) Door Nosing.
 - d) Other parts exposed to the outdoor ambient environment, except where otherwise specified.
- 19.6.1.8 The following elastomeric parts shall be of natural rubber. Synthetic rubber compounds are not permitted unless approved by NYCT.
- a) All resilient mounts.
 - b) Elastomeric truck components.
- 19.6.1.9 Elastomers used within pneumatic or hydraulic equipment shall be as necessary to meet the performance requirements of this specification for the pneumatic or hydraulic device.

19.6.2 Tests

- 19.6.2.1 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 19.1.10. The results of the testing shall be submitted to NYCT.
- 19.6.2.2 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 for each different production batch.

19.6.2.3 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.

19.6.2.4 Test requirements are defined in Table 19-2.

Table 19-2 – Testing Requirements for Elastomers

Physical Property	Test Method	Test Value
Hardness	ASTM D2240	45 to 75, Durometer A (or as specified)
Tensile strength	ASTM D412	1500 psi
Ultimate elongation	ASTM D412	350%, min
Ozone resistance	ASTM D1149, Type A, 7 Days, Ozone concentration 100 ppm, 104°F	No cracks under 7x magnification
Oil aging resistance	ASTM D471, Test oil/fuel shall be representative of application, 72 hours, 158°F	+30% maximum change in volume
Permanent-set resistance	ASTM D395, Method A or B	25% Maximum Set
Tear resistance	ASTM D624, Method B	300 ft-lb/in
Brittleness temperature	ASTM D746	Brittleness temperature no greater than -40°F
Resistance to heat aging	ASTM D573, 96 hours, 158°F	-25% change in elongation -15% change in tensile strength -5 to +15 change in hardness

19.6.3 Elastomer Bonded to Metal Parts

19.6.3.1 For all parts made by vulcanizing an elastomer to metal, any premature failure (less than seven 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.

19.6.3.2 Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020, SAE 1045, or SAE J403 hot-rolled steel or equal, suitably cleaned for bonding. Elastomeric materials shall be tested to verify compliance with performance requirements as provided in Table 19-2. The Contractor shall submit certificates stating compliance with the requirements of the standards.

19.6.4 Bonding

19.6.4.1 The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers shall not be allowed unless the Contractor submits the application, bonding procedure, and bonding agent technical data for approval prior to the purchase of any materials.

19.6.5 Truck Parts

19.6.5.1 Truck bumpers, snubbers, chevrons, 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.

19.6.6 Seals

- 19.6.6.1 Gaskets and seals used around all door mating edges, door, and window seals, and glazing strips shall be of neoprene material or approved equal material.
- 19.6.6.2 The durometer hardness measured with a Shore Type "A" durometer at a temperature between 70°F (21°C) to 90°F (32°C) shall be 70 ±5, except for the side door nose rubbers which shall be 80 ±5.

19.6.7 Neoprene Foam

- 19.6.7.1 Neoprene foam (flexible cellular rubber products) shall be high-resiliency foam latex. Base elastomer of latex shall be polymerized chloroprene (polychloroprene) and shall contain no reclaimed rubber.
- 19.6.7.2 The structure of the foam shall consist of a network of closed cells of uniform character.
- 19.6.7.3 The foam shall have a high resistance to flexing, tearing, and wetting.
- 19.6.7.4 The contractor shall provide the physical and performance characteristics of all neoprene foam used in the car. [CDRL]
- 19.6.7.5 The dimensions of flexible cellular rubber products used for sealing applications such as profiles, foam, gaskets, etc., shall comply with ASTM D1055, "General Applications".
- 19.6.7.6 Foam products (Sponge or Expanded Rubber) used for sealing applications such as profiles, foam, gaskets, etc., shall also comply with ASTM D1056, Class B.

19.7 Glazing Materials

19.7.1 Safety Glass

- 19.7.1.1 Safety glass shall meet the requirements under Item 1, Table 1 of SAE (ANSI) Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code" and FRA 49 CFR 223 Type I or II test as appropriate for the application.
- 19.7.1.2 Test reports to verify glazing material compliance per the criteria specified in this section shall be provided for NYCT review. [CDRL]

19.7.2 Laminated Safety Glass Type

- 19.7.2.1 Laminated safety glass shall be used exclusively and shall conform to the following general, manufacturing, and finish requirements:
- 19.7.2.2 Float glass quality shall conform to ASTM C1036, Type 1, Class 1, quality Q3 for passenger window / windscreen glazing, quality Q2 for glazing used in the operator cab.
- 19.7.2.3 Glass pane flatness shall be per ASTM C1172, the glass shall not indicate a bow of more than 0.03 inch per linear foot (0.76 mm per 305 mm).
- 19.7.2.4 If tempered glass is used in the laminate, it shall be fully tempered in accordance with ASTM C1422, surface compression level 3, case depth level B.
- 19.7.2.5 Edges shall be seamed and ground smooth per SAE J673, Edge no. 4, and sealed with aluminum tape or equivalent.
- 19.7.2.6 Any overlap of one sheet of glass with respect to the other at an edge shall not exceed 0.03 inch (0.76 mm).

- 19.7.2.7 The thickness tolerance of the individual sheets as supplied shall be held within 0.02 inch (0.51 mm).
- 19.7.2.8 The dimensional tolerance for the cut size dimensions of rectangular shapes, including squareness will be according to ASTM C1036 (Table 2: Dimensional Tolerances for Rectangular Shapes of Type 1—Transparent Flat Glass), but not to exceed 0.04 in (1.0 mm).
- 19.7.2.9 For other shapes, the cut size shall not exceed 0.0625 inch (1.59 mm) of the dimension specified. Unspecified corners shall have a 0.0625 inch (1.59 mm) radius.
- 19.7.2.10 All the laminates of the safety glass shall be so nearly free from haze that the glass shall have approximately the same clarity as a light of the same nominal thickness of plate glass when viewed against a north light.
- 19.7.2.11 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 un-bonded areas ("let-go's") shall not be used.
- 19.7.2.12 Masking, if used, shall be applied between the laminated layers of the glass.
- 19.7.2.13 Tinted assemblies, if approved by NYCT, shall use a tinted Polyvinyl Butyral (PVB) layer with clear glass laminate.
- 19.7.2.14 Manufacturers stamp shall be positioned in lower right hand corner as viewed from inside the car. The marking of glass shall contain the information as specified in Appendix C-19 (Specification for the Supply of FRA II Laminated Safety Glass for the New Car Passenger Window, 3063-MATL-98).
- 19.7.2.15 Window glazing shall be bonded with an approved type of plasticized PVB resin in the form of a membrane 0.045 inch (1.14 mm) \pm 10 percent thick, which shall not be degraded by UV or visible light, water absorption, or temperatures that can be obtained by solar heating.
- 19.7.2.16 Laminated glass separation and discoloration shall be per ASTM C1172, Table 1, Vertical Glazing. There shall be no more than \pm 4 percent variation in the color of individual lights of laminated sheet glass when examined over a white background.

19.7.3 Laminated Safety Glass Classification

- 19.7.3.1 Laminated safety glass testing shall be performed on sample sizes representative of the actual application within the car, and shall also conform to the requirements of the applicable classification, as described in Sections 19.7.3.1 to 19.7.3.4.
- 19.7.3.2 Group I, FRA Type I compliant glass shall comply with the following additional requirements:
- a) Glass shall be clear (no tint) laminated safety glass used for forward facing glazing, i.e. windshields.
 - b) Glass shall be coated, if required, to have maximum solar transmittance of 68 percent according to ASTM E424, Method A.
 - c) Glass shall meet the requirements of 49 CFR, Part 223, FRA Type I rating.
 - d) Glass shall be certified to comply with the requirements of SAE (ANSI) Z26.1, Table 1, Item 1.

- 19.7.3.3 Group II, FRA Type II compliant glass shall comply with the following additional requirements:
- a) Glass shall be clear (no tint) laminated safety glass, used for cab (operator) side windows, or tinted laminated safety glass, with a neutral gray tint, used for passenger side, and door windows.
 - b) Glass shall be coated, if required, to have maximum solar transmittance of 68 percent according to ASTM E424, Method A.
 - c) Glass shall be certified to comply with the requirements of SAE (ANSI) Z26.1, Table 1, Item 2.
 - d) Glass shall meet the requirements of 49 CFR, Part 223, FRA Type II rating.
- 19.7.3.4 Group III Utility glass shall comply with the following additional requirements:
- a) Glass shall be tinted laminated safety glass, with a neutral gray tint, used for car interior glazing.
 - b) Glass shall be coated, if required, to have maximum solar transmittance of 34 percent according to ASTM E424, Method A.
 - c) Glass shall be certified to comply with the requirements of SAE (ANSI) Z26.1, Table 1, Item 3.
 - d) Glass shall be tinted to match supplied samples (a neutral gray tint with a visible light transmission of 28 percent \pm 2 percent).

19.7.4 Tempered Safety Glass

- 19.7.4.1 Tempered safety glass used in a non-laminated application is prohibited.

19.7.5 Inspection Criteria

- 19.7.5.1 The inspection criteria defined in NYCT document "Inspection Criteria For Glass (Safety Glass & Windshield) and Vandal Shield" Appendix C-23 shall be applied to safety glass, windshield glass and vandal shield.

19.8 Insulation - Carbody

19.8.1 General

- 19.8.1.1 Insulating materials shall be fire-retardant, non-hygroscopic, resistant to fungus, and provided with a vapor barrier as required to prevent the entry of moisture, oil, gases, and dust.
- 19.8.1.2 The materials shall not absorb fluids and gases and shall possess the required properties to meet the noise and vibration requirements of this specification.
- 19.8.1.3 The method of insulation retention in the carbody, for all insulating materials, shall be subject to NYCT approval.
- 19.8.1.4 The Contractor shall submit for approval data on thermal and acoustic insulation materials and application processes. [CDRL]

19.8.2 Acoustical Insulation

- 19.8.2.1 Acoustical insulating materials shall be applied to properly cleaned underframe, sides, ends, roof, and floor sheets, as required in Section 15.2.3 to the supplier's recommendations.

- 19.8.2.2 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.
- 19.8.2.3 Insulation shall be Daubert Chemical Company's V-Damp® 3680 sound deadening compound, Aquaplas No. DL-10, or NYCT approved equal.
- 19.8.2.4 The finished application of the damping material shall have a vibration decay rate of not less than 40 dB per second, as measured by the Geiger-Hamme Thick Plate Test Method at 60°F (16°C), or other approved method. The damping material shall have a hydrodynamically smooth finish.

19.8.3 Thermal Insulation

- 19.8.3.1 Thermal insulation materials shall be transportation grade of the rigid, non-rigid, or spray-on type. Insulation shall be installed with a vapor barrier to preclude moisture accumulation.
- 19.8.3.2 The type of thermal insulation to be used shall not be susceptible to mold or rot and shall not absorb water.
- 19.8.3.3 Insulation shall not corrode any metals used in the construction of the car or settle under car vibration.
- 19.8.3.4 The car thermal insulation shall not have an odor or be capable of absorbing odors, and shall not sustain vermin.
- 19.8.3.5 Urethane foam insulation shall not be used under any circumstances.
- 19.8.3.6 Thermal insulation material shall have a thermal conductivity of not greater than 0.25 Btu/hr-ft²-F°/in (13,000 J/hr-m²-C°/cm) when tested in accordance with ASTM C177.

19.9 Rubber Floor Covering

19.9.1 General

- 19.9.1.1 The floor lining shall provide a high coefficient of friction in both wet and dry conditions. The coefficient of friction of the floor rubber shall not be less than 0.60 when tested to ASTM D2047. (Note, a modification may be made to the test procedure ASTM D2047, to include the addition of 1.0 oz (30 mLs) of water to the test criteria to obtain the "wet" friction result). The alternative test method of ASTM C1028* may also be used.

** ASTM C1028 is currently withdrawn, however the test method is still valid for this application.*

- 19.9.1.2 The Contractor shall submit color/material samples for NYCT approval. **[CDRL]**
- 19.9.1.3 Prior to the installation of the floor covering, any depressions, voids, or cracks in the sub-floor shall be filled and the sub-floor shall be leveled and smoothed with an approved leveling compound.
- 19.9.1.4 The floor covering shall be permanently secured to the sub-floor with an approved adhesive and as recommended by the flooring manufacturer. The bottom side of the flooring shall be sanded and then securely bonded to the sub-floor panels. The floor covering and adhesive shall be resistant to cleaning solutions and solvents normally encountered in rail transit maintenance and cleaning.

- 19.9.1.5 Joints and seams in the floor covering shall be minimized in the layout of the floor covering sections, and shall be filled with appropriate material, compatible with the covering material, to provide a continuous, water-tight surface. There shall be no appreciable color or height differences in the seam areas.
- 19.9.1.6 At 68°F (20°C), the rubber flooring shall bend 180 degrees around a 1 inch (25.4 mm) diameter mandrel without breaking, cracking, crazing, or showing any change in color.
- 19.9.1.7 The rubber compound shall contain 44% (nominal, by weight of compound) Butadiene Styrene rubber unless otherwise approved by NYCT. The rubber compound shall be non-staining, non-discoloring and 100 percent non-oil extended, and contain additives to preclude damage or discoloring to UV light.
- 19.9.1.8 Only high-quality hard clay shall be used as filler. No limestone shall be used in the compound. Re-ground or recycled rubber components shall not be used.
- 19.9.1.9 The rubber flooring shall be homogeneous throughout (i.e., the color speckles in the floor covering shall extend throughout the entire thickness of the material).
- 19.9.1.10 The rubber flooring material shall comply with ASTM F1344, table 1, with tile size adjusted for maximum sheet coverage, class 1, B, and also comply with the Flammability, Smoke Emission and Toxicity section of this specification.

19.9.2 Inspection and Repair Criteria

- 19.9.2.1 This section addresses rubber floor covering defect types that may be cause for rejection, their allowable limits, and repair methods, where repairs are permitted.
- 19.9.2.2 There shall be no tears or cracks allowed in the installed floor covering. Non-penetrating defects such as blisters, lumps, craters, and deformations shall be no greater than 0.03 inch (0.76 mm) in height difference from the nominal, surrounding rubber thickness, and shall occur no more than the following:
- Defect diameter \geq 1 inch (25 mm) – Not permitted.
 - 1 inch (25 mm) > Defect diameter > 0.25 inch (6.4 mm) – 1 defect each every 6 feet (1.8 m) allowed, but must be repaired.
 - Defect diameter \leq 0.25 inch (6.4 mm) – 3 defects per 12 inch x 12 inch (305 mm x 305 mm) square area allowed, with no others closer than 3 feet (0.91 m).
- 19.9.2.3 A blister is a lump which, when finger-pushed, will collapse. Any blisters which cannot be satisfactorily repaired using the methods below, shall be cause for rejection of the floor sheet.
- 19.9.2.4 Blister Repair Method - using a hypodermic needle, apply just enough Super Bond 420, Bostik 1685, or NYCT approved equivalent, compress the blister and to bring to a flush surface.
- 19.9.2.5 A hole is a defect which is 50 percent through the material. Any holes found in the floor sheet shall be cause for rejection of the sheet.
- 19.9.2.6 A thin area is a defect where the sheet is of reduced thickness locally, with the following rejection criteria.
- Maximum Size - 0.03 inch (0.76 mm) deep at the lowest point, 3 in² (1,936 mm²) with the longest dimension of 5 inches (127 mm).
 - Maximum Population - one thin area in a 40 inch x 40 inch (1016 mm x 1016 mm) area, and no other thin area within 3 feet (0.91 m) of this area.
 - Repair Method - rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

- 19.9.2.7 The appearance of the flooring material with respect to color, pattern (e.g. marbled, speckle distribution, etc.), shall be subject to the approval of NYCT.
- 19.9.2.8 Samples showing the tolerance variations expected for the production runs shall be submitted for NYCT review and acceptance. These samples shall be the basis for evaluating the variations in production materials.
- 19.9.2.9 If the base coloring or pattern is not consistent over the entire surface, as compared to the sample materials, the material shall be rejected.

19.10 Structural Panels

19.10.1 General

- 19.10.1.1 Structural panels include, but are not limited to, composite, plymetal, honeycomb, balsa, foam, or lumber-core panels, with metal or other approved facing material. The panel construction, including all materials used in the construction of the panels, and the strength analysis (including test reports as applicable) shall be submitted for approval. [CDRL]
- 19.10.1.2 Sandwich panels shall be fully balanced in construction (i.e. having layers of similar strength on each side). The method of construction shall ensure that the panel skin, cladding, or covering is securely bonded over the entire load range that the panel will be exposed.
- 19.10.1.3 Panel core materials shall be fully encapsulated in the panel construction. Edges and penetrations shall be sealed to prevent moisture from entering into panel core. All penetrations into the panel shall be suitably reinforced.

19.10.2 Plymetal

- 19.10.2.1 The term "plymetal" as used in this Specification means metal-faced plywood. Plymetal panels used in floor panel application shall be faced on both sides and at all edges with stainless steel (wrapped). All plymetal panels shall have the metal seams properly bonded together.
- 19.10.2.2 All exposed edges of the panels, drilled holes, fastener heads, openings, or cutouts within the panels shall be waterproofed and sealed with an approved epoxy paint/coating at the time of initial panel fabrication. Modifications made to panels (such as during installation fitting) shall be immediately sealed at the time the modification is made.
- 19.10.2.3 Each plywood panel shall be formed from one piece. Jointed panels shall not be allowed.
- 19.10.2.4 Plymetal panels shall also meet the test criteria defined in Table 19-3.

Table 19-3 – Test Criteria for Plymetal Panels

Minimum Metal to Wood Test*	Minimum Value
Dry Shear	250 lbf/in ² (1.72 N/mm ²) to 80% wood failure
Boil shear, 3 hr boil, tested at 68°F (20°C)	150 lbf/in ² (1.03 N/mm ²) to 80% wood failure
Wet shear, 48 hr soak, 68° F (20°C)	150 lbf/in ² (1.03 N/mm ²) to 80% wood failure
Creep, under static load for 48 hr, 68° F (20°C)	250 lbf/in ² (1.72 N/mm ²) to 80% wood failure

** The plymetal test reference refers to inactive standard MIL-P-8053 which remains applicable to this Specification.*

- 19.10.2.5 The metal face of a plymetal panel that is faced with melamine shall be constructed in accordance with Section 19.10.7 prior to the melamine-faced metal panel being laminated to the plywood core.

19.10.2.6 Floor panels shall also resist puncturing (from top or bottom) equal to 300 lbf (1.33 kN) static load applied to a 0.375 inch (9.5 mm) diameter rod without permanent deformation exceeding 0.03 inch (0.76 mm) and no visible fracture, crack or indications of delamination of the panel skins from the core material.

19.10.3 Lumber

19.10.3.1 Lumber shall be sugar or black maple, or sweet or yellow birch only. Lumber shall be thoroughly air seasoned or kiln dried before using, so as not to have a moisture content of greater than 12 percent. Lumber 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.

19.10.4 Plywood

19.10.4.1 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) APA PS1-09, Exterior Grade B-B, High Density Overlay - Industrial , and then stored under cover.

19.10.4.2 Scarf or finger jointed panels are not allowed.

19.10.4.3 All plywood shall be sealed with two coats of an epoxy paint on all edges and cutouts as soon as possible after fabrication.

19.10.5 Honeycomb Panels

19.10.5.1 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. Aluminum honeycomb materials shall be commercial-grade meeting the requirements of SAE-AMS-C-7438, Grade B, Class 2, Type N.

19.10.5.2 Bonding for structural panels shall follow the guidelines in MIL-HDBK-83377, for a Type 1 Classification. Bonding shall be sufficient to develop the full strength of the honeycomb material.

19.10.5.3 Stainless steel honeycomb panels consisting of a honeycomb core bonded to a stainless steel face shall meet the adhesive bond strength requirements of Table 19-4 when tested to SAE-AMS-STD-401 (ASTM D1781).

Table 19-4 – Test Requirements for Adhesion of Honeycomb Panels

Test	Requirement
Core adhesion to facing	15 lb/inch (2.7 kg/cm)
Frame Adhesion to facing	30 lb/inch (5.4 kg/cm)

19.10.5.4 Stainless steel honeycomb panels shall be tested in accordance with SAE-AMS-STD-401-to demonstrate the requirements listed in Table 19-5.

19.10.5.5 No other honeycomb materials are permitted.

Table 19-5 – Test Requirements for Stainless Steel Honeycomb Panels

Property	Required Performance
Core shear yield at 200°F (93°C)	250 lb/in ² (1.72 MPa)
Flatwise tension at 200°F (93°C)	250 lb/in ² (1.72 MPa)
Beam flexure at 200°F (93°C)	75,000 lb/in ² (517 MPa)
Core shear fatigue at 68°F (20°C)	150 lb/in ² @ 10 ⁶ cycles (1 MPa)
Flatwise tension at 68°F (20°C)	250 lb/in ² @ 10 ⁶ cycles (1.7 MPa)
Beam flexure at 68°F (20°C)	50,000 lbt/in ² @ 10 ⁶ cycles (345 MPa)

19.10.6 Phenolic Composite Panels for Flooring Applications

- 19.10.6.1 Phenolic composite floor panels shall be constructed in accordance with the requirements in Section 3.4.17 and shall be capable of supporting the loads in Section 3.2.13.
- 19.10.6.2 The floor panels shall be designed to withstand the physical requirements below with no visible or audible indications of delamination of the panel skin from the core.
- 19.10.6.3 Permanent deformation of the top surface shall be less than 0.1 inch (2.5 mm).
- 19.10.6.4 There shall be no puncture or damage to fibers of the top surface. There shall be no separation of any core from the top or bottom skin and there shall be no fracture of the core unless otherwise specified.
- 19.10.6.5 Except for indentation resistance, the panel test configuration shall be: a representative sample section of the floor panel, simply supported on two opposite sides, using beams spaced at the maximum spacing as used on the car, with floor panel to beam attachment using production bonding and fastening techniques. The test panel shall be tested as a bare panel (e.g., without rubber floor covering attached) and shall meet the requirements defined in Table 19-6.

Table 19-6 – Performance of Phenolic Composite Floor Panels

Physical Property	Test Method	Test Value
Indentation Resistance	ASTM D6264, Modified per ASTM D7766, Procedure A, using a 300 lbf (1.33 kN) contact force, 0.375 inch (9.5 mm) diameter, flat face indenter, with 0.0625 inch (1.6 mm) radius on bottom edge.	No puncture or damage to fibers of the top surface.
Static Load Test - Maximum Loading	A uniformly distributed load of 200 lb/ft ² (9.6 kPa) shall be applied to the floor	No damage to panel.
Small Area Static Load Test	300 pound (1.33 kN) load shall be applied to a 1 inch x 3 inch (25 mm x 76 mm) depressor directly over the specimen centerline of the span, 6 inches (152 mm) from the unsupported edge. Depressor shall be flat faced within 0.01 inch (2.5 mm), edge radius not to exceed 0.125 inch (3.2 mm).	0.2 inch (5.1 mm) maximum deflection. No damage to panel.
Small Object Impact Test	ASTM D7136, Modified per ASTM D7766, Procedure C. The drop weight shall be an 8.5 inch (216 mm) diameter sphere, weight 16 lb (7.2 kg), dropped from a height of 60 inches (1.52 m) directly over the specimen centerline of the span, 24 inches (610 mm) from the unsupported edge.	No puncture or damage to fibers of the top surface. Dent Depth 0.0625 inch (1.6 mm) Maximum. Delamination / core damage 3 inch (76 mm) maximum diameter.
Large Object Impact Test	ASTM D7136, Modified per ASTM D7766, Procedure C with a rigidly backed, 3 inch x 8 inch (76 mm x 203 mm) contact pad ("footprint") faced with a 1 inch (25 mm) thick rubber pad of Shore D 70 minimum. The contact pad shall have a flat contact surface with an edge radius of 0.03 inch (0.76 mm) maximum. The drop weight shall be a 150 lb (68 kg) weight, dropped from a height of 12 inches (305 mm) directly over the specimen centerline of the span, 24 inches (610 m) from the unsupported edge.	Dent Depth 0.03 inch (0.76 mm) Maximum. Delamination/core damage extending to a perimeter of 1 inch (25 mm) maximum surrounding the force application zone.

19.10.7 High Pressure Laminates

- 19.10.7.1 High pressure laminate materials (such as trade name: Melamine, Wilsonart, Formica, etc.) used in the construction of the car (e.g. Interior panels, access covers, etc.) shall be two-ply laminates and shall consist of a hard plastic film facing permanently bonded to a base sheet of phenolic or aluminum. Contact adhesives shall not be used to bond the laminate to the base.
- 19.10.7.2 The final laminate assembly shall comply with NEMA LD-3, General Purpose Type, and comply with the flammability, smoke emission and toxicity section of this specification.
- 19.10.7.3 Aluminum based laminate sheets shall not be less than 0.025 inch (0.64 mm) in thickness when used as a facing on plywood. The aluminum sheets shall not be less than 0.081 inch (2.06 mm) 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.
- 19.10.7.4 The use of contact adhesives to bond the melamine sheets to the aluminum backing is not acceptable.

19.10.7.5 The bond between the melamine and aluminum sheets shall, as a minimum, meet the requirements of Table 19-7:

Table 19-7 – Performance of high pressure laminates

Property	Test Method	Required Performance
Internal bond	ASTM D952	2,600 psi (17.9 MPa)
Flexural strength	ASTM D790, Test S	
With grain:		26,500 psi (182.7 MPa)
Crossgrain:		25,300 psi (174.4 MPa)
Modulus of elasticity	ASTM D790, Test E	
With grain:		2.8×10^6 psi (19.3 GPa)
Crossgrain:		3.1×10^6 psi (21.4 GPa)
Tensile strength	ASTM D638	
With grain:		22,300 psi (153.8 MPa)
Crossgrain:		20,300 psi (140 MPa)

19.10.8 Panel Flatness

19.10.8.1 The overall flatness of the unloaded panel shall not exceed a maximum deviation of 0.015 inch (0.38 mm) per lineal foot, with a maximum of 0.125 inch (3.2 mm) deviation of any point on the panel measured from a reference plane taken from any three corners. The overall deviation of the panel thickness shall not exceed 0.031 inch (0.8 mm).

19.10.9 Panel Contour Tolerance

19.10.9.1 Surfaces exposed to passengers shall not deviate from the specified contour by more than 0.094 inch (2.39 mm) in any 36 inch (914 mm) distance. The slope of any such deviation shall not exceed 0.094 inch (2.39 mm) in 12 inches (305 mm).

19.11 Cab Seat

19.11.1 Cab Seat Cushion

19.11.1.1 Cab seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials. The thickness shall be approved during design review.

19.11.1.2 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.

19.11.1.3 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.

19.11.1.4 Flexible foam shall meet the physical property criteria defined in Table 19-8 when tested without upholstery material.

Table 19-8 – Performance of Cab Cushion Flexible Foam

Property	Test Method	Specification Value / Notes
Indentation Force Deflection (IFD)	ASTM D3574, Test B1	<u>Headrest:</u> 8-17 lb (36-76 N) @ 25% deflection, 23-43 lb (102-191 N) @ 65% deflection. <u>Back:</u> 8-10 lb (36-45 N) @ 25% deflection, 23-28 lb (102-125 N) @ 65% deflection. <u>Seat Bottom:</u> 10-12 lb (45-53 N) @ 25% deflection, 25-28 lb (111-125 N) @ 65% deflection
Compression set	ASTM D3574, Test D, 50% deflection, 22 hr, 70°F (21°C)	Silicone Foam: less than 2% compression set Neoprene Foam: less than 10% compression set
Tensile	ASTM D3574, Test E	8 psi (55 kPa), Minimum
Elongation	ASTM D3574, Test E	140% Minimum
Tear strength	ASTM D3574, Test F	2.5 psi (17.2 kPa) Minimum

19.11.2 Cab Seat Upholstery Material

- 19.11.2.1 Upholstery fabrics for cab seat upholstery shall be approved transportation-grade fabrics with backing. Fabric shall be able to be cleaned by at least three widely available commercial industrial cleaning agents that are known to be chemically compatible. See NYCT's list of approved cleaning agents contained in Appendix C-3 ("Cleaners and Other Products Approved for Use on Railcars and Railcar Parts").
- 19.11.2.2 Fabrics used for cab seat upholstery shall be made of woven, transportation grade fabrics of a 90 percent wool and 10 percent nylon blend. The maximum fabric shrinkage shall be two percent in either the warp or fill direction.
- 19.11.2.3 Seat upholstery material shall be subjected to the physical tests of textile products required by the latest revision of the following ASTM methods, and the results shall not be less than the values defined in Table 19-9.

Table 19-9 – Performance of Cab Seat Upholstery Material

Physical Property	Test Method	Requirement
Weight	ASTM D3776, Option B	16.5 oz/yd ² (560 g/m ²) (not including back coating)
Fabric Construction	ASTM D3775	43 Ends per Inch (25 mm) x 43 Picks per Inch (25 mm) minimum
Tensile Strength	ASTM D5034	150 lb Warp (667 N) 200 lb Fill (889 N)
Tearing Strength (Tongue)	ASTM D2261	Warp - 70 lb (311 N) Fill - 70 lb (311 N)
Crocking	ASTM D3597, Sec 7.9, (American Association of Textile Chemists and Colorists (AATCC) Method 16, Option E)	4.0 Dry 4.0 Wet
Pilling Resistance	ASTM D3512	Pass, level 4 (slight pilling)
Shrink Resistance	AATCC 99	2% maximum
Light Fastness	ASTM D3597, Sec 7.10, 40 hr	4 @ 40 Hours
Seam Strength (sewing)	ASTM D1683, Sec 11.1	8 to 10 stitches per inch Warp - 100 lb (445 N) Fill - 100 lb (445 N)
Yarn Slippage (sewing)	ASTM D4034	Warp - 50 lb (222 N) Fill - 50 lb (222 N)
Abrasion Resistance	ASTM D3884, Taber 500g, CS 10 Wheel	700 Cycles Minimum, No breaks
* Abrasion Resistance	ASTM D3597	15,000 dbl. rubs - no breaks
* Abrasion Resistance	ASTM D4966	25,000 cycles - no breaks

** Only one of these tests needs to be conducted.*

19.12 Fiberglass-Reinforced Plastic

19.12.1 General

- 19.12.1.1 FRP shall be polymeric-glass fiber reinforced laminated material, composed of a gel-coated surface, fiberglass reinforcement, and a polyester, acrylic, phenolic, or approved equal resin matrix. Fire retardant additives may be included as necessary.
- 19.12.1.2 FRP products shall meet the Flammability, Smoke Emission, and Toxicity requirements (See Section 19.1.10).
- 19.12.1.3 FRP shall withstand, without any physical deformation or structural damage, the environmental conditions in Appendix A (Fixed Facilities Description), and be resistant to acids, alkalis, and cleaning solutions recommended by the Contractor.
- 19.12.1.4 Fiberglass components shall be molded, stored, and mounted in their final, designed, shape, and shall not be mounted in a deformed/stressed condition.

- 19.12.1.5 FRP shall be manufactured by an open molding or matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.
- 19.12.1.6 An analysis shall be performed to confirm that the construction method chosen is adequate for its intended purpose and meets the strength requirements within Section 19.13.3.
- 19.12.1.7 Finished gel-coated surfaces shall have a minimum gloss value of 85 when measured with a 60° glossometer and shall exhibit no print through of the reinforcements or have any appreciable orange peel.
- 19.12.1.8 FRP parts shall have a greater thickness at attachment points and edges. Exposed sharp edges will not be allowed on any parts.

19.12.2 Construction

- 19.12.2.1 The resin shall be of good commercial grade, thermosetting, vinyl-ester, acrylic, or phenolic material selected to meet the physical, flammability and smoke emissions properties of this Specification and molding process requirements.
- 19.12.2.2 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. Glass content by weight shall be 30 percent minimum when tested to ASTM D2584. Higher levels of glass content are preferred.
- 19.12.2.3 The gel coat shall be resistant to scuffing, fire, weather, water absorption and cleaning agents. The gel coat shall have a minimum thickness of 0.015 inch (0.38 mm). 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 19.22.
- 19.12.2.4 If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color scheme selected by NYCT. Gelcoat used as a cosmetic surface must contain UV inhibitors/stabilizers, or be formulated to minimize any discernable yellowing or color degradation.
- 19.12.2.5 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 Section 19.12.3, and the flammability requirements of Section 19.1.10.
- 19.12.2.6 Antimony Trioxide (Sb_2O_3) shall not be used.
- 19.12.2.7 Mineral filler shall not exceed 28 percent of the finished weight for any preformed matched die molding process.

19.12.3 Strength Requirements

- 19.12.3.1 Independent laboratory tests shall be performed on test coupons that are trimmed from production parts.
- 19.12.3.2 Independent laboratory test certificates shall be provided stating that the production reinforced plastic material complies with the requirements of the standards listed in Table 19-10. The certificates shall be made available to NYCT upon request.

Table 19-10 – Testing Standards for FRP

Mechanical Property	Test Method	Minimum Requirements	
		Open Moldings	Matched Die Moldings
Tensile Strength	ASTM D638	13,000 psi (90 MPa)	18,000 psi (124 MPa)
Compressive Strength	ASTM D695	22,000 psi (152 MPa)	32,000 psi (221 MPa)
Flexural Strength	ASTM D790	21,000 psi (145 MPa)	28,000 psi (193 MPa)
Impact	ASTM D256	10 ft- lb/inch (5.3 J/cm) of notch	13 ft-lb/inch (6.9 J/cm) of notch
Hardness	ASTM D2583	45 Barcol	45 Barcol
Heat	None	175°F (79 °C) Continuous	-
Thickness	None	0.125 inch (3.2 mm), minimum	0.125 inch (3.2 mm), minimum
Gelcoat Thickness	None	0.014 inch or 14 mils (0.36 mm), ±2 mils (±0.05 mm)	N/A

19.13 Thermoplastic Sheet

19.13.1 General

- 19.13.1.1 Thermoplastic sheet used in the construction of this car shall not contain PVC vinyl and shall withstand, without any physical deformation or structural damage, the environmental conditions described in Appendix A (Fixed Facilities Description), and shall be resistant to NYCT cleaning solutions. Thermoplastic sheet shall be used as extruded or vacuum-formed.
- 19.13.1.2 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 15.9.4.
- 19.13.1.3 Only UV stabilized pigments shall be used to create the specified color of the thermoplastic sheet.
- 19.13.1.4 The color and surface finish of parts manufactured from this material shall be approved prior to the production run of any parts.

19.13.2 Quality

- 19.13.2.1 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 0.01 inch (0.25 mm), and the population of these defects is greater than one defect in 4 square feet (0.37 m²).

19.13.3 Strength Requirements

- 19.13.3.1 Independent laboratory test certificates shall be provided stating that the thermoplastic sheet complies with the requirements of the standards listed in Table 19-11. Extruded sheet in the surface finish specified shall be used for testing.

Table 19-11 – Testing Standards for Thermoplastic Sheet

Mechanical Properties	Test Method	Value
Specific Gravity	ASTM D792	1.20 to 1.45
Tensile Strength	ASTM D638	5,500 psi (38 MPa) minimum
Elongation	ASTM D638	50 percent
Flexural Strength	ASTM D790	8,000 psi (55 MPa) minimum
Flexural Modulus	ASTM D790	3.3 x 10 ⁵ psi (2.28 GPa)
Hardness Rockwell "R" Scale	ASTM D785	90 to 110
Heat Shrinkage 15 minutes at 350°F (177°C)	--	10 percent maximum
Heat Deflection (annealed) @ 264 lb ft/in ² (1.82 MPa)	ASTM D648	165°F (74°C) minimum
Impact Strength Fabricated Parts (Gardener Impact) Geometry GE at 73°F (23°C)	ASTM D5420	0.125 inch (3.2 mm) thick sample 320 in-lb (36 N-m) minimum
Impact Strength Fabricated Parts (Gardener Impact) Geometry GE at -20°F (-28.9°C)	ASTM D5420	35 in-lb (4 N-m) minimum

MECHANICAL DESIGN AND PROCESS REQUIREMENTS

19.14 Piping and Tubing

19.14.1 General

- 19.14.1.1 All piping, valves, fittings, installation methods, and testing shall be in accordance with the Code for Pressure Piping, ASME B31.1. All joints shall be easily accessible.
- 19.14.1.2 After full installation on the car, and before connection or installation of system components, the piping system shall be completely flushed with a suitable liquid solution, using appropriate pressure and velocity to fully dissolve all contaminants from manufacture and installation. The piping systems shall be cleaned a second time, following completion of component installation, using approved procedures. The Contractor shall submit flushing and cleaning procedures for the piping and piping system for NYCT review. [CDRL]
- 19.14.1.3 Following installation, piping systems shall be pressure tested in accordance with ASME B31.1 or other approved method. All leaks which appear during pressure testing shall be repaired and re-tested until acceptable under the NYCT approved test criteria.

19.14.2 Air Piping, Tubing, and Fittings

- 19.14.2.1 The main reservoir pipe and brake pipe shall conform to ASTM A53, or ASTM A106, Schedule 80 seamless pipe.
- 19.14.2.2 Type "K" annealed copper tube per ASTM B 88, latest revision, may be used for carbody piping with the following provisions:
- a) It shall be installed not lower than 2 inches (51 mm) below the floor pan or structural member.
 - b) It shall be protected by means of equipment or approved steel guards from potential impact damage. Where suitable protection in damage-prone areas is not possible or practical, NYCT-approved steel or stainless steel piping sections shall be provided.
 - c) Joints for copper tubing shall utilize fittings of wrought copper or non-porous cast brass in accordance with ASME B16.22 and B16.18.
- 19.14.2.3 Piping installed on the truck shall be ASTM A106, Schedule 80 seamless pipe.
- 19.14.2.4 Alternate pipe materials for carbody and truck piping may be proposed for NYCT review and approval.
- 19.14.2.5 Welding, brazing, and soldering of piping shall conform to the applicable requirements of Sections 19.14.4 and 19.21.

19.14.3 Air Conditioning System Piping, Tubing, and Fittings

- 19.14.3.1 The design, construction, and testing of refrigerant piping shall be in accordance with the Code for Pressure Piping, ASME B31.5.
- 19.14.3.2 Air conditioning refrigerant lines shall be of seamless copper tubing, type "K" or type "L" per ASTM B280 or B743, with wrought copper sweat type fittings.
- 19.14.3.3 Joints shall be kept to a minimum and all inaccessible runs of tubing shall be without joints.
- 19.14.3.4 Finned tubing in evaporators and condensers shall be copper.
- 19.14.3.5 Instead of elbows, tubing may be bent utilizing a bending tool designed specifically for bending of the tubing to be used.

- 19.14.3.6 Condensate drain lines shall be primarily seamless copper tubing, type "K" or seamless stainless steel tubing. Rubber tubing may be used to connect metal tubing where additional flexibility is required subject to NYCT review and approval.
- 19.14.3.7 Suction lines shall be designed and installed without traps. The suction line shall be sized for 3 psi (gauge) (21 kPa gauge) maximum system pressure drop and the liquid line shall be sized adequately to prevent flashing due to pressure drop.
- 19.14.3.8 Lines subject to condensation shall be insulated with an approved insulation, applied with an approved contact cement.
- 19.14.3.9 The liquid line shall be insulated in all areas where required to provide additional mechanical or thermal protection.
- 19.14.3.10 Insulation at all joints and fittings shall be mitered and sealed with an approved material.
- 19.14.3.11 The insulation, adhesive, and sealant shall meet the requirements for thermal, smoke emission, and flammability performance in Section 19.1.10.
- 19.14.3.12 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.
- 19.14.3.13 Vibration eliminators shall be used in piping connections to the HVAC compressor unless deemed unnecessary by NYCT.
- 19.14.3.14 Tubing installations shall be designed so that ease of maintenance can be achieved, as approved by NYCT.

19.14.4 Brazing and Soldering of Piping, Tubing, and Fittings

- 19.14.4.1 All brazing and soldering shall comply with the applicable parts of Section 19.21, and the following requirements.
- 19.14.4.2 All refrigerant piping and air system copper tubing shall be joined using silver solder conforming to Federal Specification QQ-B-654A, BAg-5, or BCuP-5. For copper-to-copper connections BCuP-3 may also be used.
- 19.14.4.3 Refrigeration piping and tubing shall be internally swept with a continuous flow of a non-oxidizing gas such as dry nitrogen during brazing.
- 19.14.4.4 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.
- 19.14.4.5 After fabrication, the refrigeration and air systems shall be cleared of all dirt and foreign matter, flushed with a degreasing agent, and dried. Alternate cleaning processes may be proposed for NYCT review and approval. The procedure used by the Contractor shall be submitted with the Critical Design Review package for NYCT's reference and included in the appropriate Maintenance Engineering & Instruction Manual.

19.15 Pressure Vessels

- 19.15.1.1 All pressure vessels shall conform to the latest revision of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels.
- 19.15.1.2 A test report shall accompany each pressure vessel received by the Contractor.
- 19.15.1.3 Each pressure vessel shall be stamped by the certified testing facility to verify successful completion of unit testing.
- 19.15.1.4 Drain cocks shall be provided at the low points of all reservoirs.

19.16 Bearings and Lubrication

19.16.1 General

- 19.16.1.1 All bearings and lubricants shall be readily available in the United States.
- 19.16.1.2 Grease fittings or plugs commonly used in North America shall be provided for all bearings not internally splash or bath-lubricated.
- 19.16.1.3 All rotary shafts shall be supported by cylindrical or tapered roller bearings where practicable. Ball bearings may be used, subject to NYCT approval. Rotary/Motor shafts shall be suitably protected against corrosion to allow unencumbered removal of bearings.
- 19.16.1.4 Bearings subject to atmospheric or liquid contamination shall be sealed by labyrinth, lip, or face seals. Bearings installed in a vertical application shall have suitable protection to prevent moisture or contaminants from accumulating on or from entering the bearing.
- 19.16.1.5 Bearings that are not splash or bath lubricated shall be provided with standard grease fittings and drain plugs or pressure-release devices for re-lubrication. Ball bearings of 1 inch (25 mm) shaft size and smaller may be factory lubricated-for-life, subject to NYCT approval.
- 19.16.1.6 Bearings shall be installed and removed without major disassembly of related components. Thrust style bearings shall be used whenever there is an axial load on the rotating shaft carried across rolling elements.
- 19.16.1.7 Sleeve bearings shall be used for shafts with rotary motion of less than one full revolution. Sleeve bearings shall be adequately lubricated. Sleeve bearings supporting ferrous shafts shall be composed of bronze, brass, phenolic, or aluminum alloys as approved. Sleeve bearings may be used to support rotary shafts if space limitations preclude the use of anti-friction bearings.
- 19.16.1.8 Self-lubricated bushings (sintered metal) shall be used in accordance with the manufacturer's recommendations, but shall not be used for shafts with speeds greater than 500 rpm.
- 19.16.1.9 The Contractor shall submit bearing and lubricant specifications and data for approval.
[CDRL]

19.17 Air Filters

19.17.1 HVAC and Equipment Ventilation Filters

- 19.17.1.1 Filters shall be selected in accordance with NYCT Specification 2061-PROD-89 contained within Appendix C-10 ("Air Conditioning Filters for NYCTA Subway Cars, Supply of (Dry Pleated Media)") for the specific equipment involved.
- 19.17.1.2 All filters shall have an integral frame.
- 19.17.1.3 Filters shall be the single use, disposable type.
- 19.17.1.4 All filters shall be freely accessible for maintenance.

19.17.2 High Pressure Air Filters

- 19.17.2.1 Air filter assemblies with replaceable filter elements shall be provided in the air line that connects each subsystem to the air supply system.

- 19.17.2.2 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.
- 19.17.2.3 It shall be possible to gain access to the filter element for replacement without requiring any pipe fittings to be disconnected or loosened.
- 19.17.2.4 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) Carbody height control valve.
 - c) Coupler controls.
 - d) Horn.

19.17.3 Low Pressure Air Filters

- 19.17.3.1 Replaceable media type filters shall use resin-bound, spun-glass fiber materials having an uncompressed thickness not less than 3.5 inches (89 mm).
- 19.17.3.2 Filters 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 (258 g/m²) of a dust-retaining, viscous adhesive film. This film shall be stable at temperatures up to 150°F (66°C).
- 19.17.3.3 The filter medium shall be cut not less than 0.5 inch (13 mm) oversize to ensure adequate sealing between the edge of pad and its integral frame.

19.18 Joining and Fastening

19.18.1 Joining, General

- 19.18.1.1 Joining and fastening of components and assemblies, both internally within an assembly, and mounting the assembly or components to the car structure, shall consider the materials being joined. Specifically the design shall consider the strength, service life, maintainability, and aesthetic requirements as described in this Specification.
- 19.18.1.2 When providing drawings that include joining and fastening, the drawings shall be accompanied by the joining and fastening data, specifications, and standards for all types and methods of fastening and joining being used. Welding shall be addressed separately, following the requirements of Section 19.21.

19.18.2 Joint Design and Fitting Requirements

- 19.18.2.1 Joints shall be properly fitted, whether exposed or concealed. Joint design shall consider the materials being joined, possible corrosion, and other possible failure modes.
- 19.18.2.2 Insulating paints, moisture-proofing materials, or gaskets, as applicable to the materials being joined, shall be used to prevent corrosion.
- 19.18.2.3 Protective finishes shall be applied to the components prior to joining. Protective coatings shall be allowed to fully cure before assembly.
- 19.18.2.4 The Contractor shall submit for approval joining and fastening data, specifications, and standards for all types and methods of fastening and joining used. [CDRL]
- 19.18.2.5 Extreme care should be exercised in joining materials or components to ensure that the finished product is free from rattles and objectionable noises.
- 19.18.2.6 Where materials are riveted or bolted to metal, contact surfaces shall be free of dirt, grease, rust and scale per the Steel Structure Painting Council (SSPC – now Society for Protective

- Coating) SP11 minimum and, except for stainless steel parts, shall be coated with a metal base primer that will not interfere with later finish coating application or sealants. Primers shall be allowed to fully dry before assembly commences.
- 19.18.2.7 Joints shall be closely fitted with minimum gap per the approved drawings. Where gaps are necessary as identified on the approved drawings, or installation criteria, the joint shall be properly spaced to provide a uniform appearance.
- 19.18.2.8 For bolted and riveted joints, unless otherwise specified and justified by the Contractor, all gaps between joints shall be held to a dimension not greater than 10 percent of the thinnest material being joined, or 0.002 inch (0.05 mm), whichever is greater.
- 19.18.2.9 Where gaps greater than those permitted by accepted drawings or standards, are found to exist at mating surfaces of structural, bolted, or riveted metal-to-metal connections, metal shims shall be used with the written approval of NYCT.
- 19.18.2.10 When used, shims shall be made of the same material as that of the deficient metal part and shall be permanently fastened to one of the base parts being joined.
- 19.18.2.11 Gaps in joined components shall be uniform in width and surface height, per the approved drawings. Exposed edges of components at the gap location shall have a smooth finished appearance.
- 19.18.2.12 The use of epoxy or other plastic filler to fill joints at such locations is expressly prohibited.
- 19.18.2.13 All joints between aluminum, steel, or stainless steel, shall be suitably insulated from each other to prevent corrosion.
- 19.18.2.14 At assembly, fasteners shall not be used to "pull" joints together.

Visibility Criteria

- 19.18.2.15 No protruding screws, rivets, mounting bolts, or similar items shall be permitted on the visible portion of the exterior of the car.
- 19.18.2.16 The use of exposed fasteners on the car interior shall be minimized. Interior fasteners shall be countersunk where possible or use low profile heads where countersinking is not possible.
- 19.18.2.17 Interior fasteners shall not protrude sufficiently to become a tripping or snagging hazard.
- 19.18.2.18 Fasteners exposed to public view shall be treated as follows:
- a) On the car interior, all exposed fasteners shall be stainless steel or chrome plated, with flat or oval heads, properly countersunk.
 - b) On the car exterior, all exposed fasteners shall be stainless steel, unless otherwise specified.
 - c) Exposed screws accessible to passengers shall be of an approved tamper-proof type.
- 19.18.2.19 Fasteners not exposed to passengers on the car interior shall be of stainless steel in areas exposed to water intrusion; otherwise, fasteners may be stainless steel or zinc-plated steel.

Safety Hanging Requirements for Equipment Mounting

- 19.18.2.20 Equipment mounting assists (such as hooks, tabs, or alignment pins) shall be provided for all components of 25 lb (11.3 kg) or more, that require holding in place during installation, in order to insert or latch fasteners.

- 19.18.2.21 The mounting assist method used shall be capable of supporting the components full weight during the installation process.
- 19.18.2.22 Equipment located under the car shall be mounted on pads or hangers such that the equipment is not directly supported by bolts in tension.
- 19.18.2.23 Equipment mounting design shall consider the proper orientation of the component and include design elements that preclude mounting the equipment incorrectly. These may be the addition of a pin, tab, offset hole-pattern, or other element such that the equipment can only be mounted in the correct orientation.

Fastening to Structural Members

- 19.18.2.24 To the extent possible, fastening to structural members shall be done only on the low stress portion of the member and shall not be located less than two times the fastener diameter from any edge of a structural member.
- 19.18.2.25 The Contractor shall ensure that any fastening or joining to structural members does not result in moisture accumulation within any structural member. To this end, fastenings to hollow, closed section structural members shall not be accomplished using drilled holes in the structural member.

19.19 Fasteners

19.19.1 General

- 19.19.1.1 The contractor shall establish a Fastener Quality Plan to identify and monitor the fastener requirements. The Fastener Quality Plan shall be submitted for NYCT review and approval. [CDRL]
- 19.19.1.2 The Fastener Quality Plan shall contain the following minimum requirements:
- a) Sourcing Information (certificate of origin).
 - b) QA/QC plans and Lot Control.
 - c) Certifications of Compliance (C of C).
 - d) Evidence of verification of NYCT requirements.
 - e) Sampling and testing for dimensional and material properties.
 - f) Bolt and nut Identification and marking.
- 19.19.1.3 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.
- 19.19.1.4 The Contractor shall minimize the number of different sizes and styles of fasteners used.
- 19.19.1.5 Any fasteners requiring modification from the original, standard form shall be performed only by the original fastener manufacturer. Post-manufacture modifications are prohibited.
- 19.19.1.6 Throughout the car the use of inch-standard fasteners is preferred. However, ISO Metric fasteners may be used in conformance with Section 1.5.4. Fasteners shall be properly marked per the system adopted.
- 19.19.1.7 All threaded fasteners shall comply with ASME B1.1 class 2 requirements, unless otherwise specified or approved. All structural threaded fasteners shall have rolled threads.
- 19.19.1.8 The use of self-tapping or thread forming screws is prohibited.
- 19.19.1.9 Use of threaded inserts or special or non-standard fasteners shall require NYCT approval.
- 19.19.1.10 All fasteners used on this car shall be classified under one of four categories: critical, electrical and electronic, general-purpose, or decorative, as described below:

- a) Critical fasteners include, but are not limited to, those applied to undercar equipment, trucks and truck mounted equipment (such as: brake equipment; CBTC equipment; trip cock brackets; traction motors and gearbox mounts, etc.), bolsters, couplers, and power collection devices.

A fastener is safety related if failures cannot be tolerated, that is, if one or more fasteners fail, there is a possibility of brake failure, derailment, an accident, or injury.

In the event of a dispute, NYCT will be the final arbiter on which fasteners are classified as critical.

The sizing and arrangement of all critical fasteners shall be justified by analysis or testing using standardized or published methods and procedures. See Section 19.19.7.

- b) Fasteners used to secure wire terminations to an electrical or electronic device are considered electrical and electronic fasteners, and are specified in appropriate Materials and Workmanship subsections for electrical devices and wiring.
- c) Fasteners used to attach interior lining or trim and exposed to passenger view are specified under Decorative and Appearance Fasteners. See Section 19.19.8.
- d) All fasteners not falling into one of the preceding three classifications shall be considered general-purpose fasteners. See Section 19.19.15.

19.19.1.11 All fasteners, in any category, that attach to the car structure shall also be in accordance with Section 3.4.5.

19.19.1.12 Fasteners and fastener components used on the visible areas of the car or roof areas shall be stainless steel except in cases where high strength fasteners such as SAE grade 8 or metric property class 10.9 are required, as approved.

19.19.1.13 Underfloor equipment fasteners shall be selected and sized in accordance with the Specification requirements.

19.19.1.14 All fasteners used to secure access covers, doors, or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used.

19.19.1.15 Access panels, where access for service is expected more often than every 5 years, shall be equipped with quarter-turn fasteners.

19.19.1.16 Quarter-turn fasteners shall be properly sized for the application and have a minimum shank diameter of 0.25 inch (6.4 mm).

19.19.1.17 Unless otherwise approved by NYCT, threaded fasteners shall not be threaded directly into non-metallic materials. Tapping pads or metal threaded inserts, as approved, shall be used when a threaded fastener is secured to a non-metallic material.

19.19.2 Threaded Fasteners

19.19.2.1 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.

19.19.2.2 Fasteners shall not be permanently mounted in such a manner that they are not replaceable if damaged.

19.19.2.3 Fastener grip length shall be sized to ensure, to the extent possible, that the unthreaded shank of a bolt is in the shear plane of mated surfaces.

19.19.2.4 For Critical Fasteners, the fatigue and ultimate loading requirements of this Specification shall also guide the selection of fastener grip (and bolt) length.

19.19.2.5 At least 1½ screw threads shall be visible beyond the top surface of all nuts. When used without elastic stop nuts, bolts shall not project more than 1½ threads plus 0.25 inch (6.4

mm) for bolts 0.25 inch (6.4 mm) diameter or less, and shall not project more than 5 threads for larger diameter bolts, unless otherwise approved. With elastic stop nuts, bolt threads shall not project more than 0.25 inch (6.4 mm) beyond the top (metallic) surface of the nut, regardless of bolt size.

- 19.19.2.6 When making connections to heat producing apparatus, thermal expansion of the components shall be taken into consideration for selection of fastener materials.
- 19.19.2.7 If the joined components are high expansion alloys such as copper or austenitic stainless steel, austenitic stainless steel fasteners shall be used.
- 19.19.2.8 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.

19.19.3 Fastener Materials

- 19.19.3.1 Fastener component materials (screws, nuts, washers, etc.) shall be properly selected for the application and shall not be mixed within an assembly.
- 19.19.3.2 All fasteners shall be passivated stainless steel or steel finished with protective coating such as, dichromate or zinc-plating, depending on the specific application.
- 19.19.3.3 Threaded aluminum fasteners shall not be used.
- 19.19.3.4 Stainless steel nuts and bolts shall be used for stainless-to-stainless joints. Anti-seize compounds shall be used on all threaded stainless steel fasteners.

U.S. Standard Fasteners

- 19.19.3.5 Threaded fasteners shall conform to the following standards:
 - a) B1.1 Standard, Unified Inch Screw Threads, (UN and UNR Thread Form) or Industrial Fasteners Institute Fastener Standards, and SAE J429 standards for externally threaded fasteners and SAE J995 standards for internally threaded fasteners.
 - b) Steel fasteners 0.25 inch (6.4 mm) diameter and above shall be SAE Grade 5, minimum.
 - c) Nuts shall be selected to provide the suitable matching strength, material, and finishing, compatible with the mating fastener.
- 19.19.3.6 All critical bolts in any application and general-purpose bolts, of any material, shall be a minimum Grade 5, with sizing based upon the design strengths for grade 2 bolts and class A nuts.
- 19.19.3.7 The minimum size for fasteners used in undercar equipment shall not be less than 0.375 inch (10 mm) diameter, regardless of design load.
- 19.19.3.8 Stainless steel fasteners shall be manufactured from austenitic stainless steel alloys, according to ASTM F593, with a nominal tensile strength of 100 ksi. All fasteners shall be clean and free of manufacturing scale.
- 19.19.3.9 Non-structural screws, such as Phillips or slotted head screws smaller than 0.25 inch (6.4 mm) diameter may be SAE grade 2 minimum.

Metric Fasteners

- 19.19.3.10 Carbon steel Metric threaded fasteners shall conform to the following standards:
 - a) ASME B1.13M (ISO-metric), and SAE J1199, or the current equivalent, specified, DIN or ISO standards.
 - b) Carbon steel fasteners 6 mm diameter and above shall be property class 8.8 minimum for external threads, property class 8 minimum for nuts, per ISO 898/1 and ISO 898/2.

- c) Nuts shall be selected to provide the suitable matching strength, material, and finishing, compatible with the mating fastener.
- 19.19.3.11 All critical bolts in any application and general-purpose bolts for undercar equipment, shall be a minimum property class 8.8, with sizing based upon the design strengths for property class 4.8 bolts and property class 4 nuts. The minimum size for fasteners used in undercar equipment shall not be less than 10 mm diameter, regardless of design load.
- 19.19.3.12 Stainless steel fasteners shall be manufactured from A2 or A4 grade, austenitic stainless steel with a minimum property class of 70 per ISO 3506, with a minimum nominal tensile strength of 700 MPa.
- 19.19.3.13 Non-structural screws, such as Phillips or slotted head screws smaller than 6 mm diameter, may be property class 4.8 minimum for steel, property class 50 for stainless steel. Manufacturing tolerances shall be according to DIN 267, part 2, m (medium class).
- 19.19.3.14 All metric fasteners, washers, nuts, etc. shown on drawings or in Bills of Material are to be accompanied by their ISO-metric classification.

19.19.4 Threaded Hardware

- 19.19.4.1 All Critical and General Purpose threaded fasteners used in the cars shall require a submittal of Certifications of Compliance (C of C) with each shipment of hardware to the end user. The C of C shall be traceable to a manufacturer (see Section 19.19.7).

19.19.5 Locking Nuts

- 19.19.5.1 All nuts shall be of a grade, class, and material (inclusive of plating) compatible with the mating fastener (see also Section 19.19.10).
- 19.19.5.2 Inch standard nuts shall conform to ASME B18.2.2 for diameter of 0.25 inch (6.4 mm) or larger, and ASME B18.6.3 for diameters less than 0.25 inch (6.4 mm). Metric nuts shall conform to ASME B18.2.6.
- 19.19.5.3 Prevailing torque nuts shall be regular height, nylon insert, self-locking stop nuts (ESNA or approved equal), conforming to Aerospace Industries Association/ National Aerospace Standards, Metric AIA / NASM-21044 and Military Specification MIL-DTL-32258.
- 19.19.5.4 Where nylon-insert self-locking stop nuts cannot be used, self-locking bolts and screws conforming to MIL-DTL-18240 Type L may be used.
- 19.19.5.5 Nylon insert lock nuts shall not be used near heat sources that will exceed the manufacturer's recommended operating temperature. For application over 200°F (93°C), all metal prevailing torque locknuts shall be used.
- 19.19.5.6 The prevailing torque value for each fastener size used shall be established using published data and verified by measurement or test. For all fasteners above 0.25 inch (6.4 mm) diameter, the prevailing torque shall be added to nominal tightening torque.
- 19.19.5.7 When required by the application, slotted nuts may be used in conjunction with cotter pins. Bolts with holes for lock wire or cotter pins shall be chamfered on both sides of the hole.

19.19.6 Electrical and High Temperature Connections

- 19.19.6.1 Stainless steel fasteners are preferred in all applications exposed to high temperature connections such as used in mounting and in making connections to resistors and other heat-producing apparatus.

- 19.19.6.2 If approved by NYCT, plated steel screws or bolts, nuts, flat washers, and lock-washers may be used in high temperature applications. These fasteners shall be suitable for high temperatures without degradation of the strength or corrosion resistance.
- 19.19.6.3 Flat washers shall be used on both sides of all electrical connections (under bolt head and under nut).
- 19.19.6.4 Nylon insert type fasteners shall not be used in high temperature applications. See Section 19.19.5.5.

19.19.7 Critical Fasteners

- 19.19.7.1 All critical fasteners shall have documentation identifying manufacturer and purchase specifications available for examination at the Contractor's QA department by NYCT. 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.
- 19.19.7.2 All critical fasteners shall either a) be manufactured, tested, and distributed in accordance with Category 3 of ASME B18.18, 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 at an independent testing laboratory using sample quantities as proposed by the Contractor and approved by NYCT. 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.
- 19.19.7.3 All critical fasteners made from SAE Grade 8, Metric Grade 10.9 or higher that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement.

19.19.8 Decorative and Appearance Fasteners

- 19.19.8.1 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.
- 19.19.8.2 Bright finished fasteners used for stanchions shall be austenitic grade stainless steel. Bright finished interior fasteners for other applications may be either austenitic or plated martensitic stainless steel.
- 19.19.8.3 All exterior fasteners visible to passengers shall be austenitic stainless steel for steel, LAHT steel, and stainless steel carbodies.
- 19.19.8.4 Exterior aluminum shall be joined by austenitic stainless steel or aluminum alloy fasteners, as appropriate to the design and appearance requirements.
- 19.19.8.5 Fasteners used on the side sill to attach heavy equipment brackets are structural fasteners specified under either the critical or general-purpose fasteners section, as appropriate for the application.

- 19.19.8.6 Fasteners on access panels, plates, covers, or other components accessible by passengers shall be of a single style tamperproof type, approved by NYCT.
- 19.19.8.7 All decorative and appearance fasteners shall have documentation that identifies the manufacturer, the fastener type base material, and plating or finish if applied. The Contractor or supplier shall maintain this documentation on file for NYCT to review for a period of not less than the expiration of the warranty on the last car delivered.

19.19.9 Fastener Pre-Load and Torqueing

- 19.19.9.1 All critical fasteners and general-purpose fasteners used to secure any equipment to the carbody, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, shall be torqued to a minimum preload equal to 75 percent of their proof load and "torque striped" after torqueing by using a torque seal compound that clearly indicates any loosening movement. All other fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service.
- 19.19.9.2 Fastener installation torque for standard oiled or waxed bolts with standard or heavy hex nuts may be calculated from Industrial Fasteners Institute, Fastener Standards, equations using values for "K" of 0.18 for un-plated and 0.15 for plated threads. The Contractor shall demonstrate these values are consistent with the fastener as installed during production. Validation of "K" factors shall be conducted using an approved procedure and industry standard test methods.
- 19.19.9.3 Locknuts shall be torqued in accordance with their manufacturer's recommendations or the Contractor may conduct tests to determine installation torque.
- 19.19.9.4 For those nuts or bolts requiring "torque striping," NYCT may require bolt torque-tension tests to verify that installed preload is equivalent to 75 percent of proof loads.
- 19.19.9.5 The contractor shall submit for approval a Fastener Analysis and Application Plan (FAAP) that addresses all category of fasteners, regardless of size and application. [CDRL]
- 19.19.9.6 The FAAP shall describe, at a minimum, the following in detail:
- The methodologies that will be used to analyze critical and general purpose for operating loads, fatigue loading, and ultimate loading cases for all fasteners.
 - Mechanical properties of all fastener elements and clamped elements, as appropriate, including fatigue allowables.
 - Design preloads with appropriate tolerances and all failure criterion.
 - The required application torque, the preload developed at the application torque, the condition of the threads, nut and head bearing surfaces (lubrication or "K" factor).
 - The added prevailing torque required for all locking fasteners.
- 19.19.9.7 The derivation of all values shall be indicated. The method of torque application or tightening shall be indicated. If a range of acceptable torque is established, the minimum torque shall meet the requirements of this Specification. When necessary, alternate methods of determining fastener preload may be proposed for NYCT's consideration. All threaded fastener installation torque and lubrication conditions shall be indicated on the drawings for each fastener.

19.19.10 Locking Requirements

- 19.19.10.1 Critical and general purpose fasteners shall be provided with secondary locking devices.
- 19.19.10.2 Secondary locking devices shall be lockwire, locking plate, or liquid adhesive locking compound, torque patch, or prevailing torque type locknuts as appropriate for the application or service. Lockwire, if used, shall be stainless steel as specified in Section 19.2.

- 19.19.10.3 A cleaning procedure per the manufacturer's recommendation shall be developed, demonstrated to NYCT, and applied on all installations where liquid adhesive locking compounds are used. These procedures shall be included in the appropriate Overhaul Process Manuals for NYCT's reference and use.
- 19.19.10.4 Helical spring and serrated style lock washers shall be limited to Electrical, Decorative, and Appearance Fasteners, for example terminal connections or interior panels.
- 19.19.10.5 At the discretion of NYCT, additional and/or alternate locking devices may be mandated in certain Critical Fasteners.
- 19.19.10.6 Prevailing torque locknuts shall be of the nylon collar insert type. Previously installed and removed locknuts shall not be reused. High temperature applications may use metallic distorted thread locknuts upon NYCT approval.
- 19.19.10.7 Bolts for use with prevailing torque locknuts shall not be drilled for cotter pins or lockwire.
- 19.19.10.8 All locknuts shall comply with the Industrial Fasteners Institute requirements regarding their ability to resist loosening.
- 19.19.10.9 When oversized or elongated holes are provided for installation tolerance allowance, flat washers per ASTM F436 hardened (structural) of suitable size to cover oversized holes without deforming shall be used in all locations adjacent to the hole. In this case, at least one hole shall be of standard bolt hole tolerance to ensure accurate positioning of component.
- 19.19.10.10 If slotted holes are provided as a means of adjusting a piece of equipment, a secure method of fixing the adjustment shall be provided, such as adjustment screws, ribbed or toothed adjustment washers, or drilled holes and pins.
- 19.19.10.11 Helical Spring Lock washers shall not be used for fatigue applications where the fastener must be torqued and marked. Prevailing torque nuts shall be used for these applications.
- 19.19.10.12 Other types of washers, including Belleville washers, may be used for special applications with NYCT's approval.
- 19.19.10.13 Lock washers, when applied, shall conform to ASME B18.21.1.
- 19.19.10.14 Locking plates or locking tabs that are captured under the head of the bolt, under the nut, or in between any of the faying surfaces being clamped by the bolt or nut intended to be locked by the tab shall not be used unless otherwise approved by NYCT.

19.19.11 Rivets and Lock Pins

- 19.19.11.1 Rivets and lock pins exposed to passengers shall be austenitic stainless steel or aluminum, as appropriate to the materials being joined.
- 19.19.11.2 Structural steel rivets shall conform to ASTM A502 or ASME B18.1.2 standards. Rivets may be hand driven when hot and shall completely fill the rivet holes.
- 19.19.11.3 Rivets driven cold shall be mechanically driven. Exposed heads shall be concentric with the shank and free from rings, fins, pits, and burrs.
- 19.19.11.4 Two-part swage-locking rivets consisting of a pin and collar (such as "Huck-Bolt" types) fasteners shall conform to Military Specification MIL-P-23469.
- 19.19.11.5 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. NYCT shall be the final arbiter in determining whether an application is hazardous to maintenance personnel.

- 19.19.11.6 Blind rivets may be used subject to NYCT approval. Blind rivet materials may be stainless steel, or plated carbon steel with plated steel or stainless steel mandrels compliant with SAE J1200.
- 19.19.11.7 The mandrel shall break flush or slightly below the surface of the rivet head, but shall remain locked in place as a structural part of the rivet assembly.
- 19.19.11.8 All rivets shall be installed according to the rivet manufacturer's instructions, using equipment approved by the rivet manufacturer.
- 19.19.11.9 Rivet nuts shall be of the positive locking type, with either exterior serrations or hex cross sections to preclude spinning once installed. The rivet nut hole shall be made per the rivet nut manufacturer's recommendations.

19.19.12 Plating and Treatment of Fasteners

- 19.19.12.1 All steel fasteners shall be zinc-plated with the highest protective service condition available per thread configuration.
- 19.19.12.2 Stainless steel fasteners shall be passivated.
- 19.19.12.3 Chrome plated steel fasteners used for interior cosmetic applications shall be plated per ASTM B456, class SC-3. If stripping and re-plating of fasteners is required to meet the aforementioned criteria, documentation must be made available to NYCT to verify that all applicable post plating treatments and standards have been met. NYCT may require batch testing of stripped and re-plated fasteners to ensure there is no hydrogen embrittlement.
- 19.19.12.4 After manufacturing, U.S. Standard steel fasteners shall be electroplated, zinc with a yellow chromate conversion per ASTM B633, Type II - Yellow (refer to table 19-12 for thickness).
- 19.19.12.5 After manufacturing, metric steel fasteners shall be electroplated, zinc with a yellow chromate conversion per ISO 4042 (refer to Table 19-12 for thickness).

Table 19-12 Plating Thickness for Steel Fasteners

Plating Thickness for Steel Fasteners, Zinc, Yellow Chromate Conversion			
Bolt size	U.S. ASTM B633	Metric DIN 267	Thickness (Inch / Micro meter)
Dia. up to #8 (M3)	-	A1L	.00012 inch/3 μm
Dia. >#8 (M3) to 5/16" (M8)	SC1	A2C or A2L	.00020 inch/5 μm
Dia. >5/16" (M8) to 7/8" (M22)	SC2	A3C	.00031 inch/8 μm
Dia. >7/8" (M22) to 1-1/8" (M33)	SC3	A4C	.00051 inch/13 μm
Dia. >1-1/8" (M33) and greater	-	A5C	.00059 inch/15 μm

19.19.13 Hydrogen Embrittlement

- 19.19.13.1 Fasteners or fastener components with Vickers hardness (HV) greater than or equal to 320 HV (32 HRC) are susceptible to hydrogen embrittlement when these parts are pickled and/or electroplated. This condition may cause these fasteners to fail at relatively low loads even if stress relief annealing (baking) is performed after plating. Examples of hardened fasteners are steel bolts – U.S. Grade 8 (Metric property class 10.9), hardened steel washers, spring washers, etc. These types of fasteners shall be mechanically plated to avoid hydrogen embrittlement per ASTM B695, Type II, Class 5 minimum, with the thickness increasing as appropriate for class of thread fit. Electroplating of the aforementioned hardened fasteners is prohibited.
- 19.19.13.2 All safety-related (see Section 19.19.7), high strength fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement, based on a representative sample of the actual production fasteners, tested for hydrogen embrittlement by the manufacturer or original equipment manufacturer (OEM), Contractor, or a supplier following ASTM F519 procedures. An ASTM F606 wedge-test sample may be used in place of the F519 standard samples. Test loads shall be a minimum of 80 percent of yield strength or proof load and held for a minimum of 168 hours. Any failures shall require rejection of the entire lot.

19.19.14 Rivet and Bolt Holes

- 19.19.14.1 Rivet and bolt holes shall be accurately sized, located, and aligned for the intended fastener. If necessary during assembly, holes shall be reamed round to specified size in position. Bolt hole clearances shall not exceed the requirements of ASME B18.2.8 for normal clearance.
- 19.19.14.2 All removed and replaced rivets shall have the holes reamed to the size required such that the next larger rivet may be driven securely.
- 19.19.14.3 All rivet holes shall be de-burred on all edges using an approved procedure.
- 19.19.14.4 Blind rivet holes shall be verified for size and grip at installation using tooling recommended by the rivet manufacturer.

19.19.15 General Purpose Fasteners

- 19.19.15.1 All general-purpose fasteners shall have documentation that identifies the manufacturer, base material, plating or finish if applied, and the fastener type. The Contractor or supplier shall maintain this documentation on file for NYCT to review for a period of not less than the expiration of the warranty on the last car delivered.
- 19.19.15.2 Fasteners used within equipment shall be selected and sized such that they can be classified as general-purpose. General-purpose fasteners must meet all requirements of Section 19.19, other than the requirements specifically listed for critical fasteners or decorative fasteners, and shall be sized as appropriate for the application.

19.20 Adhesives, Sealants, and Caulking

19.20.1 General Requirements

- 19.20.1.1 All bonding and sealing materials that are applied prior to curing shall be applied according to the manufacturer's full recommendations, including surface preparation, mixing criteria, application temperature, shelf life limits, pot life limits, curing temperature, curing exposure (before handling or loading), etc.

- 19.20.1.2 The Contractor shall submit for approval a listing of proposed sealants and caulking materials, intended application on the car, including location, technical data and specification sheets, MSDS, and flammability properties. Adhesives used in small quantities may not require flammability data, subject to NYCT approval. [CDRL]
- 19.20.1.3 All uncured material shall be stored and applied according to the manufacturer's full recommendations. All materials shall be used within the specified shelf life limits; material that has exceeded the shelf life shall not be used.
- 19.20.1.4 Preparation prior to bonding or painting the surface shall be prepared according to ASTM D2651. Caulking shall not be applied to bare carbon steel.
- 19.20.1.5 For adhesives and sealants used in applications that will require overhaul or potential repair, NYCT prefers they be manufactured by U.S. (or North American) manufacturers. If foreign sourced products are used, documentation and labels shall be written in English and the Contractor shall identify North American alternatives in the submittal noted in Section 19.20.1.2.

19.20.2 Adhesives

- 19.20.2.1 Adhesives to be used for installation of floor covering, panels, insulation, and vibration isolation materials shall have a satisfactory history of performance in a rail transit environment.
- 19.20.2.2 Joining of components by adhesives shall be completed within the maximum working times as follows:
- a) The application and aligning of bonded components shall be completed within 70 percent of the adhesives maximum working time, considering application conditions.
 - b) When two-part compounds are being used, only the amount of adhesive that can be used within 70 percent of the maximum recommended pot life shall be mixed.
- 19.20.2.3 Adhesives that use atmospheric or humidity cure shall be installed such that they are exposed to air circulation until full cure of the adhesive is achieved.
- 19.20.2.4 Adhesive selection and bonded joint design shall consider the guidelines in ASTM D6465. The contractor shall submit the procedures used to prepare, clean and apply adhesive bonded joints for review. [CDRL]

19.20.3 Sealants and Caulking

- 19.20.3.1 The use of caulking and sealing compounds shall be minimized.
- 19.20.3.2 Caulking and sealing compounds shall be applied in accordance with the manufacturer's instructions and recommendations, shall be non-staining, and shall be supplied in colors closely matching those of adjacent materials and surfaces.
- 19.20.3.3 Caulking used in exterior applications shall be UV resistant. If butyl-type is used, it shall be extruded polyisobutylene sealer compound of 100 percent solids.
- 19.20.3.4 Caulking primers shall be quick-drying, colorless, non-staining sealers of a type and consistency recommended by manufacturers of caulking materials for the particular surface involved.
- 19.20.3.5 Packing (backstop) shall be non-staining, resilient material, such as fiberglass roving, neoprene, butyl, closed-cell foams, or other compressible materials compatible with the caulking compound used.

- 19.20.3.6 Joints, spaces, and junctures to be packed and caulked or sealed shall be completely cleaned of dirt, dust, oil, and other foreign materials that would adversely affect caulking quality. A suitable primer shall be used to achieve full adhesive bond.
- 19.20.3.7 Surfaces shall be thoroughly dry before caulking compounds are applied.
- 19.20.3.8 Caulking compound application shall be compatible with prior or subsequent paint application. When so stipulated by the sealant manufacturer, paint and other protective coatings shall be removed from surfaces to be caulked prior to priming and application of sealants.
- 19.20.3.9 Compounds shall be applied with pneumatic guns. Where the use of a caulking gun is impracticable, suitable hand tools shall be used.
- 19.20.3.10 Unless otherwise indicated, the entire perimeter of each opening shall be caulked.
- 19.20.3.11 The finish of caulking joints on flush surfaces and in internal corners shall be neatly pointed; excess material shall be removed; and, where exposed, the caulking shall be free of wrinkles and uniformly smooth.
- 19.20.3.12 Application of polysulfide or silicone compounds shall be in accordance with the manufacturer's instructions and recommendations.
- 19.20.3.13 Compounds shall not be used when they become too gelled to be discharged in a continuous flow or exceed their stated shelf life, and they shall not be modified by addition of liquids, solids, or powders.
- 19.20.3.14 Compounds shall be installed within the manufacturer's defined temperature range.
- 19.20.3.15 Installation and working of compounds shall be completed within the maximum working times as follows:
- a) The application and working of caulking material shall be completed within 70 percent of the minimum "skin" time, considering application conditions.
 - b) When two-part compounds are being used, only the amount of caulking that can be installed within 70 percent of the maximum recommended pot life shall be mixed.
- 19.20.3.16 Adjoining surfaces, finishes, and fixtures shall be carefully protected throughout caulking operations. Stains, marks, or damage as a result of caulking and sealing work shall be removed.

19.21 Welding and Brazing

19.21.1 General

- 19.21.1.1 All welding practice not specifically covered in this section shall be in accordance with the applicable requirements and recommendations of the AWS, as contained in the latest revisions of the following:
- a) Structural Welding Code (AWS D1.1).
 - b) Aluminum Welding Code (AWS D1.2).
 - c) Structural Welding Code - Sheet Steel (AWS D1.3).
 - d) Guide for Welding Iron Castings (AWS D11.2).
 - e) Recommended Practices for Resistance Welding (AWS C1.1).
 - f) Railroad Welding Specification (AWS D15.1).
 - g) Specification for Resistance Welding (AWS D17.2).
 - h) AWS Welding Handbook (AWS WHB).

- i) AWS Brazing Handbook (AWS BRH).
 - j) AWS Filler Metal Procurement Guidelines (AWS A5.01).
- 19.21.1.2 The Contractor shall demonstrate compliance with AWS welding requirements and standards. Where non-AWS welding is proposed, the supplier shall provide documentation to demonstrate equivalence to AWS requirements for NYCT review and approval.
- 19.21.1.3 The Contractor shall be responsible for the quality of all welding and brazing, including the welding and brazing done by its suppliers and subcontractors.
- 19.21.1.4 Prior to welding, all surfaces shall be thoroughly cleaned to remove corrosion, rust, scale, slag, grease, oil, water, paint, and other foreign materials in accordance with applicable parts of AWS D1.1, Section 8.5 on Workmanship and Technique.
- 19.21.1.5 Parts to be joined by welding shall be supported and held in position by tables, jigs, or fixtures to prevent warping and to maintain their proper interrelation during welding.
- 19.21.1.6 Weld joint design and welding method shall be selected to include provisions for shrinkage and warping due to the welding process.
- 19.21.1.7 Welding shall be applied in a manner to minimize distortion. Acceptable distortion levels shall be submitted for NYCT approval. [CDRL]
- 19.21.1.8 Weld quality shall be in accordance with acceptable weld criteria as defined in AWS welding codes. The Contractor shall submit demonstration of compliance with AWS for all Welding Procedures Specifications (WPS), Procedure Qualification Records (PQR), and welder certifications for approval. [CDRL] All PQRs shall be prepared using materials from production lots. At the discretion of NYCT, additional material weldability testing may be requested, depending on the Contractor's selection of materials and grades selected.
- 19.21.1.9 If laser welding is used, the appropriate documentation defining the design parameters, process control, qualification, and quality control shall be submitted for review and approval by NYCT.
- 19.21.1.10 Laser welding shall, at a minimum, comply with the recommended practices in AWS C7.2, latest revision. Alternative standards for laser welding, such as international standards, may be proposed but shall be submitted for review and approval by NYCT.

19.21.2 Structural Welding

- 19.21.2.1 All structural welding practices shall be in accordance with the following requirements, considering the requirements for dynamically loaded structures:
- a) Structural Welding Code - Steel for 0.125 inch (3 mm) and over thickness steel (AWS D1.1).
 - b) Structural Welding Code - Aluminum (AWS D1.2).
 - c) Structural Welding Code - Sheet Steel for under 0.0125 inch (3 mm) thickness (sheet) steel (AWS D1.3).
 - d) Structural Welding Code – Stainless Steel (AWS D1.6).
 - e) AWS Handbook.
- 19.21.2.2 Cast steel welding shall be according to ASTM A488/488M, "Steel Castings, Welding, Qualification of Procedures and Personnel."
- 19.21.2.3 Resistance welding shall be in accordance with AWS D17.2.

- 19.21.2.4 If alternative welding practices are utilized, such as laser welding, the appropriate documentation defining the design parameters, process control, qualification, and quality control shall be submitted for review and approval by NYCT.
- 19.21.2.5 Structural welding of ferritic and austenitic stainless steel shall be governed by AWS D1.6, "Structural Welding Code-Stainless Steel," ASME Boiler and Pressure Vessel Code (BPVC) Section IX and ASME Section VIII, Part UHA.
- a) SAE 201L, 201LN, SUS 201, and 301LN stainless steels shall be treated as P-No. 8, Group-No. 3 category for reference to ASME requirements.
 - b) Ferrite number for welds shall be between WRC4 and WRC10 per AWS A4.2 (Welding Research Council), or as proposed by the Contractor and approved by NYCT.
 - c) 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.
 - d) Fatigue allowable stresses shall not exceed the lesser of fatigue limits in Section 2.20.6 of AWS D1.1, or 50 percent of the joint strength level calculated from ASME maximum allowable stress values. Higher values shall only be used if qualified by Contractor tests.

19.21.3 Welder Qualification

- 19.21.3.1 Welders shall make only those welds for which they have been qualified according to the requirements of the AWS, ASME BPVC Section IX, ASTM A488/488M, or other approved qualifying procedures. Records of welder qualification tests shall be made available to NYCT for review.
- 19.21.3.2 NYCT shall have the right to require the making of test welds by any welder, whether under the direct control of the Contractor or a supplier or subcontractor, to ascertain his/her competence and to determine the suitability of the welding procedure used.

19.21.4 Inspection of Welds

- 19.21.4.1 The Contractor shall visually inspect all structural welds in accordance with AWS D1.1 and AWS D1.6 requirements.
- a) The Contractor shall use and demonstrate the use of personnel qualified to perform weld inspection.
 - b) An AWS Certified Welding Inspector (CWI) shall be utilized for inspection or oversight of welding inspection.
 - c) A record of all non-destructive testing NDT inspections shall be included in the Car History Book.
 - d) Personnel performing non-destructive testing shall have documented qualifications in accordance with American Society of Non-destructive Testing (ASNT), SNT-TC-1A, Level II minimum qualification.
- 19.21.4.2 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. The Contractor shall specify a sample nondestructive inspection rate for all subsequent welds.
- 19.21.4.3 For the test truck, the non-destructive surface inspection (dye penetrant or magnetic particle) shall be completed on all critical welds and the results submitted to NYCT for review and analysis.

- 19.21.4.4 Additionally, all non-critical external welds of the test truck shall be examined by magnetic particle inspection and the results submitted for review and analysis.
- 19.21.4.5 Major weldments and all full penetration welds shall be nondestructively, volumetrically inspected (ultrasonic or radiographic methods) according to AWS D1.1 and AWS D1.6 requirements on all first-production structures.
- a) The Contractor shall specify a random sampling plan for volumetric inspection of subsequent full penetration welds for approval. [CDRL]
 - b) The minimum acceptable inspection plan shall require inspection of one portion of a full penetration weld for every 200 production welds made.
 - c) The proposed test welds shall be selected from among welds that are most critically loaded as decided by calculations or load test results.
 - d) With approval, destructive sectioning and metallurgical examination may be substituted for some or all of the required volumetric inspection requirements for production welds.
- 19.21.4.6 If ring welds are used, on the first structure, all ring welds shall be nondestructively inspected by magnetic particle or dye penetrant methods.
- 19.21.4.7 The Contractor shall submit a random sampling plan for additional nondestructive 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. [CDRL]

19.21.5 Post-Weld Cleaning Requirements

- 19.21.5.1 All welds exposed to passengers or on sliding contact surfaces of truck frames and bolsters shall be completely cleaned of all spatter.

19.21.6 Contractor Documentation

- 19.21.6.1 All welding procedures, material specifications, and documents, including Procedure Qualification Records, and Resistance Spot Welding Schedules, shall be submitted for NYCT approval before application. [CDRL]
- 19.21.6.2 Specifications for purchase of welding electrodes, welding wires, and cover gases shall be submitted for NYCT approval before their application. [CDRL]
- 19.21.6.3 If the Contractor proposes to use laser welding, documents such as WPS/Procedure Qualification Record (PQR) are required to be submitted to NYCT for approval to implement laser welding.

19.21.7 Special Welding

- 19.21.7.1 Procedure and qualification records for structural welding of stainless steel to LAHT shall be submitted to NYCT for approval. As part of the qualification of all dissimilar metal welds, sample welds shall be sectioned and examined metallographically to determine Heat Affected Zone (HAZ) hardness. The HAZ hardness shall not exceed 400 HV. [CDRL]
- 19.21.7.2 Austenitic stainless steel electrodes or wire shall be used to join carbon to LAHT steels to stainless steels.
- 19.21.7.3 Galvanized steel shall not be welded to stainless steel.
- 19.21.7.4 Procedures and qualification records for structural welding of other combinations of metals or conditions not covered by AWS specifications or codes shall be submitted to NYCT for approval.

19.21.8 Resistance Welding

- 19.21.8.1 Resistance welding of stainless or carbon steels shall be according to AWS D17.2, Class B for structural applications and Class C for non-structural applications. Contractor-proposed deviations from AWS D17.2, including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted to NYCT and approved before application on production hardware.
- 19.21.8.2 Design strengths higher than standard certification and production strength requirements shall be qualified according to AWS D17.2 for one thickness.
- a) Requires a test lot size of 180 spot welds.
 - b) Additional thickness combinations with the same increased strength ratio may be qualified by 25 spot weld shear tests plus 3 macro-sections.
 - c) Twenty of the 25 shear test specimens may be recorded from production witness tests taken from 20 consecutive production days (not calendar days).
 - d) The Contractor shall submit records of the settings, ultimate shear strength, weld diameter, and weld penetration for approval.
- 19.21.8.3 Surface indentation shall not exceed 20 percent of material thickness or 0.01 inch (0.25 mm), whichever is greater. However, for exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10 percent of material thickness or 0.005 inch (0.13 mm), whichever is greater.
- 19.21.8.4 For exposed welds, visible from the platform, the Contractor shall vary welding parameters and conditions within their acceptable ranges to minimize indentations. Surface burn and discoloration, visible from the platform, shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.
- 19.21.8.5 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.

19.21.9 Resistance Spot Weld and Intermittent Weld Spacing

- 19.21.9.1 Spacing of resistance and spot welds shall be according to approved structural drawings. Spacing shall not exceed 2 inches (51 mm) plus twice the weld nugget diameter for any structural application, including car body side sheets, roof sheets, and corrugation. Where the compressive stress is not critical, wider spacing may be approved on a case by case basis.
- 19.21.9.2 Intermittent fusion-weld spacing pitch shall not exceed 5 inches (127 mm) for 2 inch (51 mm) (minimum) weld lengths (40 percent minimum of length welded), unless otherwise approved by NYCT.
- 19.21.9.3 There shall be two spot welds between each node for any corrugation application, if the pitch of the corrugation nodes does not allow for the weld spacing per 19.21.9.2, unless otherwise approved by NYCT.

19.21.10 Toughness of Welded Assemblies

- 19.21.10.1 The Contractor shall prove all welded steel structures are above the ductile-brittle transition temperature for the specified environmental exposure. Specifically, the HAZ and base metal shall resist service impact loads at the lowest specified operating temperature without brittle failure.
- 19.21.10.2 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 lb ft (20.3 Nm) of absorbed energy at the lowest specified operating temperature.
- 19.21.10.3 NYCT shall have the right to require impact tests to verify the specified toughness.

19.21.11 Torch Brazing

- 19.21.11.1 All brazing, defined as heating above 840°F (449°C), shall follow the recommendations contained in the AWS Welding Handbook, Volume 2.
- 19.21.11.2 Procedures for, personnel who perform brazing work shall be qualified in accordance with AWS B2.2, "Standard for Brazing Procedure and Performance Qualification". [CDRL]

19.21.12 Torch Soldering

- 19.21.12.1 All structural (not electrical) soldering, defined as heating below 840°F (449°C), shall follow the recommendations contained in the AWS Welding Handbook, Volume 2.
- 19.21.12.2 Procedures and personnel who do torch soldering shall be qualified through the preparation and testing of samples of production torch soldering.
- 19.21.12.3 Test samples shall be prepared and submitted for approval before production torch soldering. [CDRL]

19.22 Paints and Coatings

19.22.1 General Requirements

- 19.22.1.1 The portion of the carbody or any of its components receiving paint shall be painted as required by the Specification and in accordance with the specified color scheme.
- 19.22.1.2 Paints and coatings shall meet the requirements contained within Appendix C-24 (Paints and Coatings).
- 19.22.1.3 Any austenitic stainless steel portions of the car body shall not be painted, unless otherwise specified by NYCT for cosmetic reasons.
- 19.22.1.4 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.
- 19.22.1.5 All painting to be applied on the car body or any other component shall be performed in accordance with the paint manufacturer's recommendations.
- 19.22.1.6 The Contractor and its paint supplier shall supply a touch-up procedure and assure that a continuing supply of touch-up paints in colors used on the car, in quantities of 5 to 10 gallons (19 to 38 L), and suitable for spot application by spray, roller, or brush, will continue to be available in the United States for a minimum of 15 years after delivery of the last car.

19.22.2 Materials and Preparation

- 19.22.2.1 Primer, finish paint, and related components shall be supplied as a complete system, manufactured by a single manufacturer.
- 19.22.2.2 All mixed paint materials shall be used within the first 70 percent of the mixed pot-life time.
- 19.22.2.3 Paint shall be applied within the manufacturer's recommended temperature range, but at a temperature no less than 55°F (13°C).
- 19.22.2.4 All paint materials shall be used at the consistency recommended by the paint supplier. If thinners or reducers are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended.
- 19.22.2.5 Painting shall be done by experienced labor, using proper equipment under competent supervision.
- 19.22.2.6 Preparation of the substrate surface and application of painting materials by roller, brush, or spray shall be in accordance with the paint supplier's recommendations.
- 19.22.2.7 All painting materials for all surfaces shall be a high quality finishing system resistant to corrosion, chipping, and fading and shall retain the gloss level. The coating shall be a two-part, high solids, low Volatile Organic Compound (VOC), two-part polyurethane paint system with a solids content between 50 and 70 percent.
- 19.22.2.8 Alternate paint systems, such as base coat-clear coat systems, or direct-to-metal paint systems will be considered if the paint performance equals or exceeds two-part polyurethane.
- 19.22.2.9 All paint and filler materials that are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components.
- 19.22.2.10 Metal portions of the carbody not constructed of austenitic stainless steel shall, after fabricating, be prepared for painting by either abrasive grit blasting or power tool cleaning according to ASTM D2200. The surface finish shall be Near White Metal, using Method "A", or Method "B" of SSPC SP-10.
- 19.22.2.11 The surface shall be immediately painted with an approved epoxy primer, or washed with an alkaline solution, properly rinsed, phosphate coated or painted with a coat of wash (etch) primer, and then coated with an approved epoxy primer.
- 19.22.2.12 After erection of the framing structure and body sheets, all undercar metal, except stainless steel, shall receive a polyurethane finish as specified above.
- 19.22.2.13 The color of the underframe paint shall match DuPont charcoal gray, Color No. 6334.
- 19.22.2.14 The supplier shall submit color samples and corresponding tri-stimulus values for approval.
- 19.22.2.15 The exterior cosmetic finish shall have a gloss level greater than 80 as measured with a 60° glossmeter per ASTM D 523 - 60° axis angle with equivalents shown for 80° and 20°.
- 19.22.2.16 Use of water-based paint is prohibited.
- 19.22.2.17 Paint supplied to NYCT for touch-up purposes shall not require the use of thinners.

19.22.3 Exterior Painting

- 19.22.3.1 All exterior surfaces that are to be painted shall be prepared and the paint applied according to the paint manufacturer's recommendations.

- 19.22.3.2 The paint shall be uniformly applied over all surfaces to be covered and shall be free from runs, sags, "orange peel," or other application defects.
- 19.22.3.3 Surface irregularities such as orange peel shall be evaluated according to visual comparison such as the ACT Test Panel Technologies supplied Orange Peel Standards, or measurement by Byk-Gandner wave scan. The Contractor shall propose levels of surface irregularities based on location on the car and visibility to passengers for NYCT review and approval.
[CDRL]
- 19.22.3.4 Painting shall be done in a clean, dry atmosphere at an ambient temperature as recommended by the paint manufacturer.
- 19.22.3.5 Cosmetic coatings of paint shall have specified gloss levels for the appearance desired. Gloss levels are defined according to common terminology, with the criteria in Table 19-13 based upon the ASTM D523 - 60° axis angle with equivalents shown for 80° and 20°.

Table 19-13 – Gloss Level Requirements for Exterior Paint

Gloss Level Definition	Glossmeter Setting and Gloss Value		
	20 degree	60 degree	85 degree
High Gloss	85-90%	90-95%	95-100%
Semi-Gloss	0-10%	20-30%	50-60%
Flat Gloss	0%	0-10%	10-20%

- 19.22.3.6 At least two coats of finish paint shall be applied, with appropriate surface preparation between coats.
- 19.22.3.7 Touch-up paint shall be identical in all respects to the original paint. Color chips for color match may be provided by the contractor for NYCT approval, to establish acceptable color match tolerances. It is the Contractor's responsibility to ensure that the color match is acceptable. It may be required that the color match be made according to ASTM D2244. In no case shall color mismatch detract from the overall appearance of the equipment.
- 19.22.3.8 Before painting any car surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed as applicable for the material type, so as to minimize the use of filler material. These surfaces shall be properly cleaned and wash primed following straightening (where used). Any remaining dents or other surface imperfections shall then be filled with an approved filler and sanded smooth.
- 19.22.3.9 The maximum allowable filler thickness shall be as recommended by the filler manufacturer for the environment and service to which it is to be exposed, but in no case shall it exceed 0.125 inch (3.2 mm).
- 19.22.3.10 The final painted surface shall be tested on the first car to the following criteria:
 - a) Hardness - Pencil Hardness tests shall be performed according to ASTM D3363. The range of acceptance shall be between H and 2H and shall be the average of 10 readings taken from typical surface locations. This is a destructive test and will require the tested surfaces to be repaired.
 - b) Adhesion - Adhesion shall be tested per ASTM D3359 and achieve a minimum 4B rating. This is a destructive test and will require the tested surfaces to be repaired.
 - c) Thickness - The minimum and maximum dry film thicknesses shall be provided by the paint supplier. Dry film thicknesses beyond the manufacturer's recommendations will not be accepted. Non-destructive testing shall be performed to verify final dry film thickness.

- d) Paint Cure - A solvent rub test shall be performed per ASTM D5402. The test procedure requires no less than 50 double-finger rubs with a cloth wetted in acetone or methyl isobutyl ketone to the painted surface. No paint color should transfer to the cloth. After 72 hours, the painted surface must retain all original characteristics such as gloss and hardness.

19.22.4 Apparatus and Underfloor Equipment

- 19.22.4.1 All underfloor apparatus (motors, control boxes, junction boxes, brake valves, and other equipment as specified) shall be primed and painted in accordance with Sections 19.22.4.2 through 19.22.4.6 unless otherwise indicated. All other apparatus shall be painted in their approved colors.
- 19.22.4.2 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 Sections 19.22.2 and 19.22.3.
- 19.22.4.3 The interior and exterior surface of all propulsion control equipment enclosures shall be coated with an approved insulating, thermosetting, resin-based, powder coating or polyurethane paint system.
- 19.22.4.4 The interior of the boxes, including insides of covers, shall be white and the exteriors shall match the undercar paint scheme.
- 19.22.4.5 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.
- 19.22.4.6 An exterior finish of polyurethane to match DuPont charcoal gray, Color No. 6334, shall be provided for equipment control groups, traction motors and gear boxes, unless otherwise approved by NYCT.

19.22.5 Painting Restrictions

- 19.22.5.1 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.
- 19.22.5.2 The following items shall not be painted:
 - a) Copper tubing, piping, and fittings.
 - b) Wire and cable.
 - c) Power resistors.
 - d) Heat transfer surfaces.
 - e) Electrical insulators.
 - f) Elastomeric portions of air and refrigerant lines.
 - g) Grounding pads.
- 19.22.5.3 The following truck-related items shall not be painted:
 - a) Wheels.
 - b) Axles.
 - c) Elastomeric parts (ex. Primary suspension chevrons, Air suspension elements, etc.).
 - d) Grease fittings.
 - e) Linkages.
 - f) Threaded parts used for adjustments.

- g) Electrical equipment.
- h) Wearing surfaces.
- i) CBTC and ATC equipment.

19.22.6 Interior Painting

- 19.22.6.1 All exposed interior surfaces, including molding and trim, shall be as specified in Section 15.9, or shall be powder-coated metal not requiring paint.
- 19.22.6.2 Interior surfaces requiring painting shall be coated with an approved thermosetting powder coating. Parts that are to be powder-coated shall be cleaned and prepared in accordance with the recommendations of the powder coating supplier.
- 19.22.6.3 The Contractor and its powder coating supplier shall supply a touch-up procedure and assure that a continued supply of touch-up paint in the proper colors suitable for spot application will continue to be available in the U.S. for at least 15 years after delivery of the last car.

19.22.7 Corrosion Protection

- 19.22.7.1 Concealed surfaces capable of rusting or oxidation shall be properly cleaned, receive a wash primer, and then be primed with an epoxy paint and painted with an approved finish coat of paint.
- 19.22.7.2 Where arc welding is performed on joints between stainless steel and other materials, the joint shall be de-scaled, cleaned, receive a wash primer coating, and then be painted in accordance with Section 19.22.2 and 19.22.3.

19.22.8 Paint Process Documentation

- 19.22.8.1 The Contractor shall prepare a paint coating and application document containing procedures for surface cleaning and preparation, priming, surfacing, and painting for the car body and all equipment that is painted or powder coated.
- 19.22.8.2 A detailed paint schedule showing the equipment painted, paint type and manufacturers, recommended thickness, and other pertinent information shall also be included. Technical Data and Specification Sheets (TDSS), and inspection, test and repair procedures shall also be included.
- 19.22.8.3 The paint schedule document shall be submitted for approval prior to painting of any surfaces or components and shall be made part of the maintenance manuals. [CDRL]

19.22.9 Truck Painting

- 19.22.9.1 All truck components that are to be painted shall be given a full coat of primer prior to assembly. All machined surfaces shall be protected during the painting process.
- 19.22.9.2 Following assembly, all exposed surfaces of each truck, including machined mounting surfaces which are not used for the specific assembly, shall be cleaned by blowing off with compressed air and solvent-wiped to remove all dirt and grease.
- 19.22.9.3 These surfaces shall then be sprayed with one coat of an NYCT-approved black truck paint (a type that will not conceal cracks that may develop in service) and air-dried.

ELECTRICAL DESIGN AND WORKMANSHIP

REQUIREMENTS

19.23 Wires and Cable

19.23.1 General Requirements

- 19.23.1.1 The number of different wire types and sizes used in the car shall be kept to a minimum.
- 19.23.1.2 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 the properties delineated in this Specification.
- 19.23.1.3 All applications of shielded cable shall be approved.
- 19.23.1.4 Extra-fine wire stranding shall be utilized on applications subject to repetitive motion.
- 19.23.1.5 Except as otherwise specified, wire and cable selection and application shall conform to APTA PR-E-RP-009-98 and AAR; RP-585, RP-586, RP-587, and RP-588, as applicable.
- 19.23.1.6 Prior to utilizing any wire and cable, the Contractor shall submit samples (at least 12 inches [305 mm] long), specifications, and qualification test documentation to NYCT for approval. This requirement shall apply to any wire and cable produced by the Contractor and the Contractor's sub-suppliers. All submittals shall be transmitted to NYCT through the Contractor. **[CDRL]**
- 19.23.1.7 A copy of notarized, certified test reports shall be furnished by the Contractor.
- 19.23.1.8 Only wire or cable shall be used for carrying electrical current. Exceptions are third rail shoes and other devices specifically designed to be electrical conductors.
- 19.23.1.9 Where this Specification uses wire insulation trade names, the use of an approved equal is acceptable.
- 19.23.1.10 Wiring shall comply with NYCT Specification for irradiated crosslinked polyolefin insulated wire and cable, TX-3, see Appendix C-47.

19.23.2 Conductors

- 19.23.2.1 Conductors for wire AWG No. 12 and larger shall be soft, annealed nickel-plated copper, constructed in accordance with SAE-AS22759/6.
- 19.23.2.2 Conductors for irradiated cross-linked polyolefin wire shall be soft, annealed tinned copper, in accordance with ASTM B33.
- 19.23.2.3 Minimum stranding shall conform to AAR Standards RP-585, RP-586, RP-587, and RP-588, as applicable, or ASTM B-172 Class K or NEMA WC 70, 71, and 74 for AWG No. 10 or larger, as appropriate for the application.
- 19.23.2.4 Stranding and conductor construction for wire sizes AWG No. 12 to AWG No. 16 shall be in accordance with ASTM B-174 Class K or NEMA WC 70, 71, and 74, as appropriate for the application.
- 19.23.2.5 Stranding and conductor construction for wire sizes AWG No. 18 and smaller shall be in accordance with ASTM B-174 Class L or NEMA WC 71 and 74, or shall be 19-strand construction, as appropriate for the wire size.
- 19.23.2.6 The use of solid wire is not permitted except for approved wire wrap applications.

19.23.2.7 Wiring which is operating within its manufacturer's rating, and manufacturer's recommendations for its installation, shall be RMS rated, sized and de-rated for the ambient temperature and cooling capacity of its immediate surroundings, to provide insulation life in excess of the vehicles lifetime set in TS 2.1.4. For each circuit acting independently, a current applied indefinitely at the trip value of the associated overcurrent protection shall not deteriorate the insulation of the wiring of the circuit.

19.23.2.8 In no case shall wire smaller than the following sizes be used:

- a) Wire that is pulled through conduits or wireways - AWG No. 14.
- b) Wire on and within electronic units, cards, and card racks - AWG No. 28.
- c) Wire within control compartments - AWG No. 18.
- d) Multi-conductor cables where current is not a factor in wire size selection - AWG No. 18.
- e) All other wire, including that which is not pulled through wireways and conduits - AWG No. 16.
- f) Ethernet cables for signal transmission for train backbone and equipment control - AWG No. 22

19.23.3 Insulation

General Wiring Insulation

19.23.3.1 Fluoropolymer, Extruded Ethylene Tetrafluoroethylene (ETFE) (Tefzel™), abrasion resistant insulation meeting the requirements of SAE-AS22759/16, may be used on all sizes AWG No. 12 to AWG No. 28.

19.23.3.2 Otherwise, all general car body wiring insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material meeting the requirements of AAR Standard RP-585, and the following:

- a) A continuous temperature rating of 230°F (110°C).
- b) Insulation rated at 2,000 volts dc (in the case of wires carrying a nominal voltage greater than 100 volts AC or DC or for use in compartment where > 100 volts is used).
- c) Insulation rated at 600 volts DC (in the case of wires carrying a nominal voltage of 100 volts or less, AC or DC).
- d) For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility.

19.23.3.3 All insulation other than irradiated cross-linked polyolefin shall meet the following test requirements based on SAE-AS22759 and using the following parameters:

- a) Dielectric - Test per SAE-AS22759/10 (for 1,000 volts wire with tests at 9.5 KV impulse) or SAE-AS22759/6 (for 600 V wires with tests at 8 KV impulse).
- b) Insulation Resistance - Test per ASTM D470. Minimum accepted value shall be 1,000 megohms per 1,000 feet (304.9 m), using a 1,000 Vdc megohmmeter.
- c) High Potential ("Hipot") test – 100 percent of all single conductor cables and all single conductor cables being used in a multi-conductor cable shall be capable of withstanding the test requirements by Impulse Dielectric Test or by chain electrode hipot test. Hipot test apparatus and procedures shall be in accordance with SAE-AS22759. Hipot test voltages shall be equivalent to impulse test voltages by corresponding RMS value at 3 kilohertz, as shown in Table 19-14.

Table 19-14 – Hipot Test Voltages

Impulse Test Voltage KV Peak	3 KHz Test Voltage KV RMS
8	5.7
9.5	6.7
10	7.1

- d) Cold Bend - Test per ICEA S-95-658, except test temperature shall be -40°F (-40°C).
- e) Weight Loss - Weight loss of the insulation material shall not exceed 1 percent when subjected to an oven temperature of 266°F (130°C) for 500 hours.
- f) Chemical Resistance - An appropriate length of sample shall be measured for insulation diameter and total weight to record initial values. The wire shall be immersed to within 3 inches (76 mm) of each end in the test fluid for 24 hours at 149°F (65°C). During the immersion stage, the minimum bend radius of the wire shall be 10 times the diameter of the wire being tested. Upon removal from the test fluid, the specimen shall be cooled to room temperature for 1 hour and the diameter gauged and reweighed for comparison with the original values. The maximum diameter and weight increase shall not exceed 30 percent. Typical fluids for this test include:
- Humble No. 2214 Railroad Diesel Lubricating Oil and lubricants (100 percent solution).
 - Humble Diesel 260 or Railroad T fuel oil (100 percent solution).
 - Mineral oil (100 percent solution).
 - Hydrochloric acid, nitric acid, sodium hydroxide, sulfuric acid (0.1 percent solution).
 - Potassium hydroxide (0.1 percent solution).
 - Petroleum distillates and other graffiti removers and cleaning compounds listed in Appendix C-3 (Cleaners and other products approved for use on Railcars and Railcar parts) (100 percent solution).
 - Kerosene solvents (100 percent solution).
 - Trisodium phosphate solution (50 percent solution).
 - Skydrol 500 B hydraulic fluid (100 percent solution).
 - Water.

19.23.3.4 Qualification and Production Tests - The tests required for this Specification concerning Qualification and Production shall be in accordance with tests required in SAE-AS22759 for all lots produced, as called for in this Specification.

19.23.3.5 All test reports covering Production and Qualification tests shall be furnished to NYCT with the requested samples prior to any shipment of materials.

Wire Insulation for High Temperature Applications

19.23.3.6 High temperature insulation shall be used where connected to heat-generating apparatus, where the ambient temperature can exceed 125°F (52°C) or where Teflon is specified as a requirement.

19.23.3.7 The insulation shall be rated at 1,000 volts DC in the case of wires carrying a nominal voltage greater than 100 volts AC or DC, and rated at 600 volts DC in the case of wires carrying a nominal voltage equal to or less than 100 volts AC or DC.

- 19.23.3.8 Wire used for connections to heating elements and high temperature applications, shall be rated at 150 percent of the maximum temperature exposed in the connection to the heating element.
- 19.23.3.9 Cross-linked polyolefin insulation is not permitted for use on wires connected to heater elements or any other high-temperature device.
- 19.23.3.10 The insulation shall have a continuous temperature rating and be in accordance with the following requirements:
- For wire sizes AWG No. 16 and larger: abrasion resistant Teflon (Polytetrafluoroethylene - PTFE) meeting SAE-AS22759/6 or /10, as appropriate for the voltage level used, or silicone rubber meeting AAR Standard RP-587.
 - For wire sizes AWG No. 18 and smaller: abrasion resistant Teflon (PTFE) meeting SAE-AS22759/6 or 10, as appropriate. When used for interconnecting pieces of apparatus, this type wire shall be in bundles with a protective covering of high temperature rated, low smoke generating insulation.
- 19.23.3.11 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.
- 19.23.3.12 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. [CDRL]

Wire Insulation within Equipment

- 19.23.3.13 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 D3159 and insulation construction per SAE-AS22759/16, irradiated cross-linked polyolefin or Teflon (PTFE) type EE per NEMA HP 3.

Wire Insulation at Crowded Locations

- 19.23.3.14 Wire for connections to the control console, or in any other locations where there are equally crowded concentrations of low voltage control wiring, may be insulated with Tefzel (ETFE) per ASTM D3159 and insulation construction per SAE-AS22759/16, except the wall thickness shall be 0.025 inch (0.64 mm).
- 19.23.3.15 When used for this application, these type wires shall be bundled with a protective covering of irradiated cross-linked modified polyolefin or similar, approved, high temperature rated, low smoke generating insulation.

19.23.4 Multi Conductor Cables

General

- 19.23.4.1 Multi-conductor cables shall be constructed using wiring as described in Sections 19.23.2 and 19.23.3 and shall conform to MIL-DTL 27072 "General Specification for Cable, Power, Electrical, and Cable, Special Purpose, Electrical, Multiconductor and Single Shielded".
- 19.23.4.2 For multi-conductor and Ethernet cables carrying low-voltage, high-speed, serial data, exceptions to the wiring requirements may be submitted for approval, based upon availability of wire to meet the application requirements.
- 19.23.4.3 Multi-conductor cables shall be terminated with a multiway connector as specified in Section 19.25.5.

- 19.23.4.4 Cables for Ethernet networks shall be Category 7 or better, as defined in ISO/IEC 11801 "Information technology — Generic cabling for customer premises".

Fillers and Tape

- 19.23.4.5 Where required, 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.
- 19.23.4.6 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.

Shield

- 19.23.4.7 The shield, if required, shall consist of either tin plated copper braid, concentrically served copper, or aluminum/polyester tape with a drain wire, as is appropriate for the application.
- 19.23.4.8 Tape shields will be permitted for fixed installations only.
- 19.23.4.9 The shields shall have the following minimum properties:
- a) Copper shield shall be made of either tinned, coated copper strands which conform to ASTM B33, or silver-coated copper strands which conform to ASTM B298, as is appropriate for the wire insulation. Shield coverage shall not be less than 85 percent. Shield strand size and application shall be as recommended by the cable manufacturer for the particular application, but shall not be smaller than AWG No. 38.
 - b) Aluminum/polyester tape shields shall consist of a helical wrap of aluminum/polyester tape with a nominal thickness of 0.0004 inch (0.01 mm) aluminum on a backing of 0.001 inch (0.025 mm) polyester. The tape shall have a minimum overlap of 10 percent of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be an AWG No. 22 7/30 tinned copper drain wire conforming to ASTM B33 and B 174.

Jackets

- 19.23.4.10 The overall jacket of multiconductor cables shall be of flame retardant, irradiated, cross-linked, modified polyolefin; Tefzel (ETFE), or Teflon (PTFE) to be fully compatible with the wire insulation and application as approved.
- 19.23.4.11 The coupler cable shall have a jacket of low temperature arctic grade neoprene per MIL-DTL-13777, with a wall thickness suitable for 600 volts.
- 19.23.4.12 The jacket shall be extruded and vulcanized over the cabled conductors, and shall be centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice.
- 19.23.4.13 The nominal jacket thickness for polyolefin, Teflon, Tefzel and Neoprene shall be that shown in Table 19-15, with the minimum wall not less than 80 percent nominal value.

Table 19-15 – Nominal Wall Thickness for Jackets

Nominal Jacket Wall Thickness (in Inches)			
Cable Diameter Under Jacket	Modified Polyolefin	Teflon or Tefzel	Neoprene
0.000-0.250	0.045	0.01	0.072
0.251-0.500	0.045	0.015	0.087
0.501-0.750	0.06	0.021	0.1
0.751-1.000	0.08	0.021	0.1
1.000-1.500	0.08	0.025	0.115
1.501-2.000	0.11	-	0.135
2.001-2.500	0.13	-	0.152
2.501-3.000	0.14	-	0.195

19.23.5 Wire Wrap

19.23.5.1 Wire wrap connections shall only be used with NYCT approval.

19.24 Wiring

19.24.1 Wire Handling

- 19.24.1.1 All wiring shall be performed by qualified, experienced wiring personnel using wiring tools and equipment as recommended by the manufacturer.
- 19.24.1.2 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.
- 19.24.1.3 When removing insulation, wire strands shall not be nicked or broken in excess of the requirements of IPC/WHMA-A-620B, Class 3, for critical circuits and control electronics, and Class 2 for all other circuits (Ref: Table 3-1, 2012 edition).
- 19.24.1.4 Conductors shall not be cut or modified to reduce circular MIL-area (CMA) to fit into a termination.

19.24.2 Wiring Layout and Installation

Wire Harness

- 19.24.2.1 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.
- 19.24.2.2 Wiring shall be pre-fabricated into standard harnesses, wrapped or tied with spiral wrap or tie wraps. Harnesses shall be installed with identical arrangement and location in each car having similar equipment.
- 19.24.2.3 Separate harnesses shall be provided for major circuit groups or types, or as required for specified circuit separation.
- 19.24.2.4 All circuits and branches shall be separated by means of terminal boards to isolate portions from others for troubleshooting and searching for ground faults.
- 19.24.2.5 Alternative methods for fabricating and installing wiring, which are standard Contractor practice, will be considered for approval by NYCT.

- 19.24.2.6 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.
- 19.24.2.7 Each harness or group of wires between equipment enclosures shall contain a minimum of 10 percent spares, but no fewer than two spares for each wire size.

Circuit Separation

- 19.24.2.8 When running in parallel, High Voltage (600VDC) and AC power circuits shall be physically separated from other circuit groups by at least 1 inch (25 mm).
- 19.24.2.9 The following major circuit groups shall not be harnessed or bundled together, High Voltage (600VDC) and AC power circuits shall not run in the same conduit as the other groups, and shall be physically separated and secured in enclosures, wire ducts, junction boxes, or other wire routing devices:
- a) CBTC circuits.
 - b) CCTV feeds and cabling and communication circuits.
 - c) High voltage circuits. (600VDC)
 - d) AC power circuits.
 - e) Not used.
 - f) Battery voltage level circuits.
 - g) High Voltage semiconductor gating voltage level circuits. (600VDC)
 - h) Third Rail circuits. (600VDC)
 - i) Conductors carrying in excess of 100 amperes.
- 19.24.2.10 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.
- 19.24.2.11 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.
- 19.24.2.12 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.
- 19.24.2.13 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.
- 19.24.2.14 In cases in which adequate physical separation is impossible, shielded wire shall be used for all conductors involved.

Wire and Cable Runs

- 19.24.2.15 Wire runs shall be continuous and unbroken between connection points, shall be supported at no greater than 2 ft. (0.61 m) spacing, and shall be protected at each support point against mechanical crushing and abrasion.
- 19.24.2.16 A watertight bushing and drip loop shall be provided on all exposed cable entries.

- 19.24.2.17 All cable bundles and wires shall be routed a minimum of 1 inch (25 mm) above the bottom of equipment enclosures.
- 19.24.2.18 All undercar wiring smaller than AWG No. 6 shall be run in closed wire ducts, conduits, or open wire mesh wireways in an approved manner.
- 19.24.2.19 Wire and cable shall be secured within ducts or open wireways, including each entrance and exit point, to prevent chafing due to movement.
- 19.24.2.20 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.
- 19.24.2.21 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 by NYCT.
- 19.24.2.22 Short runs of cables or harnesses entering or leaving conduit and apparatus shall have an approved guard mounted to the car body to protect the wires from mechanical damage.
- 19.24.2.23 Lead wires to solidly-mounted, electrical apparatus and equipment enclosures shall run in conduit connected to the apparatus or enclosure.
- 19.24.2.24 Any wiring that runs through the floor shall be run in ducts or conduit.
- 19.24.2.25 Wiring, even if enclosed in loom, must not be run through partitions without suitable bushings being provided at such points of passage.
- 19.24.2.26 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.
- 19.24.2.27 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.
- 19.24.2.28 Wires or cables shall not pass through or over the battery compartment and shall not pass over heat generating equipment such as braking resistors, even if the wires or cables are in conduit.
- 19.24.2.29 Harness exposed, short cable runs or harnesses entering or leaving exposed raceways shall have an approved, fire-resistant flexible dielectric sleeve over the raceway edges and grommet-type insulation of any penetration holes. Wiring shall be retained to the sleeve with tie-wraps.

Cable Cleating and Support

- 19.24.2.30 All cable and wiring exiting wireways/wire ducts, or that which is not installed in conduit, shall be cleated using split-block cleats made of fiber glass with neoprene liners or molded / cut neoprene.
- 19.24.2.31 Cables shall be cleated and bushed when passing through bulkheads and structural members.
- 19.24.2.32 The cushioning material shall be non-conductive, fire retardant insulating material with a durometer of 50 to 60, meeting the requirements of Section 19.23.3.
- 19.24.2.33 Each cleat shall have a stiffener of at least 10 gauge material on the side away from the mounting bracket which shall act to spread the bolt clamping force over the entire length of the cleat.
- 19.24.2.34 Bolts used for cleats shall have lock nuts.

- 19.24.2.35 The Contractor shall minimize the quantity of different configuration cable cleats.
- 19.24.2.36 AWG No. 6 or larger insulated wire may be cleated in place without conduit, duct or open wireway. However, in the areas over the truck, in the wheel wash, and not protected by underfloor-mounted equipment, the wire shall be mechanically protected by an open mesh, expanded metal or other type of approved guard. The guard may be attached to the bottom of each cleat with the cleat clamping bolts or other approved arrangement.
- 19.24.2.37 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.
- 19.24.2.38 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.
- 19.24.2.39 Cables in areas where wire dressing is critical, such as traction motor and between-car cables, shall have permanent markings indicating correct cable cleat location, to ensure consistent manufacturing and foster proper redressing of cables during maintenance.
- 19.24.2.40 Wire splices will not be permitted, except with express written NYCT approval and in accordance with the wire splicing requirements of Section 19.25.8.
- 19.24.2.41 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 panels. It shall not be necessary to disconnect or disassemble conduit to accomplish this task.
- 19.24.2.42 Wiring run in loom shall not be carried over a potential chafing hazard.
- 19.24.2.43 Wires entering any removable box shall be harnessed and secured to facilitate removal of the box.
- 19.24.2.44 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 car.
- Wire Securement and Termination**
- 19.24.2.45 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.
- 19.24.2.46 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.
- 19.24.2.47 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 19.27.2. Exterior junction boxes shall be weathertight.
- 19.24.2.48 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.
- 19.24.2.49 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.

19.24.2.50 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) AWG No. 10 and smaller - Three re-terminations.
- b) AWG No. 8 and larger - Two re-terminations.

19.24.2.51 A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.

Spare Wires

19.24.2.52 Spare wires, which are part of a wire harness, shall be bundled separately inside of the equipment box to which the harness is being terminated.

19.24.2.53 Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of re-terminations.

19.24.2.54 The spare wire "break-out" bundle may be ty-wrapped to the main harness, but shall be easily removed from the main harness without disassembling it.

19.24.2.55 The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals.

Wire Tying

19.24.2.56 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 UV light.

19.24.2.57 Wire and cable ties shall be trimmed and located to eliminate any hazard to personnel from sharp edges.

19.24.2.58 Wire tying devices shall be snug, but shall not be so tight as to cause indentation and cold flow damage to the insulation.

19.24.2.59 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.

19.24.2.60 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.

19.24.2.61 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 (25 mm) above the bottom of the box, unless otherwise approved by NYCT. Wire entry into control or junction boxes shall not be permitted through the bottom of the box.

19.24.2.62 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.

19.24.2.63 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.

19.24.2.64 Any wiring needed to calibrate and test car functions shall be a part of the permanent car wiring to enable NYCT to conveniently maintain and test the equipment. This wiring shall terminate in approved connectors in the respective control groups and cabinets.

19.24.2.65 Wiring and cabling shall be readily accessible for inspection and maintenance. Extensive wiring and cabling in the car 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. [CDRL]

19.24.2.66 Wire and cables that are subject to high currents in fault conditions or normal operation must be secured against secondary damage due to the high magnetic forces that are developed. This includes damage to bus bars or devices to which the cables terminate.

Circuit Shielding

- 19.24.2.67 Wire shields used in trainline circuits shall be continuous up to the car's electrical coupler contacts, including contacts of the jumper cable connector at the intermediate couplers.
- 19.24.2.68 The wire shields shall be connected through all applicable connectors and junction boxes. Circuits shall be categorized based on the intended function of the shielding.
- 19.24.2.69 Shields shall not be interconnected with other shields and shall not carry signal or DC current unless specifically approved by NYCT.
- 19.24.2.70 Shields on low-level signal wires shall not be interconnected with shields on high-level signal wires in the same category.
- 19.24.2.71 Each shield, or where justified, each group of shields shall be carried through on a connector pin or pins, or on terminal strips that shall be in the immediate proximity of the categorized group of circuits.
- 19.24.2.72 Formation of loops due to interconnections of shields shall not be permitted.
- 19.24.2.73 Coaxial cables used as constant impedance transmission lines shall be terminated as dictated by the circuit termination design and shall not be considered to be shielded conductors.
- 19.24.2.74 Triaxial cables may be used as coaxial impedance transmission lines with the outer conductor employed as an RF shield.

19.24.3 Insulation Resistance

19.24.3.1 Refer to Section 19.23.3.3 for insulation resistance requirements.

19.24.4 Marking and Designation

- 19.24.4.1 The Contractor shall devise, and submit for approval, a wire and terminal marking and designation system that shall coordinate all electrical circuits in the car into a unified system. [CDRL]
- 19.24.4.2 The system shall identify all wiring, including circuit return wiring, and terminals according to their respective circuit function(s) and shall accurately correlate these designations with the car schematic diagrams.
- 19.24.4.3 Each circuit shall be individually designated from point to point. Common designations for return circuits are not permitted.
- 19.24.4.4 Each wire and cable shall have printed on the outer surface, the manufacturer's identification, conductor size, temperature rating, and voltage rating. For wire size 1/0 and larger, stranding shall be given in addition to the other parameters.
- 19.24.4.5 Except for spares, Teflon (PTFE) insulated wires and wires entirely within an equipment enclosure, each wire #8 AWG and smaller shall be permanently and legibly marked along its entire length.
- 19.24.4.6 Blank spaces between markings shall measure approximately 1.5 inches (38 mm).
- 19.24.4.7 Wires larger than #8 AWG and PTFE insulated wires may have wire markers applied at each end of the wire.

- 19.24.4.8 Spare wires and wiring entirely within an equipment enclosure may have a single wire marker at each end, subject to approval by NYCT in lieu of continuous marking.
- 19.24.4.9 Wires shall be marked with their alpha-numeric circuit designation. A circuit designation shall change only when it goes through an active or passive component such as a relay coil or relay contact, fuse or circuit breakers, lamp, motor or resistor. A circuit designation shall remain unchanged when it goes through a terminal strip or junction box stud regardless of how many wires of that circuit are common to that point.
- 19.24.4.10 There shall be no duplication of wire codes in unrelated circuits throughout the car. Where there are more than one of a particular assembly per car, each assembly shall be wired identically to the other(s) and wire marking of harnesses shall be identical in each assembly.
- 19.24.4.11 For pre-manufactured multi-conductor cables and for cases where individual circuit identification markers may be approved the following requirements apply:
- a) 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.
 - b) Identification of wires and terminals shall be by white or yellow permanent markers, with black printing or by continuous wire marking printed on the wire.
 - c) All wires shall be marked 6 inches (152 mm) from of the end of the wire. Wiring, with the exception of wiring internal to equipment, shall be marked every 12 inches (305 mm) within 10 feet (3.05 m) of the end of the wire, and every 24 inches (610 mm) over the remainder of the wire.
 - d) 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.
 - e) Wire markers shall meet the requirements as specified by SAE-AS5942, latest revision, and shall withstand all combinations of ambient and equipment temperatures. Hand-printing is prohibited.
 - f) For cable identification, the contractor shall use a basic identification system in conformance with ASME Y14.44 and shall submit the system selected for review by NYCT.

19.24.5 Pulling Compound

- 19.24.5.1 Pulling compound shall be non-conductive, non-hygroscopic, non-odorous, shall not support bacterial activity, and shall not attract vermin.

19.24.6 Solder

- 19.24.6.1 Solder shall be in accordance with ASTM B32, Grade Sn60. A flux of non-corrosive type shall be applied immediately before soldering. Upon completion of soldering, all traces of flux must be removed.

19.25 Wire and Cable Connections

19.25.1 General

- 19.25.1.1 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.

- 19.25.1.2 The Contractor shall submit the proposed design and product line for all connections for approval. [CDRL]
- 19.25.1.3 Terminal boards with M4 or Number 6 or smaller screws and quick-disconnect terminals, other than those stated herein, will only be permitted with NYCT approval.

19.25.2 Terminal Boards and Terminal Points

- 19.25.2.1 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.
- 19.25.2.2 Each board or connector shall have the necessary number of terminations plus a minimum of 10 percent spares, but no less than one spare unless approved by NYCT.
- 19.25.2.3 Binding head, screw type terminal boards will be permitted only where approved by NYCT.
- 19.25.2.4 All terminal boards shall be in accordance with General Services Administration (GSA) Specification A-A-59125.
- 19.25.2.5 Threaded studs shall have a minimum of 2-1/2 threads exposed beyond the final nuts.
- 19.25.2.6 Adequate space shall be provided to permit connecting wire terminals with standard tools.
- 19.25.2.7 All terminals shall be properly torqued to ensure sound connections. The Contractor shall develop, use, and submit to NYCT for approval terminal installation procedures that include at a minimum, the application torque value required for each terminal type, the method of torque application, and methods of verification and inspection. Low voltage wiring shall be assembled with torque control tools. The procedures shall be utilized for car level assembly. Spacers shall not be used. [CDRL]
- 19.25.2.8 Jumpers between terminal board points shall be brass or plated steel. Wire jumpers between adjacent terminals of terminal boards will not be permitted.
- 19.25.2.9 An approved permanent marking strip on each terminal board shall be provided and attached adjacent to the wire junction point to identify the wires attached thereto and/or the wires connected to terminal boards shall have the terminal point location printed on the wire.
- 19.25.2.10 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.
- 19.25.2.11 Alternate terminal block standards may be proposed for NYCT review and approval. The Contractor shall submit the alternate terminal block product line for NYCT approval.

19.25.3 Wire Terminations

- 19.25.3.1 Connectors shall normally be utilized. When specifically required, 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 NYCT approval. [CDRL]
- 19.25.3.2 All terminals for the same wire size shall be crimped with the same model tool. The Contractor shall minimize the total number of crimping tool types needed for all crimp

- connections. Terminals fitting wire sizes AWG No. 10-22 shall require no more than three tool models to provide certified crimp connections.
- 19.25.3.3 Terminals to be approved shall be tested to Military Specification MIL-T-16366F or MIL-T-7928G as appropriate for temperature rise, voltage drop, vibration, current overload, and corrosion. Test results shall be submitted for NYCT approval on a by-part-number basis.
- 19.25.3.4 Terminals and connections shall be attached to the wiring with proper crimping tools and dies as recommended by the manufacturer.
- 19.25.3.5 The terminals used on conductors of size AWG No. 10 or smaller shall be of the type that securely grips and holds the insulation of the conductor, unless approved. Terminals shall be ring tongue (aka ring lugs) in accordance with SAE Standard AS25036; spade and hook-type terminals shall not be used.
- 19.25.3.6 Corrosion protection shall be provided for all base materials.
- 19.25.3.7 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.
- 19.25.3.8 A maximum of one wire shall be crimped in any one terminal.
- 19.25.3.9 Wherever several wires are connected to terminals of a terminal strip on a device that is removable from the car for maintenance, the wires shall be terminated, with double-ring terminations, which shall be screwed to an insulating fanning strip that shall serve to keep the terminations in the correct relative locations while removed from the device, unless otherwise approved by NYCT.

19.25.4 Power Cable Terminations

- 19.25.4.1 Power cables shall be terminated with an approved compression terminal.
- 19.25.4.2 Sufficient cable slack shall be provided to preclude breaking or pull-out from bushings or terminals, and to allow two terminal changes.
- 19.25.4.3 Cable conductors shall be clean prior to installation of terminals.
- 19.25.4.4 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.

19.25.5 Cable Connectors

- 19.25.5.1 All cable connector applications shall be approved by NYCT.
- 19.25.5.2 All cable connectors shall conform to SAE-AS50151, or an equivalent standard as approved by NYCT. Cable connectors shall employ removable crimp contacts of the correct size for the wire being terminated.
- 19.25.5.3 Except as noted below, the connector contact area shall be plated with a minimum of 0.00003 inch (0.76 μm) of gold over silver plating per SAE-AS50151B, Section 3.3.3.2. For high current applications, the connector contact area shall be plated with a minimum of 0.0001 inch (2.54 μm) of silver.
- 19.25.5.4 Adjacent assessable connectors shall either use different inserts or different insert orientations to prevent erroneous connections. The receptacle half of all cable connectors shall be rigidly mounted.
- 19.25.5.5 All cable connectors used in exterior locations shall be of the environmental watertight variety. Cable connectors shall be equipped with sealing gaskets on the front mating surface

- and on the back where the cable enters. The cable jacket shall be held by a clamp within the connector body.
- 19.25.5.6 Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.
- 19.25.5.7 Plastic bodied connectors shall not be used in exterior locations.
- 19.25.5.8 Quarter turn, bayonet-lock, quick-disconnect type connectors shall not be used on trainline jumper cables.
- 19.25.5.9 Except as specified above, all cable connectors in exterior locations shall be quarter turn, bayonet-lock, quick disconnect type CIR connectors as made by Litton-Veam SPA, or NYCT-approved equal. Quarter turn, bayonet-lock connectors shall conform to all provisions in SAE-AS50151, or an approved standard, except for the screw coupling requirement.
- 19.25.5.10 Connectors in high motion areas shall have the wire connections soldered and potted, and shall have a watertight jacket molded over the cable and connector to form a unitized assembly. The Contractor shall conduct an approved vibration test on these unitized assemblies.
- 19.25.5.11 Trainline jumper connectors used shall be as made by Pyle-National or NYCT approved equal.
- 19.25.5.12 Connectors shall not be used in high vibration environments without NYCT approval.
- 19.25.5.13 Connectors for thernet networks shall be Category 7 or better, as defined in ISO/IEC 11801 "Information technology — Generic cabling for customer premises".

19.25.6 Quick-Disconnect Terminals

- 19.25.6.1 Approved quick-disconnect terminals shall be utilized to facilitate maintenance and inspection. The terminals shall provide positive terminal engagement and be shock and vibration proof. All terminals shall be provided with insulation equal to that of the wire.
- 19.25.6.2 No "Push-to-fit" (FASTON) type terminals will be permitted unless specifically approved by NYCT.

19.25.7 Grounding Return Connections

- 19.25.7.1 The return current for all electric devices shall be by a dedicated return circuit.
- 19.25.7.2 Grounding connections to the carbody and equipment shall be made through copper pads of an adequate area, silver soldered or brazed. Alternative ground pad material may be permitted in certain cases as approved by NYCT. Transition (base) plates if used, shall be made from the same alloy group as the respective carbody and piece of equipment. The base plate shall be welded to the carbody or equipment. Grounding connections shall not be made to aluminum alloy members.
- 19.25.7.3 All ground pads shall be visible and accessible for inspection and troubleshooting.
- 19.25.7.4 The ground connections shall be attached by a bolt, washer, and nut designed for the purpose.
- 19.25.7.5 An anti-corrosive grease shall be applied over the connection.
- 19.25.7.6 All equipment enclosures and shock-mounted equipment, except the operator's cab lights, shall be grounded with flexible, grounding leads bolted between a carbody grounding pad and the equipment's grounding pad.
- 19.25.7.7 Braided, strap-type leads shall be used where there is relative motion between the two items being connected. The ground strap termination method shall apply uniform pressure

to the conductive surface and the current density shall not exceed the bonding requirements of Section 19.25.7.10.

- 19.25.7.8 The Contractor shall submit to NYCT, 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. Refer to Section 9.4.9 for ground brush and related requirements.
- 19.25.7.9 Low voltage and high voltage circuits shall not be grounded to the same grounding pad or location. See Section 9.4.7 and 9.4.8.
- 19.25.7.10 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 ohm, or more than 0.025 ohm at 150 kHz for any applied ac voltage.
- 19.25.7.11 Grounding and bonding jumpers, and brazed shunt straps shall be "extra-flexible."

19.25.8 Wire Splicing

- 19.25.8.1 Splicing of conductors shall be avoided and shall be permitted only with approval on a case-by-case basis. Splicing of conductors in conduit will not be permitted.
- 19.25.8.2 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.
- 19.25.8.3 The splice shall be an insulated permanent crimp splice in accordance with SAE-AS7928, Type II, Class 1, and shall be installed with the crimping tool and die of the splice manufacturer.
- 19.25.8.4 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 un-spliced portion by more than 40 percent. Splices shall be identified in the integrated schematic.

19.26 Conduit

19.26.1 Types

- 19.26.1.1 All conduit and conduit couplings shall be of an ANSI-approved type. All conduit shall be standard weight, galvanized steel with threaded fittings.
- 19.26.1.2 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.
- 19.26.1.3 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 NEMA Standard C 80.1. The threads per inch and length of threading shall conform to ASME B1.20.1 on Pipe Threads.
- 19.26.1.4 Steel fittings shall be used to assemble steel conduit. Elbows, nipples, and couplings shall be made of the same grade of steel as that employed in the conduit. All fittings shall be treated, coated, and threaded according to the requirements for zinc-coated, rigid steel conduit and shall conform to UL 6.
- 19.26.1.5 Flexible conduit, if used, shall be watertight and interlocking aluminum such as Anaconda SEALTITE® or steel strip-protected, with an approved rust resistive coating, or equal as approved by NYCT. Flexible covering on conduit shall not contain polyurethane or PVC vinyl.

- 19.26.1.6 Liquid tight flexible nonmetallic conduit, if required for special applications, may be used with NYCT's approval. Liquid tight flexible nonmetallic conduit shall not be used where subject to physical damage or in lengths longer than 6 feet.
- 19.26.1.7 All conduit except flexible conduit shall be color-coded: red for those carrying circuits above 100 volts and yellow for under 100 volts.

19.26.2 Size and Fill

- 19.26.2.1 Conduit shall be sized such that the sum of the cross-sectional areas of the conductors and their insulation does not exceed 40 percent of the cross-sectional area of the conduit for three or more conductors.
- 19.26.2.2 For two conductors, a limit of 31 percent shall be used, while for a single conductor, a limit of 53 percent will be permitted.
- 19.26.2.3 Where conduit having a length not exceeding 24 inches (610 mm) without bends of more than 15 degrees is used between enclosures, a maximum fill of 60 percent shall be permitted.

19.26.3 Installation

- 19.26.3.1 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.
- 19.26.3.2 Bend radii at the inner surface of the bend shall be no less than eight times the nominal inside diameter of the conduit.
- 19.26.3.3 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.
- 19.26.3.4 Conduit shall be securely clamped with all runs electrically grounded to make a continuous ground. Conduit installation shall not create situations of dissimilar metals.
- 19.26.3.5 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 of the end. The conduit arrangement and installation shall be subject to approval. [CDRL]

19.27 Conduit Fittings and Junction Boxes

19.27.1 General

- 19.27.1.1 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 such parts. The Contractor shall submit the proposed product line for NYCT approval. [CDRL]
- 19.27.1.2 All conduit fittings and junction boxes shall be provided with gasketed covers as described in Section 19.27.4.
- 19.27.1.3 All conduits and their connections to electrical equipment shall be installed to make a continuous ground.

19.27.2 Junction Boxes

- 19.27.2.1 All exterior junction boxes shall be fabricated of minimum 14-gauge stainless steel.

- 19.27.2.2 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.
- 19.27.2.3 Interiors of all junction boxes shall be primed and then protected with a white, insulating coating as specified in Section 19.22.4.

19.27.3 Conduit Interface

- 19.27.3.1 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.
- 19.27.3.2 All conduit entries into removable equipment boxes shall be secured by means of a bolt-on watertight access panel.

19.27.4 Covers

- 19.27.4.1 All junction box covers shall be dust proof, retained by compressive spring-type self-fastening latches, in addition to the manual primary latch.
- 19.27.4.2 All fasteners used in junction boxes shall be stainless steel.
- 19.27.4.3 All covers shall be designed to accept or mate with a bulb-type clamp-on seal.

19.28 Wireways

19.28.1 General

- 19.28.1.1 Wireways will be permitted in approved exterior and ceiling locations only. Wireways will not be permitted in the car body sidewall area. Only conduit will be permitted in the carbody.
- 19.28.1.2 All wireways shall be of rigid, stainless steel construction.
- 19.28.1.3 Wireways shall be color-coded; red for those carrying circuits above 100 volts and yellow for under 100 volts.
- 19.28.1.4 The trays shall be adequately supported throughout their entire length in an approved manner.
- 19.28.1.5 The trays shall be completely de-burred, leaving absolutely no sharp edges, before installation on the cars.
- 19.28.1.6 Grommet clamps shall be provided at all locations where cables or wires enter or leave the wireways.
- 19.28.1.7 Under no circumstances shall leads be draped over the edge of the wireways, with or without wireway edge protection.
- 19.28.1.8 Heads of screws or bolts inside the raceways shall be flush with the metal surface. Points of screws or fasteners shall not be directed toward the interior of wireways.
- 19.28.1.9 Metal wireways, elbows, couplings, and similar fittings shall be flush with the metal surface.
- 19.28.1.10 Removable wireway covers shall be secured with captive fasteners.

19.28.1.11 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 car where the trays may be subject to foreign object damage.

19.28.1.12 Wireways shall be located to provide access to the harnesses contained within for maintenance action. They shall be provided with approved covers that may be interrupted wherever desired for entry and exit of wires and cables. Edges of such interruptions shall be completely covered with protective bushings.

19.28.1.13 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. Wireways shall preclude water entrapment.

19.28.1.14 Metal raceways and the elbows, couplings, and similar fittings shall be electrically and mechanically coupled while protecting wires from abrasion and shall make a continuous ground with the car structure.

19.28.1.15 Bends in wireways shall be avoided; however, if required, approved protection shall be provided to avoid insulation chafing at the bends.

19.28.1.16 Wireways shall not contain more than 30 current-carrying (i.e., power source as opposed to signaling) 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 percent of the interior cross-sectional area of the wireway.

19.28.1.17 All wire and cable shall be securely fastened within wireways to eliminate movement and resultant chafing.

19.29 Electrical and Electronic Designs

19.29.1 General

19.29.1.1 Except as otherwise noted herein, electrical equipment/components shall conform to IEC 60077 and electronic equipment shall conform to IEC 60571, "Electronic Equipment Used on Rail Vehicles".

19.29.1.2 All standard type tests shall be performed. All mandatory type tests and routine tests within IEC 60077 and IEC 60571 shall be performed.

19.29.1.3 The source impedance for the 1,800-volt surge test shall be no greater than 5 ohms without approval from NYCT on a circuit-by-circuit basis.

19.29.1.4 The dielectric test shall use the test voltages defined in Section 24.8.3 except where approved by NYCT.

19.29.1.5 Multiway connectors shall be used in preference to terminal boards. The use of a terminal board shall be justified and require NYCT approval.

19.29.2 Reliability Standards

19.29.2.1 A standardized MIL-HDBK-217F reliability part stress prediction shall be performed on all new electrical and electronic control systems. This reliability prediction shall be based on the "Ground Mobile" environment. Use of alternative reliability database information may be permitted for parts not contained in MIL-HDBK-217F, subject to NYCT approval or for parts that have statistically meaningful historical failure rate data. [CDRL]

19.29.2.2 Submittal of the reliability prediction shall be identified in the Reliability Program Plan specified within Section 21.1.4. The prediction shall be used during design and development

to compare competing designs, perform design tradeoffs, detect overstressed parts, and identify high failure rate items. See also Section 21.1.3.

- 19.29.2.3 A documented closed-looped Failure Reporting and Corrective Action System (FRACAS) shall be established and maintained to provide for the identification, tracking, and repair of all product/process failures. Early elimination of failure causes or trends will contribute significantly to reliability growth and continuous process improvement. See Section 21.1.7.
- 19.29.2.4 All electronic assemblies shall undergo Environmental Stress Screening (ESS). [CDRL]
- 19.29.2.5 The temperature cycling regimen shall be in accordance with Table 7.5-2, unit column, of the Reliability Design Toolkit: Commercial Practices Edition, from the Reliability Analysis Center, except as indicated below.
- a) The temperature extremes may be limited to -13°F to + 158°F (-25°C to + 70°C), at the discretion of the supplier. A minimum of 20 complete temperature cycles shall be conducted.
 - b) The ESS shall be performed with the equipment operational, powered, and oriented as per the ultimate application.
 - c) Input signals and output loads to simulate the maximum power dissipating condition in the equipment shall be applied during the rising temperature and maximum temperature portions of the temperature cycle.
 - d) The equipment shall be given a full functional test before and after the ESS, and monitored for failure throughout the ESS.
 - e) In the event of equipment failure, the repaired equipment shall be given another complete ESS test.
 - f) Alternatives to this baseline ESS may be acceptable at the discretion of NYCT.
 - g) Assemblies consisting exclusively of components rated at 50 amperes or greater, are exempt from this requirement.

19.29.3 Ability to Repair

- 19.29.3.1 All electrical assemblies, where practical, including such items as printed circuit boards, shall be designed for repair by NYCT; electrical assemblies repaired at the DCE 207th St. Electric Component Shop. Electronic assemblies/components are repaired at the Central Electronics Shop.
- 19.29.3.2 Assemblies shall not be sealed, potted, or constructed to prohibit repair by NYCT. Assemblies that must be potted or sealed by design shall have a minimum 10-year warranty.

19.29.4 Hardware

- 19.29.4.1 All hardware associated with electronic and electrical control systems shall be protected against moisture, oxidation, and common airborne contaminants.
- 19.29.4.2 Hinges and latches shall be of stainless steel.

19.29.5 Enclosures/Racks

- 19.29.5.1 All circuit boards that are rack-mounted shall plug into racks containing the mating half of the circuit board connector.
- 19.29.5.2 The circuit board rack shall mount in an enclosure conforming to requirements in this Specification.

- 19.29.5.3 The rack, circuit board, and circuit board hardware shall be designed as an integrated system.
- 19.29.5.4 Access to individual racks within multi-level rack units shall be provided for maintenance and repair.
- 19.29.5.5 The rack and enclosure shall provide environmental and EMI shielding as required to meet the requirements of this document.
- 19.29.5.6 The enclosure/rack shall not be connected to the power supply return or signal circuit, unless approved by NYCT.
- 19.29.5.7 Where it is necessary to use printed circuit boards that are not plug-in and not mounted in an enclosure, the following additional requirements apply:
- a) The printed circuit board must be protected from mechanical damage and hostile environments such as arc discharge or contact with high voltage.
 - b) If the printed circuit board is part of a high voltage circuit, special caution shall be used in its design with regard to strike distance and creepage in the transit car environment. This includes between printed circuit board components and with respect to any grounded mounting surfaces.
 - c) Any test points required in routine testing or fault isolation to the user replaceable level, shall be easily accessible with no disassembly or tools.
 - d) If replacement of the printed circuit board is required (as part of secondary maintenance), no special tools or soldering shall be required.
 - e) Each printed circuit board use and application of this type is subject to NYCT approval.

19.29.6 Optical Fibers

- 19.29.6.1 Any application of optical fibers shall be approved by NYCT prior to implementation.
- 19.29.6.2 In no case shall the on-car repair of an optical fiber require sophisticated or complex polishing and alignment.
- 19.29.6.3 The connections between optical fibers and car-replaceable units shall be via approved "quick disconnects".
- 19.29.6.4 All optical fiber cables are to utilize the same NYCT approved color for ease of identification. This color is to be unique to the fiber optic cables.
- 19.29.6.5 Fibers shall be constructed such that they are either proofed against tie-wrapped support or are supported/ located using a customized method. The method of support shall be submitted to NYCT for approval.

19.30 Semiconductor Standards

19.30.1 General

- 19.30.1.1 Semiconductors shall be selected to withstand all continuous and transient voltage and power demands present in the circuit application without damage for at least the life of the car.
- 19.30.1.2 All circuit designs shall provide for the presence of high current switching equipment on the car and the resultant induced voltages and currents in electrical equipment.

19.30.2 Ratings

- 19.30.2.1 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 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 volts. Diodes with less than 1,000 volts PIV rating may be used if adequate circuit transient protection is also provided.
 - c) All discrete semiconductors operated from regulators 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.
- 19.30.2.2 All semiconductors shall be rated to provide reliable operation in excess of the life of the car. Long-term failure modes, such as fatigue, fracture due to temperature change, etc., shall be mitigated by design.
- 19.30.2.3 Endemic failure of a circuit board containing semiconductors and/or integrated circuits shall be evaluated and applied at the designed replacement/repairable level.
- 19.30.2.4 Semiconductors shall be rated for operation over the temperature range of -40°F to 185°F (-40°C to +85°C), and shall be hermetically sealed to the extent required by the application.

19.30.3 Availability and Identification

- 19.30.3.1 All semiconductors shall be available from at least two manufacturers and available from U.S. distributors.
- 19.30.3.2 Single source devices, such as high voltage power devices, microprocessors, ASICs, and related support chips shall not be used unless approved by NYCT. 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.
- 19.30.3.3 Each device shall be labeled to identify both the manufacturer and the complete part number. Operational characteristics of the device shall be published and be made available to NYCT.

19.30.4 Burn-in

- 19.30.4.1 Refer to Section 19.29.2.4.

19.30.5 Other Prohibitions

- 19.30.5.1 Electronic equipment shall utilize stock components and shall function properly with the component manufacturer's full range of tolerances such that after-purchase screening or testing of components shall not be required.
- 19.30.5.2 Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.
- 19.30.5.3 Germanium semiconductors shall not be used.

19.31 Electrical Devices and Hardware

19.31.1 General

- 19.31.1.1 All electrical devices shall be transit industry-proven and be tested to IEC 60077 "Electrical Equipment for Rolling Stock".

19.31.2 Contactors and Relays

- 19.31.2.1 All contactors and relays (“devices”) shall meet or exceed the requirements of MIL-PRF-6106 and MIL-R-5757 respectively, with the following 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 car, in each of the three possible rotations: pitch, yaw, and roll.
 - b) Devices shall not be adversely affected by shock and vibration per IEC 61373.
 - c) If adequate documentation exists demonstrating that during functional and operational testing of the car the contactors and/or relays underwent normal duty cycle tests, it shall be considered as an acceptable alternative to a burn-in.
 - d) In selected applications, contactors and relays shall comply with the requirements of MIL-PRF-6106 (for ratings of 10 amperes or greater) and MIL-R-5757 (for ratings of less than 10 amperes) but need not be qualified to these documents if all of the following requirements are met:
 - The device is service proven in the exact same application.
 - The device is service proven in transit service.
 - All other requirements of this Specification are met.
 - NYCT approves of this application.
- 19.31.2.2 All devices shall be constructed and utilized in a safe manner; that is, all failures shall be in a minimum of failure modes such that neither the passengers, the crew, nor the equipment are placed in jeopardy.
- 19.31.2.3 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 troubleshooting purposes.
- 19.31.2.4 Contactors and relays shall incorporate means of visually determining whether they are picked up or dropped out. Relays on printed circuit boards or within electronic assemblies may be exempted from the requirement for a visual indication, as approved by NYCT.
- 19.31.2.5 There shall be a maximum of two wire terminations on any one contact of the device.
- 19.31.2.6 The coils of all devices shall be suppressed to protect the low-voltage network from generated transients.
- 19.31.2.7 Under no circumstances shall either the main or auxiliary contact tips of the devices be placed in parallel for the purpose of carrying a current load at or above the manufacturer's contact tip rating.
- 19.31.2.8 Contact tip ratings shall be stated for the worst condition of reduced surface contact that may result from tip misalignment during normal operation of the device.
- 19.31.2.9 Contactor installation shall be such that the arc spray is directed by an arc chute away from ground and any other electrical devices in the immediate proximity of the contactor.
- 19.31.2.10 Devices shall be constructed in a very heavy-duty fashion suitable for use in railroad service. NYCT reserves the right to review and approve the design and selection of all contactors and relays.
- 19.31.2.11 Contactor tip replacement shall not exceed 10 percent of the total number of tips at 90-day intervals.

- 19.31.2.12 All contactors shall be constructed so that the main contact tips make and break with a motion (wipe) that prevents deposits and pitting.
- 19.31.2.13 All DC contactors shall be built with series-fed blowout coils. The Contractor shall demonstrate the ability of each contactor type to reliably interrupt current over the full design operating range.
- 19.31.2.14 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.
- 19.31.2.15 Bifurcated contacts shall be used in low voltage applications, whenever necessary because of dry contacts or low current switching requirements.
- 19.31.2.16 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.
- 19.31.2.17 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 that may have exposed energized electrical circuits, and it shall not interfere with the operation of any other device when in this position.
- 19.31.2.18 Adequate gap and creepage distances shall be maintained from high voltage contactor tips and low voltage coil and auxiliary contacts to prevent entry of high voltage arcs or transients into the low voltage circuits. This applies to grounded mounting surfaces as well.
- 19.31.2.19 Relays shall not be affected by the accumulation of airborne dust or other contaminants.

19.31.3 Switches

- 19.31.3.1 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.
- 19.31.3.2 Switches shall be provided with a "keying" feature so that after installation, the body of the switch is constrained from mechanical rotation.
- 19.31.3.3 All switches provided shall be of the highest quality procurable and shall be fully suitable for the rigors of NYCT's operating environment.
- 19.31.3.4 Control switches are defined to mean any switches mounted near windows or doors, or mounted on the Train Operator's control console. These switches are subject to water splash and shall be environmentally sealed.
- 19.31.3.5 Toggle and push button switches shall be per MIL-DTL-3950, MIL-PRF-8805, MIL-DTL-83731, or equal.
- 19.31.3.6 All safety-critical switches shall be designed to withstand a high potential test of 1,500 volts for 1 second, in a clean, dry condition, without false conduction. The design and selection of all switches shall be subject to review and approval.
- 19.31.3.7 A maximum of two wires shall be connected to each terminal of the device.
- 19.31.3.8 Switches shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the switch to be replaced.
- 19.31.3.9 In addition to the above requirements, all switches and pushbuttons shall meet the following requirements:

- a) Contact resistance shall be less than 0.1 ohm at 3 Vdc and a 10-milliamp load.
- b) Open circuit resistance shall be 50 meg-ohms minimum.
- c) Resistance to case shall be 1000 meg-ohms minimum at 500 Vdc.

19.31.4 Circuit Breakers

General Requirements

- 19.31.4.1 All circuit breakers provided shall not be adversely affected by shock and vibration per IEC 61373. Circuit breakers shall be extremely rugged and suitable for the service intended.
- 19.31.4.2 Circuit breakers shall be of the highest quality procurable. Design and selection of all circuit breakers shall be subject to review and approval.
- 19.31.4.3 All circuit breakers of the same rating shall be of the same manufacture and model throughout the car.
- 19.31.4.4 The ON, OFF, and tripped positions of all circuit breakers shall be permanently marked on the handle or the case of the circuit breaker. Alternative means of showing circuit breaker status for specific applications may be submitted for NYCT review and approval.
- 19.31.4.5 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 its trip elements.
- 19.31.4.6 All circuit breakers shall be mounted in the vertical direction with the ON position up.
- 19.31.4.7 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.
- 19.31.4.8 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.
- 19.31.4.9 Circuit breaker terminals shall not be used as junction points.
- 19.31.4.10 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.
- 19.31.4.11 No circuit breaker shall protect more than one circuit, nor shall any one circuit be protected by more than one circuit breaker.
- 19.31.4.12 All circuit breakers shall be sized by current rating and tripping time to protect the minimum size wire used for power distribution within the protected circuit without causing nuisance tripping.
- 19.31.4.13 Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.
- 19.31.4.14 The continuous current rating of thermal-magnetic trip circuit breakers shall be selected in accordance with IEEE C37.16 for the load and type of service specified.
- 19.31.4.15 All thermal-magnetic trip circuit breakers shall conform to the requirements of IEEE C37.13 and IEEE C37.14.
- 19.31.4.16 Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.
- 19.31.4.17 Electrically operated circuit breakers shall be arranged for operation from the low voltage DC supply.

High-Voltage Circuit Breakers

- 19.31.4.18 All high voltage circuit breakers shall be devices with not less than three poles connected, as recommended by their manufacturer.
- 19.31.4.19 All distribution-type, high voltage circuit breakers shall be Westinghouse Series C, FDB frame, Heinemann type GH, or approved equal.
- 19.31.4.20 The trip elements shall be thermal-magnetic or magnetic, connected in series.
- 19.31.4.21 The circuit breaker handle shall protrude from the circuit breaker panel cover sufficiently to be manipulated in all positions.

Low-Voltage Circuit Breakers

- 19.31.4.22 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.
- 19.31.4.23 All low voltage circuit breakers shall be:
- a) General Use - Westinghouse Series C, Quicklag C frame, Heinemann Series AM or NYCT 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 NYCT approved equal.

19.31.5 Fuses

- 19.31.5.1 Fuses shall be used only where specifically called for in the Specification or where the use of circuit breakers is not technically justified, and only with specific NYCT approval.
- 19.31.5.2 Fuses shall meet requirements of Appendix C-25 (Furnishing and Delivering Fuses, 7029-FACIL 78), where applicable.
- 19.31.5.3 Fuses shall be permanently identified adjacent to the fuse. The rating of each fuse shall be permanently and clearly marked directly on each fuse.
- 19.31.5.4 Fuses shall be readily accessible. All fuses mounted in exterior equipment boxes shall be accessible without going under the car.
- 19.31.5.5 Fuse holders shall contain fuse retention devices at both ends.
- 19.31.5.6 Air gap and creepage distances shall be as approved. Fuses used in nominal 600 Vdc circuits shall be rated for no less than 1,000 Vdc.
- 19.31.5.7 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.
- 19.31.5.8 Where circuits use multiple fuses or fuses and circuit breakers, the coordination between the protective devices shall be discussed in design review.

19.31.6 Fabricated Bus Bars

- 19.31.6.1 Bus bars are to be fabricated from OFE (Oxygen Free Electronic CDA C10100) or ETP (Electrolytic Tough Pitch CDA C11000) copper. The bus bar conductivity shall be 100 percent IACS. All bus bar joints shall be silver or tin plated.
- 19.31.6.2 Nominal current densities, other than at joints, shall not exceed 1,000 amperes per square inch (1.55 A/mm²), and in any case shall not exceed a value which would cause a bus bar

- temperature rise greater than 54°F (30°C). Current densities in joints shall not exceed 150 amperes per square inch (0.23 A/mm²).
- 19.31.6.3 Bus bars shall be continuous and homogenous unless bolted connections are found to be absolutely necessary for maintenance purposes and are approved. The overlap at bus bar joints shall be no less than 10 times the thickness of the bus material.
- 19.31.6.4 Bus bar connection bolts shall be torqued to obtain a uniform bus bar connection pressure of 200 psi (1.38 MPa). Bolting hardware shall be plated steel with Belleville washers to maintain connection pressure.
- 19.31.6.5 Except for connection areas, bus bars shall be safety insulated according to its working voltages. Bus bars that are behind insulating panels or within bolted covers are exempt from this requirement.

19.31.7 Capacitors and Resistors

- 19.31.7.1 Hermetically sealed, dry tantalum capacitors, in metal cases, shall be used in place of aluminum electrolytic capacitors, except for very high values that are not commercially practical or available, in which case long life grade aluminum electrolytic types shall be used.
- 19.31.7.2 Capacitors shall be de-rated 50 percent for voltage based on the nominal supply voltage and maximum case temperature unless otherwise approved by NYCT.
- 19.31.7.3 Aluminum electrolytic capacitors utilized in the power circuits shall be selected to provide a service life of 15 years or more, when accounting for the DC and AC ripple voltages and environmental conditions encountered at NYCT. Analysis of capacitor life shall be subject to NYCT approval.
- 19.31.7.4 Use of large dry metal film polypropylene capacitors in the power circuit applications, including but not limited to the review of fault protection features and failure modes, shall be subject to NYCT approval.
- 19.31.7.5 Except for braking power resistors, all resistors shall be de-rated 50 percent for power dissipation. Other power resistor applications may be submitted for NYCT approval of lower de-rating, on a case-by-case basis.
- 19.31.7.6 Large capacitors (capacitor bank >100 Joules) and other components that use materials close to their working limits in their NYCT application shall be sized such that they remain operational and fully compliant to both this specification and their manufacturers technical description for at least 15 years of service life.

19.31.8 Transformers and Inductors

- 19.31.8.1 Transformers and inductors shall be de-rated 10 percent for current. Transformers shall:
- Have vacuum-impregnated windings.
 - Be rated to withstand at least twice the maximum peak-to-peak voltage that they shall be subjected to in operation.
 - Not emit audible noise in excess of 60 dB referenced to 20 micropascals at a distance of 2 feet (0.61 m) while operating at rated voltage and load.
 - Be designed to minimize radiated and induced EMI.
 - The location, orientation, mounting, cable connections and cable routing shall be in accordance to the overall EMI/EMC control plan for the car.
 - Be sealed to prevent incursion of moisture, and shaped to prevent water accumulation in any form.

19.31.9 Switch, Circuit Breaker, and Fuse Panels

- 19.31.9.1 All switch, circuit breaker and fuse panels shall be dead front types mounted in the specified equipment enclosures.
- 19.31.9.2 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.
- 19.31.9.3 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.
- 19.31.9.4 The dead front panel shall conform to NFPA 70. 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. See Section 19.1.7.
- 19.31.9.5 A wiring gutter shall be provided along the top, sides, and bottom, for the routing of high voltage leads to their designated circuit breakers.
- 19.31.9.6 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.
- 19.31.9.7 Power distribution to circuit breakers and switches shall be from a bus bar or bus circuit. Distributing power by successive or "daisy-chained" connections between device terminals shall not be permitted.

19.31.10 Battery Backup Circuits

- 19.31.10.1 Backup batteries are not permitted, except for real time clock functions, unless specifically approved by NYCT.

19.32 Microprocessor-Based System Requirements

- 19.32.1.1 Microprocessor-based components, assemblies, and power supplies shall be provided with voltage/current regulation and protection to ensure reliable operation within the microprocessor manufacturer's specification.

- 19.32.1.2 All interfacing wiring shall be protected against interference from other on-car or wayside electrical interference. Components and installation shall be protected from external voltage and current transients and EMI.
- 19.32.1.3 The microprocessor shall be of a family shown to be suitable for the rugged environmental conditions encountered in rail applications, and shall be supported by software development language and diagnostic programs, that are acceptable to NYCT.
- 19.32.1.4 The microprocessor assembly shall be housed in an enclosure that shields the microprocessor assembly and the surrounding circuits from EMI.

19.33 Printed Circuit Board Standards

19.33.1 General

- 19.33.1.1 Printed circuit boards shall be designed, constructed and inspected to IPC-2221, except where more stringent requirements are noted here.
- 19.33.1.2 Within IPC-2221, printed circuit board classes are designated. Printed circuit boards supplied under this Specification shall be Class 2, minimum, with the exception of wayside computers that are not utilized in car operation. Class 3 requirements shall apply to all vital equipment.
- 19.33.1.3 All printed circuit boards shall be inspected, and comply with IPC-A-610F quality standards, Class 2 or Class 3 as specified, and IPC-J-STD-001F for soldered connections.
- 19.33.1.4 Circuit board material shall be per NEMA Standard LI 1, Type FR-4, for boards that have no components whose power dissipation is greater than 2 watts and when the board is not mounted adjacent to components dissipating greater than 2 watts. Otherwise, circuit board material shall be per NEMA Standard LI 1, Type FR-5.
- 19.33.1.5 Printed circuit boards shall have a minimum thickness of 0.0625 inch (1.6 mm) base material. All conductor material shall be copper and shall be firmly attached to the board and shall be resistant to blistering and peeling when heated with a soldering iron.
- 19.33.1.6 All printed circuit boards shall be designed for ease of testability per IPC-2221 recommendations, and IPC-2221, Appendix A, "Testability Design Check List."
- 19.33.1.7 Traces shall be made as wide as practical, with the minimum width being based on a 10°C temperature rise.
- 19.33.1.8 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. Surface Mount Technology (SMT) devices may be mounted on both sides if part of an approved existing design.
- 19.33.1.9 All circuit boards shall be inherently stiff or shall be reinforced to prevent damage due to vibration or handling. Circuit boards larger than 100 square inches (64,516 mm²) shall be centrally stiffened unless otherwise approved by NYCT.
- 19.33.1.10 All printed circuit boards with the same function shall be interchangeable between equipment groups without additional adjustment.
- 19.33.1.11 All printed circuit boards shall be of the "plug-in" type, with positive support against vibration. Single board applications, where approved by NYCT, may be of a "non-plug-in" type.
- 19.33.1.12 Printed circuit boards shall be positively retained by means of keeper bars or other approved method. The enclosure or rack cover shall not be used to retain the circuit boards, unless specifically designed to do so.
- 19.33.1.13 Each circuit board shall be fitted with an ejector or hand grip to assist in board removal. The rack and the edge of each board, or the card ejector, shall be labeled with corresponding

numbers to identify board location within the enclosure. A brief functional designation shall also be included on each label.

- 19.33.1.14 Printed circuit boards shall be designed for insertion and removal with power applied, except where power is removed by a switch adjacent to the card rack and except where the mechanical construction would generally prohibit removal and insertion with power applied. Where a switch is used, it shall be labeled with a warning regarding its proper use.

19.33.2 Marking

- 19.33.2.1 All circuit boards shall be labeled with a part number, serial number, and descriptive nomenclature.
- 19.33.2.2 All components shall be labeled on the board with component drawing references and such other information as may be required to repair and troubleshoot the board, except as approved by NYCT.
- 19.33.2.3 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.
- 19.33.2.4 Integrated circuits and other multi-terminal devices shall have an index mark on the component side of the board, visible with the component inserted, to indicate proper keying and insertion; additionally the first pin on all IC packages shall be identified on the wiring side of the board.
- 19.33.2.5 The labels used to identify components on the printed circuit board shall match those used in the schematic drawings for that particular component.
- 19.33.2.6 All identification markings shall be shown in the Integrated Schematics and Circuit Diagrams, as well as the maintenance manuals for the system in question.

19.33.3 Component Mounting

- 19.33.3.1 Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration, as defined by IEC 61373. Large components shall be supported in addition to the solder connections.
- 19.33.3.2 Heat dissipating resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, and shall be spaced far enough away from the board so that resistor produced heat will not discolor or damage the board.

19.33.4 IC and Device Sockets

- 19.33.4.1 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 NYCT approval. All other components shall be soldered in place.
- 19.33.4.2 Where approved, IC sockets shall comply with approved standards such as MIL-DTL-83502 and MIL-DTL-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 0.00003 inch (0.76 μm) of gold over silver plating per SAE-AS50151B, Section 3.3.3.2 in the area of contact with IC pins.

19.33.5 Conformal Coating

- 19.33.5.1 Both sides of the assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to IPC-CC-830 latest revision, or approved equal.
- 19.33.5.2 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.
- 19.33.5.3 All IC sockets, connectors, and test points shall be masked when the coating is applied.

19.33.6 Keying

- 19.33.6.1 All printed-circuit boards shall be mechanically "keyed" to prevent insertion into the wrong slot or in the wrong orientation. Further, circuit boards in safety related control systems, such as friction brakes, CBTC, and systems that can cause damage or unsafe train operation if the car is operated with a card removed, shall be connected through a safety circuit to disable the car if a circuit board is removed.

19.33.7 Circuit Board Connectors

- 19.33.7.1 Printed circuit board connectors shall be heavy duty, high reliability, two-part type with a history of successful service in rail applications.
- 19.33.7.2 Connectors shall comply with MIL-DTL-55302, IEC 60603-1, or IEC 60603-2, and which have plated contacts as described below.
- 19.33.7.3 The connector contact area shall be plated with a minimum of 0.00003 inch (0.76 μ m) of gold over silver plating per SAE-AS50151B, Section 3.3.3.2.
- 19.33.7.4 Card edge connectors are prohibited.

19.33.8 Testing

- 19.33.8.1 Sufficient clearance shall be provided between components to allow testing, removal, and replacement without difficulty.
- 19.33.8.2 Test points shall be provided in appropriate locations on modules and printed circuit boards. A negative return test point shall also be provided.
- 19.33.8.3 The test points for manual testing shall either accept and hold a standard 0.08 inch (2 mm) diameter tip plug or shall be a turret lug similar to Cambion No. 160-1026-01-05, or NYCT approved equal, with sufficient clearance to permit it to accept a standard oscilloscope probe clip, and shall be identified by appropriate markings.

19.34 Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
19-01	19.1.6.1	Material matrix including copies of technical data and specification sheets, test reports, and material certifications	CDR
19-02	19.1.6.5	Commercial material; data, specifications and description of material composition, part/material number and manufacturer details	CDR
19-03	Not used	Not used	Not used
19-04	19.1.6.8	Material Safety Data Sheets and Technical Data and Specification Sheets for all chemical materials used in car construction	CDR
19-05	19.1.7.2	Statement of compliance regarding prohibited materials	FAI
19-06	19.1.8.3	Corrosion Control Plan	PDR
19-07	19.1.10.4	Combustible material matrix, and supporting test results for all combustible materials	CDR
19-08	19.1.10.17	Floor assembly fire test in accordance with ASTM E119	CDR
19-09	19.2.4.1	Test and inspection plan for acceptance of stainless steel	CDR
19-10	19.3.3.1	Test and inspection plan for acceptance of all structural steels	CDR
19-11	19.4.2.3	Structural castings qualification test report	FAI
19-12	19.4.3.1	Casting Quality Plan	PDR
19-13	19.4.3.5	Radiographic inspection sampling frequency plan	CDR
19-14	19.6.1.1	Non-metal materials, physical properties and specifications	CDR
19-15	Not used	Not used	Not used
19-16	19.7.1.2	Test reports to verify glazing material compliance	FAI
19-17	19.8.1.4	Thermal and acoustical insulation data and application process	CDR
19-18	19.9.1.2	Floor covering color / material samples	CDR
19-19	19.10.1.1	Structural panel, construction and strength analysis	CDR
19-20	19.14.1.2	Piping flushing and cleaning procedures	CDR
19-21	19.16.1.9	Bearing data for all recommended bearings and bushings	CDR

CDRL	Ref	Deliverable	Timing
19-22	19.16.1.9	Lubricant data for all recommended bearings and bushings	CDR
19-23	19.18.2.4	Joining And Fastening Data, Standards, and Specifications	CDR
19-24	19.19.1.1	Fastener Quality Plan	CDR
19-25	19.19.9.5	Fastener Analysis and Application Plan	CDR
19-26	19.20.1.2	Listing of All Proposed Sealants And Caulking Materials	CDR
19-27	19.20.2.4	Procedures to prepare, clean and apply adhesives	CDR
19-28	19.21.1.7	Acceptable welding distortion levels	CDR
19-29	19.21.1.8	Demonstration of AWS welding compliance	IPDR
19-30	19.21.4.5	Sampling plan for volumetric inspection of full penetration welds	IPDR
19-31	19.21.4.7	Sampling plan for nondestructive examinations of ring welds	IPDR
19-32	19.21.6.1 and 19.21.6.2	Welding specifications, procedures, and welder certifications	IPDR
19-33	19.21.7.1	Procedure and Qualification for Structural Welding Stainless Steel to LAHT	IPDR
19-34	19.21.11.2	Brazing Specifications, Procedures, and Certifications of Personnel	CDR
19-35	19.21.12.3	Soldering specifications, procedures, and certifications of personnel	CDR
19-36	19.22.3.3	Proposed paint surface irregularity levels	CDR
19-37	19.22.8.3	Paint schedule - data on paints, primers, and application processes/procedures	CDR
19-38	19.23.1.6	Samples, and specifications, of each size and type of wire and cable	CDR
19-39	19.23.3.12	Applications of high temperature wire insulation	CDR
19-40	19.24.2.65	Complete wiring and cabling plan for inspection and maintenance	CDR
19-41	19.24.4.1	Wire and terminal identification, marking and numbering plan	IPDR
19-42	19.25.1.2	Proposed design and product line for all connections	IPDR
19-43	19.25.2.7	Electrical terminal installation procedures	CDR
19-44	19.25.3.1	Wire Terminals, Fittings, and Crimp Tool Product Lines	CDR

CDRL	Ref	Deliverable	Timing
19-45	Not used	Not used	Not used
19-46	19.26.3.5	Conduit arrangement and installation	CDR
19-47	19.27.1.1	Conduit fittings and junction box product line	CDR
19-48	19.29.2.1	Reliability and part stress prediction for all electrical and electronic control systems	CDR
19-49	19.29.2.4	Electronic Assemblies Environmental Stress Screening (ESS) (burn-in)	FAI

Attachment 19-A - Requirements for Passenger Car Material Fire Risk Assessment

Function of Material ^(see comments)	Test Procedure	Performance Criteria
All car materials and components except as otherwise noted. (Wall Panels, Ceiling Panels, Partition Panels, Windscreens, Fiberglass, Plastics, Diaphragms, Non-sealing Elastomers, etc.) ^(1, 2, 9, 11, 19)	ASTM E162 ASTM E662	$I_s \leq 35$ $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$ (to exclude polyester resin FRP, use the following: $D_s (1.5) \leq 100$, $D_s (4.0) \leq 165$)
HVAC Ducting ^(1, 2)	ASTM E162 ASTM E662	$I_s \leq 25$ $D_s (4.0) \leq 100$
Lighting Diffusers / Plastic Glazing ^(2, 13)	ASTM E162 ASTM E662	$I_s \leq 100$ $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$
Thermal and Acoustical Insulation ^(1, 2)	ASTM E162 ASTM E662	$I_s \leq 25$ $D_s (4.0) \leq 100$
Flexible Cellular Foams ^(1, 2, 4, 6)	ASTM D3675 ASTM E662	$I_s \leq 25$ $D_s (1.5) \leq 100$, $D_s (4.0) \leq 175$
Elastomers – Lock strip gaskets ^(1, 2, 10, 11)	ASTM C542 ASTM E662	Pass criteria in table 1 $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$
Elastomers – Other gaskets or seals ^(1, 2, 10, 11, 14)	ASTM C1166 ASTM E662	4 inch (100 mm), maximum flame propagation $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$
Adhesives and Sealants ^(1, 2)	ASTM E162 ASTM E662	$I_s \leq 35$ $D_s (1.5) \leq 200$, $D_s (4.0) \leq 200$
Structural – Floor, Roof ^(15, 16, 17)	ASTM E119	Pass (30 minutes minimum endurance at AW3 loading)
Floor Covering ^(2, 12, 12)	ASTM E648 ASTM E662	$CRF \geq 0.5 \text{ W/cm}^2$ (22 Btu/h/ in ²) $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$
Seat Cushions, Mattresses, Padding ^(1, 2, 3, 4, 5, 6, 7, 8)	ASTM D3675 ASTM E662	$I_s \leq 25$ $D_s (1.5) \leq 100$, $D_s (4.0) \leq 175$
Seat Frame, Seat Shroud for Train Operator seat materials ^(1, 2)	ASTM E162 ASTM E662	$I_s \leq 35$ $D_s (1.5) \leq 100$, $D_s (4.0) \leq 200$
Upholstery ^(1, 2, 3, 6, 7, 8)	14 CFR (FAR) 25.853 (App F, vertical, textiles) ASTM E662	Flame Time ≤ 10 sec Burn Length ≤ 6 inch (150 mm). $D_s (4.0) \leq 200$
Wire and Cable Insulation ^(1, 18)	NFPA 130 - 2014	Requirements for Wiring and Electrical Insulation.

Numbered comments below (referenced in superscript in the Table above) are based upon NFPA 130 and 49 CFR, Appendix B to Part 238. These comments have been either quoted, combined from both, or adapted/edited to passenger transit applications.

1. Materials tested for surface flammability shall not exhibit any flaming running or dripping unless an appropriate fire hazard analysis is conducted and approved by NYCT.
2. The ASTM E662-97 maximum test limits for smoke emission (specific optical density, D_s) shall be measured in both the flaming or non-flaming mode, values shall be provided for both cases. The maximum smoke density, D_m , shall also be provided for information.

3. *Testing of a complete seat assembly (including cushions, fabric layers, upholstery) according to ASTM E1537 using the pass/fail criteria of California Technical Bulletin 133, and testing of a complete mattress assembly (including foam and ticking) according to ASTM E1590 using the pass/fail criteria of California Technical Bulletin 129 shall be permitted in lieu of the test methods prescribed herein, provided the assembly component units remain unchanged or new (replacement) assembly components possess equivalent fire performance properties to the original components tested. Testing shall be at 264 Btu/min/ft² (50 kW/m²) applied heat flux with a retainer frame. A fire hazard analysis must also be conducted that considers the operating environment within which the seat or mattress assembly will be used in relation to the risk of vandalism, puncture, cutting, or other acts which may expose the individual components of the assemblies to an ignition source. The requirements of Notes 5, 6, 7, and 8 shall be met.*
4. *Testing is performed without upholstery.*
5. *The surface flammability and smoke emission characteristics shall be demonstrated to be permanent after dynamic testing according to ASTM D3574, Test I2 (Dynamic Fatigue Test by the Roller Shear at Constant Force) or Test I3 (Dynamic Fatigue Test by Constant Force Pounding) both using Procedure B, except that the test samples shall be a minimum of 6 inches (152 mm) by 18 inches (457 mm) by the thickness of the material in its end use configuration, or multiples thereof. If Test I3 is used, the size of the indenter described in paragraph 96.2 shall be modified to accommodate the specified test specimen.*
6. *The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by washing, if appropriate, in accordance with the manufacturer's recommended procedure. If a washing procedure is not provided by the manufacturer, the fabric shall be washed in accordance with ASTM E2061, Annex A1.*
7. *The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by dry-cleaning, if appropriate, according to ASTM D2724.*
8. *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.*
9. *As a minimum, all combustible materials used anywhere in the car (except as noted in 10) are required to be tested including interior, cab components as well as exterior components. Combustible signage shall not be required to meet flame spread or smoke emission requirements if (a) the actual thickness of the signage is no greater than 0.06 in. (1.52 mm); (b) the aggregate area of combustible signage does not exceed 10 percent of the wall area of the car, including windows; and (c) no single sign is larger than 5 ft² (0.46 m²). Items that cannot be made compliant due to other dominating engineering requirements may not be required to meet the flammability or smoke emission performance criteria specified, but still must be tested to establish the relative risk and evaluated, and waived, by NYCT.*
10. *Materials used to fabricate miscellaneous, discontinuous small parts (such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that will not contribute materially to fire growth in end use configuration are exempt from flammability and smoke emission performance requirements, provided that the surface area of any individual small part is less than 16 in² (103 cm²) in end use configuration and an appropriate fire hazard analysis is conducted which addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution to flame spread.*
11. *If the surface area of any individual small part is less than 16 in² (103 cm²) in end use configuration, materials used to fabricate such a part may be tested in accordance with ASTM E1354 as an alternative to both (a) the ASTM E162 flammability test procedure, or the appropriate flammability test procedure otherwise specified in the table, and (b) the ASTM E662 smoke generation test procedure. Testing shall be at 264 Btu/min/ft² (50 kW/m²) applied heat flux with a retainer frame. Materials tested in accordance with ASTM E1354 shall meet the following performance criteria:*

average heat release rate (q'_{180}) less than or equal to 528 Btu/min/ft² (100 kW/m²), and average specific extinction area (sf) less than or equal to 2434 ft²/lb (500 m²/kg) over the same 180-second period.

- 12. Floor covering shall be tested with padding in accordance with ASTM E648, if the padding is used in the actual installation.*
- 13. For double window glazing, only the interior glazing is required to meet the requirements specified herein. (The exterior glazing is not required to meet these requirements.)*
- 14. Average flame propagation shall be less than 4 inches (102 mm) and no specimen shall be completely consumed.*
- 15. Penetrations (ducts, access openings, etc.) shall be designed against acting as passageways for fire and smoke and representative penetrations shall be included as part of test assemblies.*
- 16. A structural flooring assembly separating the interior of a car from its undercarriage shall meet the performance criteria during a nominal test period as determined by the railroad. The nominal test period must be twice the maximum expected time period under normal circumstances for a car to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the car's occupants to a safe area. The nominal test period must not be less than 30 minutes. Only one specimen need be tested. A proportional reduction may be made in the dimensions of the specimen provided it serves to truly test the ability of the structural flooring assembly to perform as a barrier against under-car fires. The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the car under worst-case conditions.*
- 17. Portions of the car body which separate major ignition sources, energy sources, or sources of fuel-load from car interiors, shall have sufficient fire endurance as determined by a fire hazard analysis acceptable to the railroad which addresses the location and quantity of the materials used, as well as vulnerability of the materials to ignition, flame spread, and smoke generation. These portions include equipment carrying portions of a car's roof, but do not include a flooring assembly subject to Note 16.*
- 18. Testing shall be conducted in accordance with ANSI/IEEE Standard 1202, with the additional requirement that circuit integrity shall continue for 5 minutes after the start of the test.*
- 19. Testing of cured materials shall be conducted on materials that are completely cured as stated by the manufacturer's specifications.*

Section 20

Program Management

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20. Program Management

20.1. Introduction

20.1.1. This section defines the requirements for management of the project, including information on how NYCT will oversee the project. It provides requirements for document submittals, key project stages, design review, and reporting.

20.2. Program Management

20.2.1. General

20.2.1.1. The Contractor shall provide program management that is sufficiently comprehensive to enable NYCT to confirm, with a high degree of confidence, that the Contractor will meet all requirements of the Contract, with a focus on the areas of technical, quality, schedule, and cost.

20.2.2. Program Management Plan

20.2.2.1. The Contractor shall develop and submit for approval a Program Management Plan (PMP). The PMP shall be updated via monthly progress reports. **[CDRL]**

20.2.2.2. The PMP shall include, but not be limited to:

- a) Organization chart with names and position titles for all personnel, for the Contractor and major suppliers. As appropriate, staff of the Contractor and major suppliers at the local office, design, manufacturing, assembly, and NYCT project site locations shall be identified.
- b) Definition of the responsibilities, decision authority, and qualifications of all personnel shown on the organization chart.
- c) Description of all facilities and resources required to execute the project.
- d) Detailed supply management plan.
- e) Manufacturing and production plan.
- f) Reference to the Contractor's Quality Assurance Program Plan and Master Test and Inspection Plan (see Sections 23.3.3 and 23.3.4).
- g) Description of all major project activities, including design reviews and audits required by this Specification.
- h) Internal methods, communications, correspondence coding system, and correspondence control plan.
- i) Risk mitigation plan to address technical, schedule, facility, and financial aspects of the project.
- j) Master Program Schedule in Critical Path Method (CPM) format showing key milestones and events as detailed in Section 20.2.5. The Contractor shall provide the software program used to create the Master Program Schedule to NYCT.
- k) List of drawings to be submitted during the design review phase of the program and a schedule for the submittal of these drawings (see Section 20.4.8).
- l) Updated and expanded Contract Data Requirements List (CDRL) based on the list at the end of each section of this Specification. The CDRL shall be a consolidated listing by CDRL number of all required data, including specific format, quantity, timing, and frequency. Additional CDRL items may be identified by the Contractor as applicable.

20.2.3. Submittal Review Plan

- 20.2.3.1. To expedite the design review and approval process, the Contractor shall develop and submit a comprehensive plan for prioritizing the review of submittals, in cooperation with NYCT. **[CDRL]**
- 20.2.3.2. The Contractor shall schedule a series of meetings with NYCT within 2 weeks of submittal of the PMP to develop the Submittal Review Plan.
- 20.2.3.3. The plan shall be based on the design review requirements of Section 20.4.8 and the CDRL submitted in the PMP.
- 20.2.3.4. The plan shall contain all submittals that must be reviewed and approved before a significant stage in the project (for example, before procurement or before testing).
- 20.2.3.5. Any proposed alternatives to the Contract requirements must be submitted to NYCT for review and approval, as part of the plan, using the methods described in Section 20.2.7.
- 20.2.3.6. The Submittal Review Plan shall also include a description of review program logistics, particularly those aspects of the program that supplement the traditional submittal and review process in order to accelerate design review and approval.
- 20.2.3.7. Submittals may be combined to address multiple submittal requirements into a single document or document package.
- 20.2.3.8. As noted in Sections 25.1.1.6 and 26.1.1.6, where a submittal for an identical design, system or component has been submitted for the R211A car, it need not be resubmitted for R211S or R211T designs.

20.2.4. Program Manager

- 20.2.4.1. The Contractor shall assign an individual on a full-time basis, who is fluent in English, and approved by NYCT, to serve as Program Manager for this Program. No substitution of the Program Manager will be permitted without NYCT's prior approval.
- 20.2.4.2. The Program Manager shall have prior experience in the management of passenger rail car procurements and be familiar with design, subcontractor equipment procurement, construction, testing, communications, and inspection of rolling stock.
- 20.2.4.3. The Program Manager shall have qualified staff in the Contractor's local office in the New York City area capable of performing a liaison engineering function.
- 20.2.4.4. The Program Manager shall be granted full authority to render decisions on behalf of the Contractor pertaining to technical and commercial decisions on the Program.
- 20.2.4.5. The Program Manager shall serve as the Contractor's representative in all meetings with NYCT and/or their duly appointed representatives.
- 20.2.4.6. The Program Manager shall arrange to have supporting staff members available for participation in these meetings, as required, such that the Contractor shall be capable of addressing all issues on the agenda for each scheduled meeting.

20.2.5. Schedule Management

- 20.2.5.1. The Contractor shall provide a Master Program Schedule using the Critical Path Method as described in Terms and Conditions Article 109. **[CDRL]**.
- 20.2.5.2. The Contractor shall update the Master Program Schedule in the following manner:
 - a) Baseline schedule shall remain the same for each update.

- b) Actual progress shall be shown using different colored lines or lines of a different pattern from those used when preparing the baseline schedule. Actual progress shall be shown directly under the activity with the percentage complete indicated as of the date prepared.
- c) Date of the updates shall be provided.
- d) Actual start/finish dates shall be shown for activities in progress.
- e) The schedule shall be updated monthly to reflect corrections and task additions.

20.2.6. Supplier Management

- 20.2.6.1. The Contractor shall ensure that all engineers and subcontractors are informed of all specified requirements (see Section 1.5.1), including any modifications to the requirements that may arise during the execution of this project, and that appropriate engineering management tools are utilized to coordinate and provide communication between the designers of interrelated systems.
- 20.2.6.2. All applications of material or equipment by the Contractor shall be with the full concurrence of the subcontractor that the application is suitable and within the recommended limits of operation of the material or equipment. Explicit confirmation from each supplier to this effect shall be provided with each design review package.
- 20.2.6.3. The Contractor shall have all relevant engineers and subcontractors available when required for:
 - a) Meetings.
 - b) Production problems.
 - c) Testing.
 - d) Resolution of design deficiencies.
 - e) All other similar situations.
- 20.2.6.4. During all phases of this project, NYCT shall have access to all engineers and subcontractors through coordination with the Contractor's Program Manager.
- 20.2.6.5. The Contractor shall coordinate all subcontractor design and installation activities with NYCT's project management team.
- 20.2.6.6. The Contractor shall be fully responsible for the performance of all subcontractors during the execution of this project.

20.2.7. Specification Deviation Requests

Specification Change Request

- 20.2.7.1. A Specification Change Request (SCR) is defined as a deviation from the specified requirement, applied to all cars or equipment or, in limited cases, a group of cars or equipment.
- 20.2.7.2. SCRs shall only be permitted at the sole discretion of NYCT.
- 20.2.7.3. The SCR shall be submitted using the standard NYCT form in Appendix C-26, accompanied by a full justification as to why the proposed alternative is equal to or better than the Contract requirements.

Specification Approval Request

- 20.2.7.4. A Specification Approval Request (SAR) is defined as an authorization to deviate from the specified requirement, where the Specification permits "approved equal" or "unless approved by NYCT", applied to all cars or equipment or, in limited cases, a group of cars or equipment.
- 20.2.7.5. SARs shall only be permitted at the sole discretion of NYCT.

- 20.2.7.6. The SAR shall be submitted using the standard NYCT form in Appendix C-27, accompanied by a full justification as to why the proposed alternative is equal to or better than the Contract requirements.

Specification Waiver Request

- 20.2.7.7. A Specification Waiver Request (SWR) is defined as a specified requirement, such as the qualification test and First Article Inspection (FAI), which does not need to be performed on a component or system that is identical and in use at NYCT.
- 20.2.7.8. SWRs shall only be permitted at the sole discretion of NYCT.
- 20.2.7.9. The SWR shall be submitted using the standard NYCT form in Appendix C-28, accompanied by a full justification as to why the proposed Contract requirement does not have to be conducted.

Software Modification Request

- 20.2.7.10. A Software Modification Request (SMR) is defined as a deviation from the specified software requirement, or as a modification to the software to correct a defect or to implement an enhancement that is necessary to satisfy a software requirement.
- 20.2.7.11. SMRs shall only be permitted at the sole discretion of NYCT.
- 20.2.7.12. The SMR shall be submitted using the standard NYCT form in Appendix C-29, accompanied by a full justification as to why the proposed alternative is equal to or better than the Contract requirements, or the proposed change is necessary, in addition to providing all details of the change, root cause, and the effects of the change on the operation or maintenance of the equipment.

Proposed Change Order

- 20.2.7.13. A Proposed Change Order (PCO) is defined as the Contractor's scope of work for a Notice of Proposed Change Order (NOPCO) issued by NYCT. See also Articles 402 and 403 of the Contract Terms and Conditions.
- 20.2.7.14. PCOs shall only be permitted at the sole discretion of NYCT.
- 20.2.7.15. The PCO shall be submitted using the standard NYCT form in Appendix C-30, accompanied by the scope of work to be performed or deleted, as well as any other changes to the provisions of the Contract requirements.

Configuration Change Form

- 20.2.7.16. A Configuration Change Form (CCF) is defined as a deviation from the material, form, fit, or function of a system, part, or item of equipment used by NYCT. This form also is used when a part or item of equipment is unchanged, but the identifying part number or description needs to be changed.
- 20.2.7.17. CCFs shall only be permitted at the sole discretion of NYCT.
- 20.2.7.18. The CCF shall be submitted using the standard NYCT form in Appendix C-31.

20.2.8. Project Communications

- 20.2.8.1. All formal project communications shall be between respective project/program managers. Communications and decisions made outside of this communication shall not be binding on either party.
- 20.2.8.2. All project communications, oral and written, shall be in English.
- 20.2.8.3. All project deliverables shall be in English, with an accurate English translation provided where any other language is used.
- 20.2.8.4. Project correspondence shall be delivered electronically for expedience.

- 20.2.8.5. In addition to the electronic copies, the Contractor shall deliver two complete copies of every official correspondence letter and attachment(s) to the NYCT project office for the official record file. All letters must be on official company letterhead and signed. Likewise, NYCT will provide one signed hard copy of its letters and associated documents to the Contractor.
- 20.2.8.6. Correspondence control shall be administered by a mature, proven project document management system, which shall maintain electronic copies of all documents and provide the ability to search and track documents and generate reports.
- 20.2.8.7. Each submittal shall be coded to allow tracking in the system throughout the process of review, from publication by the Contractor through the process of review/approval by NYCT.
- 20.2.8.8. The initial publication by the Contractor shall provide a brief description of the purpose of the submittal along with a list of:
- a) Drawing titles.
 - b) Document titles.
 - c) Document numbers.
 - d) Revisions for drawings.
 - e) Data included in each publication.
- 20.2.8.9. The system shall maintain a record of Contractor and subcontractor drawing and document status.
- 20.2.8.10. The Contractor shall plan for a review period of 21 days by NYCT of any submittal, except as noted in Section 20.5.2.
- 20.2.8.11. The Contractor shall respond to NYCT requests for information, or NYCT submittal comments within 21 days, except as noted in Section 20.5.2.

20.2.9. Project Meetings

Meeting Documentation and Logistics

- 20.2.9.1. A minimum of 5 business days' notice shall be provided for all project meetings, 15 days for meetings which require NYCT staff to travel.
- 20.2.9.2. All official project meetings shall include an agenda and an attendance sheet.
- 20.2.9.3. NYCT shall be responsible for preparing meeting minutes using the standard NYCT form Memoranda of Conferences (MOC), contained in Appendix C-32, to record discussion and action items of official meetings.
- 20.2.9.4. Meeting minutes and a list of action items resulting from the meeting shall be reviewed and agreed by all parties at the conclusion of each meeting. For each action item, a responsible party and a due date shall be established.
- 20.2.9.5. Formal meeting minutes shall be distributed within 3 business days of the end of the meeting.
- 20.2.9.6. Video conferencing and use of virtual meetings/ design reviews is encouraged where feasible to expedite resolution of issues.

Kick-Off Meeting

- 20.2.9.7. The first project meeting shall be held within 2 weeks after Notice to Proceed (NTP), at a time and location designated by NYCT, for the purpose of discussing with the Contractor all essential matters.
- 20.2.9.8. At this meeting, as a minimum, the following shall be accomplished:
- a) Introduce key personnel of the Team.

- b) The Contractor shall submit document coding schemes, schedule, and monthly report format for joint review.
- c) Confirm project control methodology and plans for initial activities before the start of formal progress reporting.
- d) Identify the early information needs and decisions required by the Contractor from NYCT.
- e) NYCT will inform the Contractor of the required NYCT Safety Training.

Specification Review Meeting

- 20.2.9.9. Within 2 weeks of the Kick-Off Meeting, the Contractor's Program Manager, the Contractor's technical specialists, major subcontractors and suppliers, and NYCT shall jointly perform a detailed line by line review of this Specification.
- 20.2.9.10. During this meeting, the Contractor shall provide an explanation of the approach planned in response to each Specification requirement. NYCT will answer questions that the Contractor may have regarding Specification requirements.

Progress Review Meetings

- 20.2.9.11. Progress Review Meetings (PRMs) will be held every month. As the Unit design is completed, NYCT may elect to decrease the frequency of the PRMs.
- 20.2.9.12. Depending on the subject matter to be covered in the PRMs, NYCT may opt to conduct certain meetings at the car construction facilities or facilities of the Contractor's subcontractors. NYCT will inform the Contractor at least at the end of the PRM prior to the next PRM.
- 20.2.9.13. The Contractor shall prepare and distribute an agenda and its contents to all participants expected to attend the meetings 3 days prior to the scheduled PRM date.
- 20.2.9.14. Based upon the agenda, the appropriate Contractor personnel, shall attend.
- 20.2.9.15. As a minimum, the agenda shall include:
 - a) Executive Summary (covering program management, engineering management, quality, procurement, production manufacturing, contract management, and in-service support issues).
 - b) Project Status Meeting issues.
 - c) Photographs to show progress, as necessary.
 - d) Project 45-Day Look Ahead.
 - e) Project Schedule (Master Program Schedule status and project risks and priorities).
 - f) Change Order Status.
- 20.2.9.16. Questions or problems not answered during the meeting shall be solved and the resolution documented by the next meeting.

20.2.10. Progress Review Report

- 20.2.10.1. A monthly progress report [CDRL] shall be provided and shall include, at a minimum:
 - a) All items listed in the Program Management Plan, including an updated Master Program Schedule.
 - b) Actual start dates for activities started during the report period.
 - c) Actual completion dates for activities completed during the report period.
 - d) Estimated remaining durations for activities in progress.

- e) Estimated start dates for activities scheduled to start during the 6 weeks following the report period.
- f) Changes in the durations of activities and minor logic changes.
- g) Any deviations from approved schedule, along with narrative explanation for the deviations and outline of recovery actions.
- h) Work-arounds needed to make up for schedule slippage, as necessary.
- i) Activities not previously included in the Master Program Schedule.
- j) Status of correspondence including open items.

20.2.10.2. The Contractor also shall provide a narrative stating the work actually completed and reflect the progress in terms of days ahead of or behind the specified dates for each of the work items, as well as percent completed.

20.2.10.3. During the manufacturing, assembly, and testing phases, the Contractor shall supplement the narrative with photographs to show the status and/or problem areas of the work in progress.

20.2.10.4. NYCT may request supplemental detailed reports and/or photographs if the monthly progress report is determined to be inadequate.

20.2.11. Contractor Site Representatives

20.2.11.1. The Contractor and its major subcontractors shall provide qualified technical and administrative support on NYCT's property, commencing with the arrival of the first Unit and concluding with the completion of the warranty program. See also Article 906 of the Contract Terms and Conditions.

20.2.11.2. Included among the personnel shall be a full range of engineering skills, until such time as all cars are accepted.

20.2.11.3. Contractor representatives shall be fluent in English and fully qualified for the onsite tasks.

20.2.11.4. All necessary specialized Contractor and subcontractor support shall be available, on short notice, to assist the onsite personnel in the investigation and resolution of car and equipment malfunctions.

20.2.11.5. Contractor representatives must be identified by the Contractor and display appropriate identification while on NYCT property.

20.2.11.6. Contractor onsite personnel must undergo NYCT's Safety Training (see Section 22.5.1.16) prior to accessing NYCT facilities and shall adhere to all NYCT rules and regulations.

20.3. Project Engineering Requirements

20.3.1. System Integration

20.3.1.1. The Contractor shall be responsible for, and shall actively employ, system integration principles throughout the design, production, and testing phases of the Contract.

20.3.1.2. The practiced principles shall control and coordinate the interfaces among the car's systems as well as between the Units and NYCT operating and maintenance environment.

20.3.1.3. The Contractor Systems Integrator shall have an understanding of the interaction of all car systems and parameters, as well as possess experience in coordinating interface requirements.

20.3.2. Industrial Design

20.3.2.1. The Contractor shall provide industrial design services during the design and manufacturing phases of the Contract.

- 20.3.2.2. It shall be the responsibility of the Contractor to finalize NYCT's industrial design concepts (see Section 1.2.5 and Renderings in Appendix E-1 in such a manner that the function, value, and appearance of its systems are optimized for the mutual benefit of NYCT and its passengers.
- 20.3.2.3. The Industrial Designer shall lead the design effort of the car's interior, exterior, and equipment layout.
- 20.3.2.4. The Industrial Designer shall be identified and presented to NYCT for approval. Prior experience as an industrial designer for rail car procurement programs is required.
- 20.3.2.5. The Contractor shall provide a minimum of 4 interior and 3 exterior finalized color detail renderings for NYCT's review during development of the car design. The renderings shall be the basis for NYCT's selection of the design that will be carried through to production.
- 20.3.2.6. The Industrial Designer shall place emphasis on safety, human factors (ergonomics), aesthetics, manufacturability, maintainability, resistance to vandalism and abuse by internal/ external persons, and cost when developing the final design of the car.
- 20.3.2.7. The industrial design services shall include, but not be limited to:
- a) Car interior aesthetics and seat arrangement.
 - b) Car exterior aesthetics.
 - c) Car configuration with respect to NYCT system clearance restrictions.
 - d) Cab equipment arrangement and Operator's cab console.
 - e) Car exterior and interior equipment arrangement and maintenance access.
 - f) Between car barriers.
 - g) Stanchion and windscreen designs.
 - h) Materials selection and application.
 - i) Human factors engineering (ergonomics).

20.3.3. Weight Control Program

Design Phase

- 20.3.3.1. The Contractor shall submit a comprehensive weight control program plan describing how the Contractor will control car weight and weight distribution to meet the requirements of Section 2.4. [CDRL]
- 20.3.3.2. Prior to the first design review, the Contractor shall submit:
- a) Proposed weight data record format.
 - b) Initial weight and balance estimates.
 - c) Proposed procedure for ensuring control of car and truck weight and balance, and car component-weight location.
- 20.3.3.3. The data in Section 20.3.3.2 shall be updated monthly throughout the car design and manufacturing phases as more precise estimates and actual weight data become available, and shall be submitted to NYCT.
- 20.3.3.4. The submission shall include the most recent weights for each truck, the Unit without trucks, and the complete Unit.
- 20.3.3.5. It shall also include a list of weights for every system on the Unit, and indication of percentage of the estimated weight that the system contributes to the total estimated weight.

Production Phase

- 20.3.3.6. As production equipment weights as measured by scale become available, they shall replace the estimated weights in the weight reports.
- 20.3.3.7. The Contractor shall require the full cooperation of its subcontractors in this effort, and shall require weighing of sample components at the earliest possible dates.
- 20.3.3.8. An NYCT approved form shall be provided by the Contractor for submitting this information.
- 20.3.3.9. The records for the prototype car of each type and for the first routine production car of each type shall contain as a minimum:
- a) Sum of estimated carbody and car-mounted equipment weights.
 - b) Location of equipped carbody Center of Gravity (CG) with indicated location of car shell CG, and the CGs of individual major equipment relative to longitudinal and transverse geometric centerlines of the finished car body.
 - c) Magnitude and location of the center of the carbody load applied to each truck centerplate relative to longitudinal and transverse geometric centerlines of the finished carbody.
 - d) Weight and CG of each truck as equipped for service.
 - e) Weight supported by the rail under each wheel for the truck alone and for the combined car and truck.
 - f) Sum of all wheel loads.
- 20.3.3.10. The Contractor shall keep detailed weight records for the first 10 cars of each type. These weight records shall itemize each major car item with:
- a) Initial design estimated weight.
 - b) Refined design estimates.
 - c) First piece measured weights.
 - d) Production piece measured weights.
- 20.3.3.11. The Contractor shall maintain accurate and up-to-date cumulative car weights and cumulative car balance data for review by NYCT.
- 20.3.3.12. The Contractor shall individually weigh each completed car at shipment using a scale that produces a printed record of the weight.
- 20.3.3.13. The weight ticket shall be furnished to NYCT in the shipping documents and data entered into the Car History Book (see Section 20.9).
- 20.3.3.14. Weight summary reports shall be included in the monthly progress report during the production phase, including:
- a) List of actual car weights by car number.
 - b) Cumulative average car weight.
 - c) Graphic comparison of cumulative average car weight with individual car weight by car number.

20.3.4. Engineering Change Control

- 20.3.4.1. For the purposes of change control, the design baseline for each system shall be established when design approval is granted at the FAI.

- 20.3.4.2. Changes made after the FAI that affect the approved design or production baseline, as presented at the FAI, shall be submitted for approval following the Engineering Change Request (ECR) process described in this Section.
- 20.3.4.3. Changes to the documents, drawings, or data shall be controlled by the processing of ECRs.
- 20.3.4.4. An engineering change to any part, assembly, or equipment item of the car shall be designated as a Class I change when form, fit, function, or interchangeability is affected. A change shall be designated as Class I if it affects any of the following:
- a) Delivered manuals.
 - b) Delivered product (retrofit).
 - c) Electromagnetic interference characteristics.
 - d) Reliability or maintainability.
 - e) Safety.
 - f) Schedules of deliveries.
 - g) Spares provisioning.
 - h) Source or repairable items (source control drawing).
 - i) Weight or balance.
- 20.3.4.5. All other changes shall be designated as Class II changes.
- 20.3.4.6. All Class I ECRs, together with documentation and cost information, shall be submitted to NYCT for review prior to implementation.
- 20.3.4.7. Class II ECRs shall be submitted to NYCT for information. Approval of Class II ECRs will only be required if the changes deviate from the Technical Specification requirements.
- 20.3.4.8. The Contractor shall maintain an Engineering Change Status Report, which shall list all approved changes, all Class II changes, their implementation status, and completion dates.
- 20.3.4.9. Implementation of an ECR shall require incorporation in all cars unless approved by NYCT as an effective point change.
- 20.3.4.10. All field modifications resulting from ECRs that need to be performed on NYCT property shall follow NYCT Document FMI-001, "New Car Field Modification and Capital Spare Parts Procedure", contained in Appendix C-33.
- 20.3.4.11. A change of supplier, manufacturing facility (technology transfer), or process, shall be considered an engineering change and shall follow the ECR process. Depending on the nature of the component and change, and as directed by NYCT, the Contractor shall repeat qualification tests, schedule First Article Inspections, and perform other validation as needed to ensure that the new product conforms to NYCT standards.

20.4. Design Review Process

20.4.1. Design Review Stages

- 20.4.1.1. Figure 20-1 contains a graphical representation of the significant stages in the design review phases. Refer to the referenced Specification sections for detailed requirements.

20.4.1.2. The activities depicted in Figure 20-1 shall be followed in the sequence shown, with NYCT approval being required to move to the next stage.

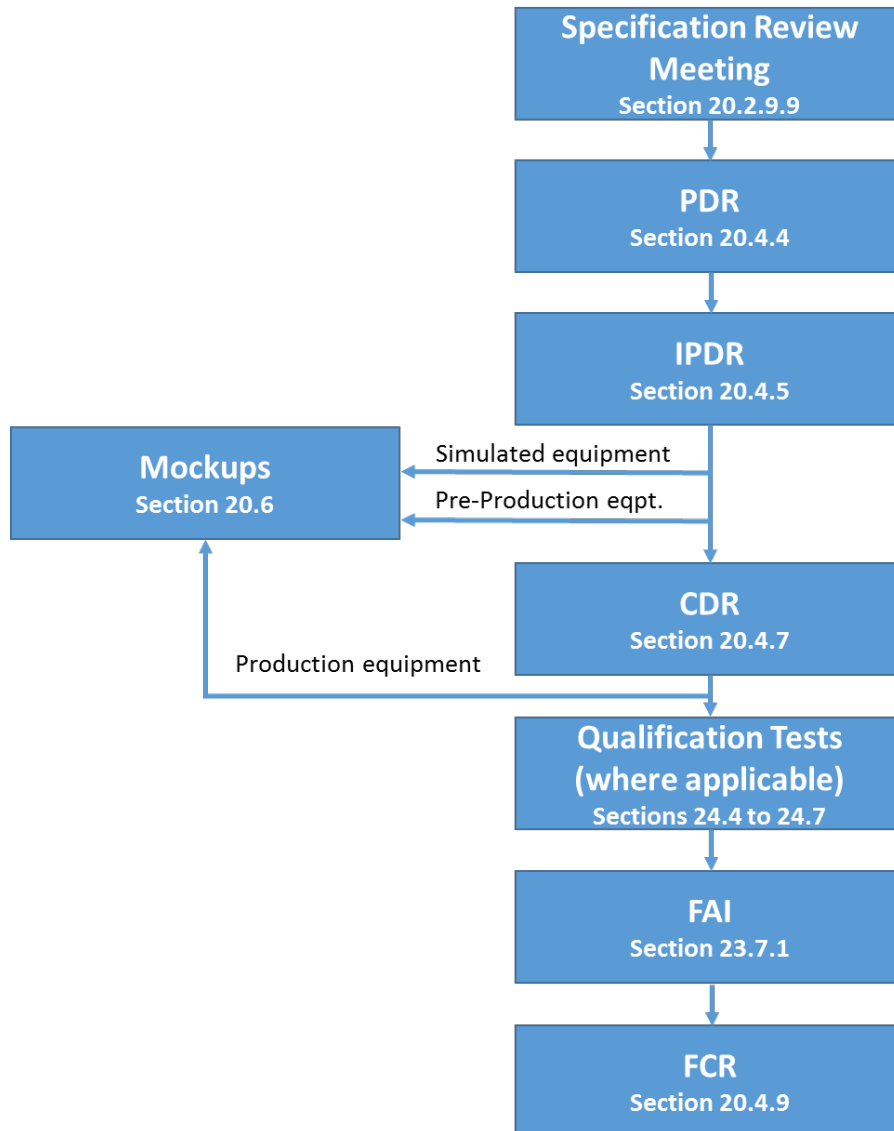


Figure 20-1 – Design Review Process

20.4.2. System Functional Descriptions

20.4.2.1. At the start of the Design Review phase, the Contractor shall submit a System Functional Description [CDRL] for the Unit that:

- a) Clearly defines the subsystems that constitute the overall system.
- b) Describes and graphically depicts each interface between the subsystems.

- c) Shows how the requirements of the Technical Specification are allocated to the subsystems. This will include descriptions of how single requirements, including control and timing requirements, will be decomposed into several requirements allocated to separate subsystems.
- d) Defines names for subsystems and the interfaces between them to assure consistent terminology used by all suppliers.
- e) Defines each system's Lowest Replaceable Units (LRUs) and Lowest Level Replaceable Units (LLRUs).

20.4.2.2. The descriptions of the subsystems, as presented in the design review documentation and presentations, shall match this overall system description in function, interfaces, and terminology. This document shall be updated as the design progresses and be resubmitted to NYCT for review and approval.

20.4.3. Design Review Meetings

- 20.4.3.1. A series of design review meetings as scheduled in the approved PMP will be held, in which the Contractor conducts a presentation in accordance with a previously approved agenda.
- 20.4.3.2. In its presentation, the Contractor shall address design approaches, concepts, and design details for the car(s), each system and subsystem, and all associated test equipment.
- 20.4.3.3. During these design review meetings, action items will be identified, with each action item assigned to an individual for disposition by a pre-determined response date.
- 20.4.3.4. Design review meetings typically will be of 1 to 3 days' duration and should not address more than one system or subsystem.
- 20.4.3.5. Ten business days prior to a design review meeting, the Contractor shall submit the agenda and a data package covering information to be addressed in the meeting.
- 20.4.3.6. Design review meetings shall be held at mutually agreed locations and may include sites of the Contractor and any of its subcontractors or suppliers.
- 20.4.3.7. Design review meeting minutes shall be prepared as defined in Section 20.2.9.
- 20.4.3.8. The first design review meeting in each phase shall cover the overall system design as described in the System Functional Description.
- 20.4.3.9. Attendance at design review meetings shall include representatives of the Contractor, appropriate subcontractors and suppliers, and NYCT or its representative.
- 20.4.3.10. The use of concurrent review by NYCT in Contractor or major subcontractor design facilities is permitted. In this case the Contractor shall provide facilities for the NYCT personnel equivalent to those defined in Article 912A of the Contract Terms and Conditions.

20.4.4. Preliminary Design Review

- 20.4.4.1. The Contractor shall prepare conceptual design drawings for review by NYCT. Drawings and documents shall be submitted for review and comment.
- 20.4.4.2. After receipt of conceptual design information, a Preliminary Design Review (PDR) Meeting shall be held, as scheduled in the approved PMP.

20.4.5. In-Process Design Review

- 20.4.5.1. As the design progresses, a review of the design progress and the work performed in making the transition from conceptual design to final design will be conducted by NYCT.

- 20.4.5.2. In-Process Design Review (IPDR) meetings will be scheduled after conclusion of the PDR and will continue until the Contractor is ready to schedule a Critical Design Review.
- 20.4.5.3. The IPDR serves the following purposes:
- a) Determines the progress of the work.
 - b) Serves as a forum to discuss design problems and alternative solutions, and to answer questions raised by the Contractor and its subcontractors.
 - c) Reviews LRU and LLRU lists.
 - d) Reviews all open PDR and previous IPDR issues.
 - e) Provides NYCT approval to commence production of pre-production hardware.
- 20.4.5.4. Following NYCT's approval of the last IPDR, the Contractor shall commence fabrication of pre-production equipment as identified in Section 20.4.6.
- 20.4.5.5. Any production fabrication started prior to NYCT approval of an IPDR package shall be at the Contractor's sole risk, and NYCT shall not be obligated to accept such product.
- 20.4.5.6. IPDR shall only be mandatory for the following items:
- Carbody
 - Brake system
 - Trainline and car architecture system
 - Monitoring and Diagnostic System
 - ATC system (R211S)
 - Open Gangway (R211T).
- 20.4.5.7. NYCT, at the sole discretion of the Project Manager, may require an IPDR for other systems if there are significant unresolved issues from the PDR that would increase project risk if deferred to the CDR stage.

20.4.6. Pre-Production Equipment

- 20.4.6.1. As part of the design review process, the Contractor shall furnish pre-production versions of the car's systems. This pre-production equipment shall be presented as part of the Critical Design Review and in advance of production of the First Article Inspection items.
- 20.4.6.2. The principal purpose of this pre-production equipment is to enable NYCT to evaluate the design prior to commencement of production. NYCT will evaluate the pre-production equipment for maintainability, repair, and replacement of LRUs, accessibility, and other general design aspects.
- 20.4.6.3. The pre-production equipment also may be utilized by the Contractor for functional testing purposes and eventual placement on the mock-ups required in Section 20.6.1.
- 20.4.6.4. Pre-production equipment to be supplied shall include:
- a) Truck assembly.
 - b) Coupler and controls.
 - c) Network controllers.
 - d) Event recorder.
 - e) Current collectors.
 - f) Main Switch (see Section 9.3.5).
 - g) Auxiliary inverters.

- h) Low voltage DC power supply (LVPS).
- i) Propulsion inverters.
- j) Traction motor.
- k) Propulsion control logic units.
- l) Gear unit.
- m) Brake resistors.
- n) Friction brake tread brake units.
- o) Air compressor.
- p) Door operator control panel.
- q) Door operator.
- r) Heating, ventilation, and air conditioning (HVAC) unit.
- s) Public address amplifier.
- t) Radio.
- u) Closed-circuit television (CCTV) system.

20.4.6.5. NYCT reserves the right to require additional items be provided as the design evolves.

20.4.7. Critical Design Review

- 20.4.7.1. The Critical Design Review (CDR) will take place when the design is essentially complete. All PDR and IPDR issues must be resolved prior to scheduling and commencing the CDR activity.
- 20.4.7.2. The CDR is to provide the opportunity to review, revise, and agree on the details of the final design prior to release of the designs for manufacture.
- 20.4.7.3. Any open engineering items and related program management issues must be discussed and resolved during the CDR to consider the CDR closed.
- 20.4.7.4. As part of the CDR, the Contractor shall present for NYCT's review and comment, the pre-production version of those systems identified in Section 20.4.6.
- 20.4.7.5. This presentation shall include a maintainability demonstration that shall be recorded, with the video recording submitted as part of the meeting minutes.
- 20.4.7.6. Satisfactory resolution of NYCT's comments shall be required for completion of the CDR.

20.4.8. Drawings and Documents Requiring Approval

- 20.4.8.1. The Contractor shall submit a master drawing tree and list of drawings. Based on the guidelines given below, the Contractor shall indicate on this list the drawings intended for submittal and NYCT approval. [CDRL]
- 20.4.8.2. As part of the drawing tree submittal, the Contractor shall include a description of the primary drawing numbering system including the significance of characters.
- 20.4.8.3. The Contractor shall submit a schedule for submittal of drawings, documentation, and data to NYCT for approval, in accordance with the Master Program Schedule and requirements of this section. [CDRL]
- 20.4.8.4. Drawings and documents to be furnished by the Contractor during the design review process for approval by NYCT shall include, but not be limited to, those listed in Attachment 20-1. NYCT reserves

the right to request additional drawings as required to clarify and amplify the intent of drawings furnished.

- 20.4.8.5. For the purpose of design review, the Contractor may submit vendor drawings without integrating them into its own drawing formatting and numbering system. After the CDR phase, vendor drawings must be integrated into the Contractor's system.

20.4.9. First Car Review

- 20.4.9.1. NYCT and the Contractor shall jointly perform the First Car Review (FCR) on all types of completely assembled prototype cars. The Contractor shall give at least 15 days' notice of the proposed FCR date, which shall be subject to NYCT approval.
- 20.4.9.2. The purpose of the FCR shall be to allow NYCT to evaluate component and system maintainability, including the removal and replacement methods of LRUs.
- 20.4.9.3. NYCT and the Contractor shall jointly establish an acceptable Quality Level for workmanship.
- 20.4.9.4. The requirements below shall apply to the FCR. The Contractor shall make available:
- a) A complete set of approved or conditionally approved drawings (with NYCT's comments).
 - b) The proper environment/work space for review and inspection of the car(s).
 - c) All necessary inspection tools/gauges and labor to facilitate mechanical or electrical measurements.
 - d) Demonstration of subsystem and component placements including methods of attachment, accessibility for removal and replacement of equipment and maintenance, equipment interfaces and clearances at the trucks, couplers, other components and structure, using special tools as required.
 - e) Cars shall be coupled to each other and checked for proper truck, drawbar, coupler, cable, and hose clearance.
 - f) Truck retention and removal functions shall be verified.

20.4.10. First Article Inspection

- 20.4.10.1. The final stage in the design review process is the First Article Inspection (FAI). FAI requirements are defined in Section 23.7.1.

20.5. Submittals

20.5.1. Requirements for Drawings, Documents, and Data

- 20.5.1.1. All drawings shall be produced electronically utilizing computer-aided design software, compatible with AutoCAD, latest version. The Contractor shall provide the software to NYCT needed to permit complete viewing and manipulation. Manual revisions to drawings shall not be permitted.
- 20.5.1.2. All dimensions shall be expressed as required by Section 1.5.4.
- 20.5.1.3. All wording shall be in the English language, and all terminology used shall be conventional to the U.S. transit and railroad industries.
- 20.5.1.4. Drawings shall be made to the third-angle projection system.
- 20.5.1.5. All drawings submitted by the Contractor shall be in the format as required by NYCT Specification 8004-GENL-87, entitled "Engineering Record Drawings," contained in Appendix C-35. Drawings shall be submitted as full-size plots, unless specifically allowed otherwise by NYCT.

- 20.5.1.6. The use of 3D models to convey design information shall be compatible with the following key requirements:
- a) The models shall be easily readable by NYCT and its representatives. If specialized software or hardware is needed to view them, these shall be provided by the Contractor.
 - b) The models shall have the capability of generating fully dimensioned 2D views, which can be printed for review and markup.
 - c) The models shall contain sufficient information to confirm the equipment is manufactured to the requirements of the model, including detailed dimensions, tolerances, etc.
 - d) The content and format of the data in the models shall be such that NYCT shall be able to access it for the life of the car, and have the ability to design modifications, source replacement parts, and perform maintenance. Such access shall be through commercially available software and hardware.
 - e) For commercial of the shelf (COTS) equipment, models will be permitted to be limited to outline and interface information.
- 20.5.1.7. Proprietary information on drawings and models shall comply with the requirements of the Contract Terms and Conditions, Articles 105 and 106.

Revision Control

- 20.5.1.8. A revision block shall be provided for all documents, drawings, and data. The revision block shall identify the revision letter, date of revision, the initials of the engineer authorizing the revision, a description of the change and a summary of the change, the location of the change on the drawing or document, and the reason for making the change.
- 20.5.1.9. The full description of the change and the reason for making the change shall be shown on a change sheet or similar document accompanying the drawing or document, and appropriately referenced in the revision block.
- 20.5.1.10. Subsequent to document, drawing, and data approval by NYCT, engineering change requests (Section 20.3.4) must be submitted to NYCT for approval before incorporation of any document, drawing, or data revisions.
- 20.5.1.11. Upon receipt of ECR approval, the document, drawing, and data shall be revised and the document, drawing, and data, with the accompanying approved ECR, shall be submitted for approval.
- 20.5.1.12. No additional revisions to an approved documents, drawings, and data shall be made without an approved ECR.

Structural Drawings

- 20.5.1.13. All structural drawings shall be of sufficient scale and size to clearly delineate the shape and size of all assemblies, members, and components.
- 20.5.1.14. The drawings shall be completely dimensioned. Build-up of materials shall be shown and identified (thicknesses dimensioned).
- 20.5.1.15. Full and complete information regarding location, type, size, and extent of all welds shall be clearly shown on the drawings.
- 20.5.1.16. All joints and connections shall be detailed, with all dimensions, showing the size of the fasteners and complete American Welding Society (AWS), or equivalent, weld symbols (including size and process).
- 20.5.1.17. The list of materials shall include the material's specification with grade, temper, thickness, and nominal size.

Referencing

- 20.5.1.18. All drawings shall be zoned to make it easier to locate details. The zones shall be approximately 3 inches (76 mm) by 3 inches (76 mm) in size. The vertical divisions shall be designated by letter and the horizontal divisions designated by number.
- 20.5.1.19. Whenever a cut, section, or detail is referenced on a drawing, its location, by sheet and zone, shall be given. Wherever the cut, section, or detail is shown, the location by sheet number and zone from whence it came shall be given.
- 20.5.1.20. All drawings supplied by the Contractor shall be delineated in a manner that permits the wiring, piping, and mechanical interface relationships between components furnished by the Contractor and its subcontractors to be clearly identifiable.
- 20.5.1.21. Whenever reference is made on a drawing to a material or process by the Contractor's own specification number, the drawing shall also give the commercial equivalent. If there is no commercial equivalent, the Contractor shall provide copies of its specification.
- 20.5.1.22. Next higher assembly drawings shall be referenced on all piece, part, and subassembly drawings.

Schematics

- 20.5.1.23. Totally integrated car schematics relating to all electrical and pneumatic systems shall include component identification, component values, waveforms, voltages, currents, resistance values, wire identification, connector identification, and connector pin numbers.
- 20.5.1.24. All components on PC boards shall be individually shown in the schematics.
- 20.5.1.25. Schematics shall be comprehensive in nature and thoroughly detailed to permit use by NYCT shop electricians and air brake specialists to troubleshoot and repair car systems.
- 20.5.1.26. Schematic location (for example, page number) of the energization portion of each device (such as the coil in a relay) shall be noted adjacent to the operating portions (such as relay interlocks) of the device.
- 20.5.1.27. A set of device tables shall be located in a single section at the rear of the schematic book. This table shall be arranged in logical manner by system device type. This table shall include data for all system and subsystem components, including but not limited to:
 - a) Electrical control and power components (groups, panels, PC cards, contactors, relays, circuit breakers, capacitors, inductors, resistors, specialized modules, rectifiers, thyristors, diodes, fuses, and other components, as appropriate).
 - b) Electrical machinery (rotating equipment, reactors, transformers, pumps, fans, compressors, switchgear, and other machinery).
 - c) Pneumatic control and power devices (valves, chokes, strainers, reducers, and other components).
 - d) Pneumatic machinery (compressors, air cylinders, air motors, air latches, and other machinery).
- 20.5.1.28. As a minimum, device listings shall include the following:
 - a) Location in schematic and schematic designation.
 - b) Type, model, and part number.
 - c) Location on car.
 - d) Function.
 - e) Schematic symbol.
 - f) Appropriate ratings data.

g) Interface information, as appropriate.

- 20.5.1.29. The integrated schematic drawings shall be formatted by subsystem, using identical device symbols, and wire and pipe designators for each subsystem.
- 20.5.1.30. All interfaces, from page to page, and subsystem to subsystem, shall be clearly delineated.
- 20.5.1.31. The integrated schematic and narrative shall be designed, drafted, assembled, and published by the Contractor, or by a single subcontractor placed under contract for that express purpose.
- 20.5.1.32. It is not acceptable to assemble a collection of subcontractor drawings, independently produced, into a single, car-integrated schematic.
- 20.5.1.33. To ensure clarity, the Contractor shall select lettering and detail size to be legible for a schematic page reduced to a size of 5 inches by 7 inches (127 mm by 178 mm); however, the schematic shall be submitted in an 8.5-inch by 11-inch (216 mm x 280 mm) page format.

Wiring Diagrams

- 20.5.1.34. Wiring diagrams shall be integrated connection diagrams and a wire list in book form based on the integrated schematic. The diagrams shall show all wiring, raceways, conduits, and connections.
- 20.5.1.35. The wire list shall include each individual wire segment in the car, listed separately, whether the wire is used for the transfer of power or information.
- 20.5.1.36. As a minimum, the following information shall be provided for each wire segment:
- a) Wire code (schematic designation).
 - b) Origin (FROM device/terminal).
 - c) Destination (TO device/terminal).
 - d) Wire size.
 - e) Voltage rating.
 - f) Length.
 - g) Appropriate specifications.
 - h) Jacket color.
 - i) Harness designation.

Instructional drawings

- 20.5.1.37. Instructional drawings shall be prepared in accordance with the requirements of Air Transport Association of America (ATA) Specification No. 100 "Specification for Manufacturer's Technical Data" and shall be prepared so that reduction can be made to 8.5-inch by 11-inch (216 mm by 280 mm) dimensions.

Drawing Standards

- 20.5.1.38. The following American National Standards Institute (ANSI) standards for the preparation of drawings shall apply: Y1.1, "Abbreviations for Use on Drawings"; Y32.2, "Graphics Symbols for Electrical and Electronic Diagrams"; and Y32.14, "Graphic Symbols for Logic Diagrams".
- 20.5.1.39. The requirements for ATA and ANSI standard graphic symbols and abbreviations may be waived by NYCT, provided a system of standard abbreviations and symbols for all drawings submitted is used and the Contractor provides NYCT with five copies of a bound booklet in a format that contains a legend cross-referencing all abbreviations and graphic symbols used on drawings to those required by the ATA and ANSI standards.

20.5.2. NYCT Review Process

Submittal Requirements

- 20.5.2.1. The Contractor shall submit one record hard copy and one electronic copy of all documents, data, and assembly and installation drawings required to convey concept, design, dimensions, maintenance, operation, and overall assembly aspects and interfaces for review.
- 20.5.2.2. The required electronic copy shall be created and submitted using a software package and version approved for NYCT. The Contractor shall provide the software required to fully view the document to NYCT.
- 20.5.2.3. The Contractor shall submit drawings in accordance with the Submittal Review Plan (refer to Section 20.2.3) within the Contractor's Program Management Plan.
- 20.5.2.4. Subassembly drawings shall also be submitted for information to facilitate the review of assembly and installation drawings.
- 20.5.2.5. Drawings shall be accompanied by material specifications, process specifications, flammability and smoke emissions data, and test data required to permit review of the drawings. NYCT reserves the right to request additional information to support the review process.
- 20.5.2.6. When submitting drawings of structural parts or assemblies for the carbody structure, equipment supports, and trucks, the Contractor shall also submit, for review and approval, stress analyses for these parts or assemblies in summary form.
- 20.5.2.7. Other Contract deliverables including material samples, test plans, test procedures, and analyses as required by this Specification shall be submitted in the quantities specified.
- 20.5.2.8. Review of Contractor submittals shall be secured before manufacturing any parts, as indicated in the Submittal Review Plan. If the Contractor elects to proceed before securing review, it shall be at his own risk as defined in Section 20.5.2.20.

NYCT Review

- 20.5.2.9. Except as provided below, or as defined in the Submittal Review Plan, NYCT will review, disposition and return submittals, within 21 days after receipt by NYCT.
- 20.5.2.10. NYCT will disposition all manuals and catalogs identified in Section 22 within 60 days after receipt by NYCT.
- 20.5.2.11. NYCT will respond to the Contractor at an address within the United States, designated by the Contractor.
- 20.5.2.12. Not used.
- 20.5.2.13. An individual drawing shall be defined by the Contractor's unique drawing identification number.
- 20.5.2.14. In the event that more than 150 drawings are submitted for review in a 30-day period, NYCT will make every effort to review them within 30 days. If this is not possible, NYCT will review them in accordance with priorities as mutually agreed between the Contractor and NYCT.
- 20.5.2.15. As submitted by the Contractor, the drawings, documents, and data shall be accompanied by a letter of transmittal listing drawing and document titles, numbers, and revisions. If more than one drawing or document is submitted at a time, the drawings and documents shall be listed in the transmittal in numerical sequence.

- 20.5.2.16. No extension of Contract time will be allowed for revision of Contractor's drawings or documents that have been either "disapproved" or "approved with comments". Such drawings and documents shall be resubmitted, and will be reviewed and returned to the Contractor within the same time intervals as would be allotted to the drawings and documents when initially submitted.
- 20.5.2.17. Drawings shall be submitted in an orderly and logical sequence to enable NYCT to readily determine and review the interface relationships between all major structural elements and their subassemblies, and also between the structural elements and the attached apparatus, equipment, wiring, piping, and hardware.
- 20.5.2.18. The Contractor shall maintain a record of Contractor and subcontractor drawing and document status. This shall include drawing and document numbers, revision letter, drawing title, date submitted, transmittal document, disposition, and the document number identifying the disposition. This status shall be kept up to date and submitted to NYCT as part of the Monthly Progress Report (see Section 20.2.10).
- 20.5.2.19. All drawings, technical data, test procedures, test schedules, test results, test reports, progress schedules and reports, drawing lists, samples, and other data submitted by the Contractor and requiring review by NYCT will be handled in accordance with the above provisions.
- 20.5.2.20. Should the Contractor proceed without NYCT approval of submittals, it shall be at the Contractor's own risk.

NYCT Disposition of Drawings, Documentation, and Data

- 20.5.2.21. NYCT review will provide one of the following dispositions:
- a) Approved
 - i. "Approved" is defined as NYCT concurs with the information in its submitted form.
 - ii. Work shall be performed in accordance with the information submitted.
 - iii. Approval of a document, drawing, and data that contain deviations from, or violation of, the Specification does not constitute authority for that deviation or violation. Such deviations must be specifically requested and granted by NYCT (see Section 20.2.7).
 - iv. Approval does not relieve the Contractor of the obligation to meet all of the requirements of the Contract.
 - b) Approved With Comments
 - i. "Approved with Comments" is defined as NYCT conditionally agrees with the submitted information in principle, but some details must be changed as indicated by the comments.
 - ii. Work on the affected item may proceed concurrent with mitigation by the Contractor of the conditions for approval.
 - c) Disapproved

- i. "Disapproved" is defined as NYCT not accepting the submitted information. The Contractor shall revise and resubmit the document, drawing, or data for NYCT approval.
 - ii. Any work performed using disapproved design information shall be at the Contractor's own risk.
- d) Accepted for Information Only
- i. "Accepted for Information Only" is defined as NYCT acknowledging the receipt of the submittal and does not require the Contractor to revise the document, drawing, or data for NYCT approval.
 - ii. Work shall be performed in accordance with the information submitted.

Contractor Review

- 20.5.2.22. Except as provided below, or as defined in the Submittal Review Plan, the Contractor shall review, and return submittals to NYCT, within 21 days after receipt of comments from NYCT.
- 20.5.2.23. The Contractor shall disposition all manuals and catalogs identified in Section 22 within 60 days after receipt of comments from NYCT.

20.6. Mock-ups and Samples

20.6.1. Mock-ups

General Requirements for Mock-ups

- 20.6.1.1. Full-size mock-ups shall be constructed and furnished for the purpose of evaluating preliminary design work, spaces, accessibility, and the human interface. Mock-ups shall provide early identification of potential problem areas and development of alternative solutions.
- 20.6.1.2. Mock-ups shall be complete with regard to both exterior and interior details, and shall show the location and arrangement of all devices.
- 20.6.1.3. Mock-ups shall be constructed in phases. The mock-ups shall be available initially for review using simulated arrangements in place of unavailable equipment. The simulated arrangements shall be replaced as the pre-production and production equipment becomes available so that the mock-ups fully comply with the description in this Section.
- 20.6.1.4. Final mock-ups shall be dimensionally and functionally accurate. The construction technique shall permit modifications quickly, easily, and economically following NYCT's review.
- 20.6.1.5. Mock-ups shall be used to demonstrate Specification compliance, design practices, material selection, removal and replacement of components, and maintainability.
- 20.6.1.6. Mock-ups shall depict the following:
- a) Operator's cab.
 - b) A Car front end.
 - c) B Car end (A Car No. 2 end, B Car No. 1 and 2 end).
 - d) Passenger area.
 - e) Side doorway area.
 - f) Undercar equipment for A Car.
 - g) Undercar equipment for B Car.
 - h) Inter-car and Between-car barriers.

- 20.6.1.7. As an alternate to providing individual mock-ups, the Contractor may combine the Train Operator's cab, A Car front end, passenger area, side doorway area, inter-car barriers, and between-car barriers into one mock-up.
- 20.6.1.8. Selected mock-ups may be used as training aids. All mock-ups shall be kept up-to-date with all car design modifications.
- 20.6.1.9. Models as specified within Section 20.6.2 shall be furnished.

Cab End Mock-up

- 20.6.1.10. The Contractor shall construct a detailed, full-scale mock-up of the No. 1 End of the A Car, extending a minimum of 25 feet (7.6 m) from the face of the anti-climber. The mock-up shall include a fully detailed cab.
- 20.6.1.11. The mock-up shall be available before cab and interior arrangements are finalized.
- 20.6.1.12. The mock-up shall contain sufficient detail to enable NYCT to fully visualize and critique the final design concept and details.
- 20.6.1.13. The mock-up shall be complete with regard to both exterior and interior details, and shall show the location and arrangement of all devices including, but not limited to, the windshield, control console, Train Operator's Display (TOD), doors, lockers, partitions, windscreens, windshield demisters, windows, windshield wipers, information signs, sun visors, and seats.
- 20.6.1.14. Operable interior and exterior lighting, and air distribution systems shall be included.
- 20.6.1.15. Substitute materials, as approved by NYCT, may be used in construction of the mock-up provided that their use does not substantially alter the configuration of the intended full design.
- 20.6.1.16. The side door system included with the mock-up shall be complete, operable, accurate in all mechanical details, and representative of all the actual components.
- 20.6.1.17. The mock-up shall be inspected by NYCT at the Contractor's facility throughout its construction phases. NYCT comments generated during inspections shall be incorporated into the mock-up.
- 20.6.1.18. The Contractor shall demonstrate on the mock-up that, as a minimum, the following requirements are met before the represented designs are finalized, and prior to production:
 - a) General industrial design of represented portions of the interior are acceptable to NYCT.
 - b) Glare and reflections on the windshield have been minimized so that light sources inside and outside of the Unit do not obscure the Train Operator's vision through the windshield.
 - c) Indicators and displays are clearly legible and readable under all conditions including bright sunlight.
 - d) The cab equipment is functionally designed with all cutouts, bypass switches, and circuit breakers logically zoned and grouped. The maintainability aspects of all cab equipment should be thoroughly investigated and defined.
 - e) The cab console inclusive of the TOD, other displays, and controls normally available for Train Operator and Conductor's use shall be developed with proper consideration for function and ergonomics.
 - f) The windshield heater is operating properly.
 - g) The sun visors properly shade the Train Operator from bright sunlight without compromising safe visibility through the windshield or side windows.
 - h) Exterior lighting levels are compliant with Specification requirements.

- i) Destination signs are clearly legible on both bright, sunlit days and dark nights from 5 feet (1.5 m) above the car floor at a distance of 150 feet (45.7 m) from the sign surface for an angle of ± 50 degrees from a line perpendicular to the sign surface.
- j) The CCTV system is operating properly.

20.6.1.19. Unless otherwise specified, the mock-ups shall then be shipped to a location designated by NYCT within New York City and shall become the property of NYCT after delivery of the first Unit.

A Car Front End

20.6.1.20. The Contractor shall construct a full-size mock-up of the exterior of the No. 1 end of the A Car. The mock-up shall be constructed of the identical materials to be used on the production car. The mock-up will be used to evaluate the equipment arrangement and industrial design of the No. 1 end exterior.

20.6.1.21. The mock-up shall accurately depict the exterior features of the car including end windows, anti-climber, coupler, grab irons, inter-car barriers, lighting, end route sign, end door and door hardware, and color scheme.

20.6.1.22. The mock-up shall incorporate finalized inter-car and between-car barriers resulting from the development of these barriers per the requirements of Section 15.7.

20.6.1.23. The mock-ups shall be inspected and approved by NYCT before the represented designs are finalized and prior to production.

Passenger Area(s)

20.6.1.24. A full-size mock-up of the passenger area of the A Car shall be constructed to represent the area from the cab wall to the second set of side doors.

20.6.1.25. A full-size mock-up of the passenger area of the B Car shall be constructed to represent the area from the end wall to the second set of side doors.

20.6.1.26. These mock-ups shall be used to evaluate ergonomics, space utilization, accessibility for maintenance, and cleanability. Actual production materials shall be used in the construction of the passenger area model.

20.6.1.27. The Contractor shall place emphasis on the following design features:

- a) Seat layout and seat design.
- b) Standee area including stanchion and handhold placement.
- c) All interior linings including windscreens, end panels, cab wall, and electrical lockers.
- d) Lighting, air distributors, destination signs, information signs, strip displays and wall displays.
- e) Wheelchair parking area and seating for the disabled.
- f) Floor covering, side entrances, and thresholds.
- g) Doorways and door pocket panels.
- h) Window design and arrangement.
- i) Compliance with Americans with Disabilities Act of 1990 (ADA) requirements and usability of passenger area by passengers with disabilities.

20.6.1.28. Mock-ups shall be inspected and approved by NYCT before the design of the cab and passenger area is finalized and prior to production.

Side Doors

- 20.6.1.29. The Contractor shall construct a full-size mock-up of a side passenger door entrance including both door panels, door pockets, and any overhead transom panels that may cover door operators.
- 20.6.1.30. Production doors, hardware, and materials, including door pocket and access panels, door operators, and door control and threshold heaters, shall be used and shall functionally demonstrate compliance with the Specification requirements.
- 20.6.1.31. This mock-up shall be used to demonstrate door operation, obstruction detection, cycle times, closing forces, visual and audible door closing warnings, accessibility for maintenance, and threshold heater operation.
- 20.6.1.32. Upon completion, the mock-up may be used for the door accelerated life test.

Inter-car and Between-Car Barriers

- 20.6.1.33. Full-size mock-ups of the inter-car and between-car barriers shall be constructed. The materials used for all barrier models shall be production material and the models shall be fully functional. See Section 15.7.
- 20.6.1.34. The Contractor shall demonstrate the effectiveness, storage, and deployment of barriers.

Underfloor Equipment Arrangement

- 20.6.1.35. The Contractor shall construct full-size mock-ups of the underfloor equipment arrangement for each type of car. Actual undercar devices and materials shall be used. All subsystems, equipment boxes, components, wiring, raceways, conduit, piping hoses, trucks, and couplers shall be included.
- 20.6.1.36. Mock-ups shall demonstrate subsystem and component placements, methods of attachment, accessibility for removal and replacement of equipment and maintenance, equipment interfaces, and clearances at the trucks, couplers, other components, and structure.
- 20.6.1.37. If the Contractor desires, a single underfloor structure may be utilized and then fitted to represent each car type.

Mock-up Alternate Full-Scale 3D Digital Demonstration

- 20.6.1.38. As an alternative to some of the “physically” constructed full-scale mock-ups, the Contractor may alternatively propose mock-ups constructed with digitally accurate 3D design models. Acceptance of such an alternative will be at the sole discretion of NYCT.
- 20.6.1.39. Should NYCT accept this alternative, if proposed, the Contractor shall submit a detailed description and technical write up with illustrations, to be submitted for approval prior to commencement of work.

20.6.2. Models

- 20.6.2.1. The Contractor shall build two physical, durable scale models of a complete NYCT five-car Unit.
- 20.6.2.2. The models shall be built to one-fiftieth scale, shall accurately represent the appearance of the Unit, and shall be complete with a mounting base, clear plastic cover, and carrying case.
- 20.6.2.3. The completed models shall be delivered to NYCT at the same time as the first two-Unit test train is delivered.

20.6.3. Samples

- 20.6.3.1. Samples of all interior materials, passenger and Train Operator's seats, glazing, decorations, and signs shall be furnished during the design for NYCT evaluation and approval.
- 20.6.3.2. Samples shall be submitted for quality, color, and finish evaluation by NYCT, and shall be generally 10 inches (254 mm) by 10 inches (254 mm) in size.

- 20.6.3.3. An interior finish schedule, giving actual samples identified with the manufacturer's name and ordering reference for each material, shall be furnished before delivery of the first Unit.
- 20.6.3.4. Three sets of samples shall be provided. The samples are to be delivered during the in-process design review meetings and may be retained by NYCT.
- 20.6.3.5. Decorative items shall be mounted to a backing as necessary and assembled into binders.
- 20.6.3.6. Each sample shall include manufacturer name and contact information.

20.7. Prototype Cars

- 20.7.1. The first car of each type to be delivered to NYCT for qualification testing shall be designated as the Prototype Car.
- 20.7.2. The Prototype Cars shall be evaluated at every stage of construction and assembly to ensure compliance with the Contract prior to undertaking any work on the remaining cars to be manufactured.
- 20.7.3. NYCT will inspect the Prototype Cars at the following stages of completion, at a minimum:
 - a) Completed car shell, including all structure, but without the equipment, insulation or liners installed;
 - b) Car shell with floor insulation installed;
 - c) Completed water test;
 - d) Car shell equipped with wall and roof insulation, all interior wiring and piping in place and connected, side doors installed and operating, overhead air conditioning units in place and connected, car interior lighting installed, but without liners installed;
 - e) All liners installed, but without seats installed;
 - f) Train Operator's cab complete;
 - g) Underfloor equipment in place and connected; and
 - h) Fully assembled car, ready to operate in a Unit revenue service.

20.8. Component Serialization

- 20.8.1. The Contractor shall furnish a comprehensive Asset Identification System as specified in NYCT Specification 8023-GENL-01, "Asset Identification System NYCT Specification", see Appendix C-34. [CDRL]
 - 20.8.1.1. Duplicate serial numbers shall not be utilized within a type or model series. Reference Section 22.6.2 for identification requirements.

20.9. Car History Books

20.9.1. General Requirements

- 20.9.1.1. The Contractor shall provide NYCT with a car History Book, as a hard copy and in an NYCT approved electronic media, for each car at the time of acceptance.
- 20.9.1.2. The Car History Book shall provide a record of tests, measurements, analyses, and procedures performed on that specific car as well as the origin and identity of major components. As such, forms and records included in the book should contain signatures and certifications where appropriate.

- 20.9.1.3. Each car's history book shall accompany the car through manufacture and acceptance. The contents of the book shall be originals.
- 20.9.1.4. After acceptance of the car, the book and an up-to-date electronic version shall be submitted to NYCT within 2 weeks.
- 20.9.1.5. The books cover/binder and all external labels shall be waterproof. The cover/binding shall reasonably match the thickness of its contents. Pages must be arranged so that photocopies can be accomplished without compromising the integrity of the binding.

20.9.2. Contents

- 20.9.2.1. Each Car History Book shall contain the following information:
 - a) Title page with the name of the Program and Project Managers of the Contractor and NYCT, respectively.
 - b) Table of contents.
 - c) Signature key page with designated blocks for printed name, signature, company affiliation, and identification number (if any) for each person given authority to sign any certifications (test, measurements, releases, etc.) in the books.
 - d) Summary of tests and formal inspections. Summary of each test and formal inspection performed on the complete car or any part thereof with signatures where appropriate. This documentation shall include tests, measurements and inspections performed during manufacture, acceptance, and warranty. The summary shall include procedure number, code number (if any), location, date of inspection, date of completion, and remarks.
 - e) Subway car introduction fact sheet.
 - f) Truck test and inspection records.
 - g) Wheels, journal bearings, and gear mounting records (including pressing charts).
 - h) Carbody test and inspection records.
 - i) Car inspection records.
 - j) Certified weight, including scale tickets. Weights shall include independent weight of each equipped truck as well as the entire car.
 - k) Factory car test records.
 - l) Acceptance inspection and test records.
 - m) Master serial number listing. List of serial-numbered apparatus and their serial numbers.
 - n) Software configuration. List of software configuration of the car at the time of acceptance. The list shall include the name of the software, a brief description of the programs purpose (such as propulsion fault monitoring), the system(s) the software operates on/controls, the software author or provider, software version, and last revision date.
 - o) Description of modifications and completion dates of incorporation.
 - p) A record of any abnormalities that occurred during the manufacture of the car or its subsystems (including assemblies such as the truck or HVAC system, etc), including their authorized repair procedures and quality control approval of work performed.
 - q) List of defects noted during manufacture and testing and the disposition of each (including Non-Conformance Reports).
 - r) Details, Material Safety Data Sheets, and location on the car of any potentially hazardous material (which shall have been accepted by NYCT) that has been incorporated into the car.

- s) NYCT Release for Shipment Certificate and the Shipment Open Items List. The release for shipment certification shall include a clause stipulating that the NYCT resident engineer/inspector releasing the car has verified that all documentation in the Car History Book is complete, with affixed signatures and certificates, as required.
- t) List of Field Modification Instructions (FMI).
- u) Conditional Acceptance and Final Acceptance.
- v) Release for Service.

20.9.2.2. The acceptance (conditional) certification shall include a clause stipulating that the NYCT signatories accepting the car have verified that all documentation in the Car History Book is complete with affixed signatures and certifications, as required.

20.10. As Built Record Drawings

20.10.1. Timing and Scope

20.10.1.1. As-built drawings shall comply with NYCT Specification 8004-GENL-87, "Engineering Record Drawings", in Appendix C-35, and shall meet the requirements of Section 20.5.1.

20.10.1.2. The Contractor shall supply reproducible As-built Drawings for the following items no later than 18 months after delivery of the last Unit:

- a) All Contractor's and suppliers' drawings, details, bills of material, and catalog cuts that are required by NYCT for future installation, maintenance, and repair purposes.
- b) All electrical schematics, electronic circuits, and wiring diagrams.
- c) All pneumatic and air conditioning schematic piping diagrams.
- d) All interface control drawings down to all LRUs.
- e) All assemblies, subassemblies, and arrangements of the car.
- f) All items that are special purpose or fabricated by the Contractor, such as tooling.
- g) All materials furnished by the Contractor and its suppliers, down to and including the module and circuit board level. In every case, outline drawings shall not be considered acceptable.

20.10.1.3. The Contractor shall provide NYCT with a complete list of reproducible drawings to be supplied by itself, each of its subcontractors and suppliers. [CDRL]

20.10.2. Format and Content

20.10.2.1. All information required by Section 20.10.1 shall also be supplied in a single electronic format usable by NYCT. The electronic format shall be same as the one used in Section 20.5.1.1.

20.10.2.2. Transparencies of each drawing shall also be produced on clear polyester film. The printing shall be on the back face and a matte surface shall be provided on the front or both faces. Printing shall be black and of "wash-off" consistency. Reproductions shall be the same size as the original drawings.

20.10.2.3. In the processing of the reproducible versions of the Contractor's Drawings, the Contractor's title block shall be obliterated or, as a minimum, reduced to 1/4 scale and located on the lower left hand corner of the drawing.

20.10.2.4. The drawing number and the drawing title shall be incorporated in NYCT's title block for identification purposes. The Bill of Material shall be left on the reproducible.

20.10.2.5. The title block change applies only to the Contractor's drawings and does not apply to subcontractor drawings of proprietary equipment such as motors, control components, or brake components.

- 20.10.2.6. The drawings shall include all revisions made during construction and be in as-built configuration.
- 20.10.2.7. Any subcontractor record drawings not produced in an electronic version shall be converted by the Contractor to the approved electronic form and submitted in accordance with the requirements above.

20.10.3. Material Identification Lists

- 20.10.3.1. Reproducible Material Identification Lists including a Contractor Number, a supplier number, and provision for NYCT's Commodity Number shall also be furnished by the Contractor in a single format. **[CDRL]**
- 20.10.3.2. These data shall provide NYCT with all the information required for procurement of materials used in the construction of all parts of the car.
- 20.10.3.3. These lists shall take the form of reproducible Bills of Materials suitable for loose-leaf binding and shall be cross-referenced to the related drawings and the Bill of Materials.

20.11. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
20-1	20.2.2.1	Program Management Plan	30 days after NTP, monthly updates
20-2	20.2.3.1	Submittal Review Plan	45 days after NTP
20-3	20.2.5.1	Master Program Schedule	21 days after NTP
20-4	20.2.10.1	Monthly progress report	Monthly
20-5	20.3.3.1	Comprehensive weight control program document	60 days after NTP
20-6	20.4.2.1	System Functional Description for the Unit	Start of PDR
20-7	20.4.8.1	Master drawing tree and list of drawings	Start of PDR
20-8	20.4.8.3	Schedule for submittal of drawings, documentation, and data	PDR
20-9	20.8.1	Comprehensive Asset Identification System	CDR
20-10	20.10.1.3	List of As-Built drawings	Delivery of last Unit
20-11	20.10.3.1	Reproducible Material Identification Lists	Delivery of last Unit

Attachment 20-1. Drawings and Documents to be submitted for NYCT Approval

Spec Ref	Content
2	DESIGN AND PERFORMANCE DOCUMENTS
	<ul style="list-style-type: none"> Weight analysis
	<p>General Arrangement drawings of A and B Cars, including:</p> <ul style="list-style-type: none"> Exterior elevations of both sides Exterior elevations of both ends Floor plan Reflected ceiling plan Roof plan Interior, longitudinal sections of both sides Interior elevations of both ends Reflected plan, undercar equipment layout Reflected plan, conduit, and cable layouts Reflected plan, piping layout Side elevation, undercar equipment layout Relation of ends of cars on curves, and showing vertical and horizontal drawbar swings both static and dynamic Carbody and wayside clearance drawings
	<p>Section views, including:</p> <ul style="list-style-type: none"> Transverse sections to show all variations in cross section such as through doors and windows, roof, etc. Transverse section to show extreme movements of car (including yaw) permitted by suspension and running gear Transverse and longitudinal sections to show physical relationship of major undercar components Transverse sections to show vertical and lateral undercar equipment clearances to rail and roadbed
	<ul style="list-style-type: none"> Interface control Drawings detailing all interfaces, electrical and mechanical; for all components from train/wayside to LRU
3	CARBODY STRUCTURE
	<p>Framing and Miscellaneous Drawings, including:</p> <ul style="list-style-type: none"> Underframe and bolster - plan, elevations, and sections Anti-climbers - plan, elevations, and sections Side frame(s) - plan, elevations, and sections Roof frame - plan, elevations, and sections End frame - plan, elevations, and sections Coupler and drawbar attachment to underframe - plan, elevations, and sections

Spec Ref	Content
	<ul style="list-style-type: none"> • Carbody structural analysis
	<ul style="list-style-type: none"> • Crash Energy Management (CEM) Energy absorption analyses
4	COUPLER AND LINK BAR
	<ul style="list-style-type: none"> • Plan, elevations
	<ul style="list-style-type: none"> • Pneumatic, mechanical, and electrical details (coupler only)
5	CAB AND CAB CONTROLS
	<ul style="list-style-type: none"> • Plan layout, cab equipment
	<ul style="list-style-type: none"> • Layout of cab console
	<ul style="list-style-type: none"> • Interior elevations of cab layout
6	SIDE DOORS
	<ul style="list-style-type: none"> • Plan, elevations, sections
	<ul style="list-style-type: none"> • Hardware and attaching details
7	HVAC
	Air Conditioning Unit: <ul style="list-style-type: none"> • Plan, elevations • Installation details • Electrical and piping schematics • Assembly details
	<ul style="list-style-type: none"> • Overall HVAC system design details
	<ul style="list-style-type: none"> • Floor heating arrangement and details
	<ul style="list-style-type: none"> • Ducting details
8	LIGHTING
	<ul style="list-style-type: none"> • Location
	<ul style="list-style-type: none"> • Assembly and installation Detail

Spec Ref	Content
9	AUXILIARY ELECTRICAL
	<p>Auxiliary Electric Equipment:</p> <ul style="list-style-type: none"> • Auxiliary power supply - assembly and installation details • Low voltage power supply - assembly and installation details • Battery - assembly and installation details • Circuit breaker panels - details • Main Switch (knife switch) - assembly and installation details • High speed circuit breaker - assembly and installation details
	<p>Electrical Drawings:</p> <ul style="list-style-type: none"> • Schematic wiring diagram - nominal 600 Vdc equipment • Schematic wiring diagram - nominal 37.5 Vdc equipment • Schematic wiring diagrams – 3-phase AC (i.e. – 230 Vac)
	<ul style="list-style-type: none"> • Grounding scheme
	<p>Auxiliary Electrical System Technical Data:</p> <ul style="list-style-type: none"> • Operating characteristics of auxiliary system power supply components • Low-voltage power supply/battery charger operating characteristics • Battery discharge curves and charging requirements • Tabulation of all low voltage dc loads, giving: <ul style="list-style-type: none"> – Maximum and average current – Circuit breaker ratings – Continuous or intermittent load
10	PROPULSION SYSTEM
	<p>Propulsion Equipment:</p> <ul style="list-style-type: none"> • Inverters - details • Controls - details • Assembly and installation details

Spec Ref	Content		
	<p>Master Controller:</p> <ul style="list-style-type: none"> • Plan and location • Assembly and installation details 		
	<p>Propulsion System Technical Data:</p> <ul style="list-style-type: none"> • Capability curves of tractive effort versus command signal and speed for both acceleration and dynamic braking mode • Single line diagram of power circuits and functional diagrams of the control loop including input and output signals • Number and connection of power semiconductors used in propulsion circuits together with current and voltage rating of each • Propulsion system estimated energy consumption • Propulsion motor characteristics based on performance criteria, specified wheel size, and offered gear ratio, showing motor voltage, speed, and efficiency versus motor current for both propulsion and braking modes • Typical cross section of traction motor • Typical cross section of gear drive units • Detail of coupling and mounting interface between gearbox and traction motor • Anticipated resilient characteristics, including natural frequency of gear and motor unit suspension 		
11	TRUCKS		
	<p>Framing and Miscellaneous Drawings, including:</p> <table style="width: 100%; border: none;"> <tr> <td style="vertical-align: top; width: 50%;"> <ul style="list-style-type: none"> • Truck assembly - plan and elevations and equipment application • Truck frame - details • Bolster - details • Suspension - details • Wheels - details • Axle - details </td> <td style="vertical-align: top; width: 50%;"> <ul style="list-style-type: none"> • Journal bearings – details • Gear units - assembly • Axle assembly - complete • Brake equipment - details • Traction motors - details • Speed sensors - details • Ground brushes – details </td> </tr> </table>	<ul style="list-style-type: none"> • Truck assembly - plan and elevations and equipment application • Truck frame - details • Bolster - details • Suspension - details • Wheels - details • Axle - details 	<ul style="list-style-type: none"> • Journal bearings – details • Gear units - assembly • Axle assembly - complete • Brake equipment - details • Traction motors - details • Speed sensors - details • Ground brushes – details
<ul style="list-style-type: none"> • Truck assembly - plan and elevations and equipment application • Truck frame - details • Bolster - details • Suspension - details • Wheels - details • Axle - details 	<ul style="list-style-type: none"> • Journal bearings – details • Gear units - assembly • Axle assembly - complete • Brake equipment - details • Traction motors - details • Speed sensors - details • Ground brushes – details 		
	<ul style="list-style-type: none"> • Truck structural analysis, including static and fatigue 		

Spec Ref	Content
	<p>Truck Technical Data:</p> <ul style="list-style-type: none"> • Drawings identifying all welds and relation of welded seams to the neutral axes of the weldment. • Quality control procedure outlining the proposed methods of assuring the structural integrity of truck frame members, with particular attention to critical sections, inspection and repair of defects • List of all car body motion limits in relation to the truck. • Suspension data shall be provided as follows: <ul style="list-style-type: none"> – Type of primary and main suspension – Manufacturer of air spring – Damping constant of each shock absorber – Spring constant of body suspension (expressed as a curve, if not linear), vertical, lateral (at working height) with ends of springs maintained parallel – Relationship of air spring pressure to vertical force at constant height and also at various heights – No load and maximum load air spring pressures – Total air spring volume; including auxiliary reservoir volume – Air spring damping orifice size and damping rates, vertical and roll for trucks – Air supply requirements – Vertical spring constants or load-deflection curves of all resilient truck components other than the body suspension system – Roll stabilizer arrangement and parameters • Material specifications and static and dynamic design stress levels of truck frame components, axles and springs • Preliminary detail drawings and material specifications for: <ul style="list-style-type: none"> – Axles – Wheels – Hydraulic shock absorbers – Elastomeric journal bearing support – Vertical stop assembly

Spec Ref	Content
12	BRAKE SYSTEM
	Brake System: <ul style="list-style-type: none"> • Air supply unit - assembly and installation details • Pneumatic control units - assembly and installation details • Electronic control units - assembly and installation details • Other brake hardware – details • Monitoring system – details
	Pneumatic Diagram: <ul style="list-style-type: none"> • Schematic piping diagram - air brake equipment • Schematic piping diagram - coupler control equipment
	Friction Brake System Technical Data: <ul style="list-style-type: none"> • Capability curve of tractive effort versus command signal and speed • Functional diagram showing control loop and values of all input and output signals • Curves of operating pressures versus torque for full operating speed range • Tabulation of all electrical loads, giving both maximum instantaneous and average demand • Documentation of safety analyses required in Section 21.3 • System flow diagram if applicable, showing functional arrangement of all valves, reservoirs, adjustment points, and operating units • Typical cross section and details of a tread brake unit including mounting details • Description of friction material proposed together with experience data from comparable applications
13	COMMUNICATIONS SYSTEM
	<ul style="list-style-type: none"> • Communications system functional description
	<ul style="list-style-type: none"> • CCTV system description
14	SIGNALING AND TRAIN CONTROL
	<ul style="list-style-type: none"> • CBTC integration plans

Spec Ref	Content
15	CARBODY EQUIPMENT
	Equipment Boxes, Compartments and Lockers: <ul style="list-style-type: none"> • Plan, elevation, and sections • Hardware details
	Seating: <ul style="list-style-type: none"> • Plan, elevations, and sections • Attaching details and stanchions • Wheelchair area plan, elevation, and sections
	Stanchions and Handrails: <ul style="list-style-type: none"> • Plan, elevations, and details
	Interior Lining Panels, Bulkheads and Windscreens: <ul style="list-style-type: none"> • Plan, elevations, and sections • Attaching details
	Sub-Floor and Finished Floor: <ul style="list-style-type: none"> • Plan, elevations, and sections • Attaching details
16	NETWORKS AND TRAINLINES
	<ul style="list-style-type: none"> • Network functional description • Trainline and Unitline allocation
17	MONITORING AND DIAGNOSTIC SYSTEM
	<ul style="list-style-type: none"> • MDS functional description and design details • TOD functional description and installation drawings • TOD menus • Event recorder functional description and design details

Spec Ref	Content
21	RELIABILITY, MAINTAINABILITY, AND SYSTEM ASSURANCE
	<ul style="list-style-type: none"> • System Safety program
	<ul style="list-style-type: none"> • Failure Mode and Effects Criticality Analysis (FMECA)
	<ul style="list-style-type: none"> • Maintainability and reliability analyses
22	TEST EQUIPMENT
	<ul style="list-style-type: none"> • Hardware drawings
	<ul style="list-style-type: none"> • Equipment lay-out diagrams
	<ul style="list-style-type: none"> • Electrical and pneumatic schematics (for non-printed circuit (PC)-based test equipment)
	<ul style="list-style-type: none"> • Mounting schematics
OTHER DOCUMENTS	
	<ul style="list-style-type: none"> • Test and inspection (QA/QC) plans
	<ul style="list-style-type: none"> • All test procedures and reports
	<ul style="list-style-type: none"> • Welding and brazing procedures
	<ul style="list-style-type: none"> • Independent laboratory test reports for all combustible materials
	<ul style="list-style-type: none"> • Flammability matrix
	<ul style="list-style-type: none"> • Flammability and Smoke Emission Data for all combustible materials in accordance with Section 19.1.10.
	<ul style="list-style-type: none"> • Material Safety Data Sheets (MSDSs)
	<ul style="list-style-type: none"> • LRU and LLRU description lists

Section 21

**Reliability, Maintainability, and
System Assurance**

Contents

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21. Reliability, Maintainability and System Assurance

21.1. Reliability

21.1.1. General

- 21.1.1.1. This section defines the requirements for Reliability, Maintainability, and System Assurance of the R211 cars.
- 21.1.1.2. The R211 shall be designed to provide a high degree of reliability and durability, and to minimize downtime during preventive and corrective maintenance activities, including troubleshooting and fault isolation.
- 21.1.1.3. The design shall ensure that the R211 trains, Units, cars, and systems and subsystems perform their designated functions in accordance with this Specification.
- 21.1.1.4. As indicated by the reliability performance goals in Section 21.1.2.1, the primary focus of the reliability design shall be to keep the train operating in service. Failures which result in a delay to service shall be kept to an absolute minimum.
- 21.1.1.5. Failures which require intervention by the Train Crew to restore the train to an operational revenue service condition shall be correctable within 4 minutes, following NYCT’s standard operating practices.

21.1.2. Reliability Requirements

Performance Requirements

- 21.1.2.1. The Contractor shall furnish equipment that meets the car level Mean Distance Between System Component Failure (MDBSCF), Mean Distance Between Failure (MDBF), and Mean Distance Between Service Failure (MDBSF) requirements defined below, considering all failure modes for components, assemblies, subsystems, and system elements.

MDBSCF	= 10,000 miles (16,094 km)
MDBF	= 150,000 miles (241,402 km)
MDBSF	= 250,000 miles (402,336 km)

- 21.1.2.2. The furnished equipment shall achieve the MDBSCF values listed in Table 21-1 for critical subsystems within the reliability requirements for the overall car.

Table 21-1 – MDBSCF Requirements for Critical Subsystems

System	MDBSCF (miles)	MDBSCF (km)
Propulsion System	50,000	80,468
Auxiliary Electrical System	120,000	193,122
Heating, Ventilation, and Air Conditioning System	100,000	160,935
Door System and Controls	100,000	160,935
Friction Braking and Air Supply System	60,000	96,561

System	MDBSCF (miles)	MDBSCF (km)
Communication Systems (including Signs, CCTV, OPTO related system)	100,000	160,935
Trainlines and Networks	300,000	482,804

21.1.2.3. The terms Mean Distance Between Component Failure, Train Delay, and Service Failure shall be based on the MDBF Measurement Period (as defined in Section 1.7.1).

Definitions

21.1.2.4. Mean Distance Between System Component Failure (MDBSCF): The MDBSCF of a system is the ratio of the total operating distance accumulated by the total population of cars in the class to the total number of relevant failures occurring for that population of components within each specified system of the cars in the class, during the time period, 't'.

21.1.2.5. Mean Distance Between Failure (MDBF): The MDBF of a car class is the ratio of the total operating distance accumulated by the total population of the cars in the class to the total number of relevant train delays (as defined in Section 1.7.1).

21.1.2.6. Mean Distance Between Service Failure (MDBSF): The MDBSF of a car class is the ratio of the total operating distance accumulated by the total population of the cars in the class to the total number of relevant failures which cause a train to be removed from service (as defined in Section 1.7.1).

21.1.2.7. Relevant Failure: A relevant failure is an independent failure that results in a temporary or permanent loss of function of that item caused by either of the following:

- a) A fault in a component while operating within its design and environmental specification limits.
- b) Improper operation, maintenance or testing of a component as a result of Contractor-supplied documentation.

21.1.2.8. For calculating the above reliability parameters, a chargeable failure shall be defined as any relevant failure that requires repair or replacement of any subsystem or vehicle component, including intermittent failures, unverified failures and software failures. Failures to be excluded are:

- a) Consumable items, except those which are not achieving their design life expectancies.
- b) Secondary failure occurrence in equipment of another subsystem, caused by the primary failure.
- c) Failure caused by wayside equipment such as CBTC, Platform-edge CCTV, Platform Screen doors.
- d) Failure of NYCT to perform the recommended preventive maintenance actions.
- e) Failure caused by operating the item outside of design or environmental specification limits.
- f) Vandalism or physical mistreatment at a human interface.
- g) Operating or weather conditions of "unusual aspect or severity" beyond those noted in Section 2.5.1.
- h) Due to an accident.

- 21.1.2.9. The term "unusual aspect or severity" shall be understood to mean a condition that does not occur on NYCT "rail lines" more often than once in 10 years. The time, place, or type of service in which the car was being operated at the time of a failure shall not be of any consequence.
- 21.1.2.10. In addition to compliance with the reliability requirements provided in this section, the Contractor shall comply with the fleet defect requirements of Article 910 of the Contract Terms and Conditions.
- 21.1.2.11. The Contractor shall monitor the reliability data throughout the warranty period.

21.1.3. Reliability Predictions

- 21.1.3.1. The Contractor shall submit a reliability prediction summary report for all car systems, which demonstrates that the specified car-level MDBSCF, MDBF, and MDSF requirements will be achieved [CDRL].
- 21.1.3.2. The calculation shall be based on the annual average operating distance as specified in Section 2.1.5.
- 21.1.3.3. The reliability prediction shall use the Part Stress Method of MIL-HDBK-217F for the "ground mobile" environment.
- 21.1.3.4. Use of alternative reliability database information may be permitted for parts that have statistically meaningful historical failure rate data, subject to NYCT approval.
- 21.1.3.5. The reliability prediction summary report shall be maintained and updated through the entire design, testing, manufacturing, delivery, and warranty periods.
- 21.1.3.6. The Contractor shall submit the reliability prediction updates to NYCT for review and acceptance on a quarterly basis, or as requested by NYCT, as the project progresses. Updates shall report on design or manufacturing changes, or problems that may affect vehicle reliability. [CDRL]

21.1.4. Reliability Program Plan

- 21.1.4.1. The Reliability Program Plan shall address, to NYCT's satisfaction, applicable elements of MIL-STD-785 B "Reliability Program for Systems and Equipment Development and Production". In addition, the Program Plan shall address:
- a) Reliability program objectives.
 - b) Reliability program schedule, which identifies specific tasks, with start and completion dates, and explains how these tasks are coordinated and integrated with major program milestones for design, manufacturing, and testing.
 - c) Methodology whereby the Contractor shall predict compliance with the reliability requirements specified in Section 21.1.2.
 - d) Reliability allocation for systems, subsystems, car, Unit, and train.
 - e) Reliability modeling and prediction process for systems, subsystems, car, Unit, and train, including part derating and thermal reliability.
 - f) Reliability development/growth testing.
 - g) Organization of personnel responsible for managing the reliability program.
 - h) Controls for activities of subcontractors and equipment suppliers to assure their compliance with reliability program methods and objectives.
 - i) Description of the Failure Review Board (FRB) process to comply with Section 21.1.6.

- j) Description of the Failure Reporting, Analysis and Corrective Action System (FRACAS) process to comply with Section 21.1.7.
 - k) Demonstration testing plans for verification of compliance with reliability requirements specified in Section 21.1.2 when calculations and analyses are inconclusive, or when past performance records are incomplete or unavailable.
- 21.1.4.2. The Contractor's Reliability Program Plan shall be submitted for NYCT approval, and shall be updated at the time of Critical Design Review (CDR), and at other times when there is a change to the plan. [CDRL]
- 21.1.4.3. Reliability progress reporting, which details implementation of the approved reliability program, shall be submitted to NYCT on a monthly basis.
- 21.1.4.4. This report shall cover the previous month's activities and shall summarize the reliability predictions during the design phase, and the observed reliability during the reliability demonstration testing phase.

21.1.5. Reliability Demonstration Plan

Plan Requirement

- 21.1.5.1. The Contractor shall submit a Reliability Demonstration Plan for NYCT approval. [CDRL]
- 21.1.5.2. The reliability demonstration plan shall address the following to illustrate compliance with the specified MDBSCF, MDBF, and MDBSF requirements:
- a) Reliability demonstration schedule (excluding Unit delivery and burn-in time).
 - b) Reliability demonstration procedures and forms for recording and submitting data.
 - c) Success-failure criteria for measuring MDBSCF, MDBF, and MDBSF values for individual equipment items, subsystems and vehicle.
 - d) Process for addressing non-compliant reliability by design modifications.
 - e) Change control procedures for implementing design changes.
 - f) Reliability demonstration report format and content.

Reliability Demonstration Period

- 21.1.5.3. The reliability demonstration shall occur during the MDBF Demonstration Period.
- 21.1.5.4. Relevant failures which occur during the first 60 calendar days from the date a Unit is placed in revenue service will not be included in the reliability demonstration, nor will the miles accumulated by the Operating Unit during this 60-day burn in period be included in the reliability demonstration. The 60-day burn in period does not apply to the first two Units.
- 21.1.5.5. If, during and at the end of the warranty period, NYCT is unable to substantiate that the equipment has met the reliability requirements, the Contractor shall make and implement any design changes and/or modifications, repairs, adjustments and replacements on all Cars and Operating Units as needed to achieve required reliability without cost to NYCT.
- 21.1.5.6. The Contractor shall furnish onsite, for the entire warranty period, a qualified Reliability Engineer to oversee associated activities. The Contractor's proposed Reliability Engineer shall be subject to NYCT approval.

Corrective Actions

- 21.1.5.7. Within 10 business days following notification of a deficiency, the Contractor shall identify the cause of the deficiency and prepare recommendations for corrective action.

- 21.1.5.8. After NYCT approval of the corrective action, the Contractor shall implement the recommendations within 30 business days, unless otherwise approved by NYCT.
- 21.1.5.9. The Contractor shall bear all costs associated with the redesign effort, including vehicle modifications and associated costs.
- 21.1.5.10. The corrective actions shall be incorporated in undelivered cars prior to delivery, all cars that are out of warranty, and in spare parts.

21.1.6. Failure Review Board

- 21.1.6.1. A Failure Review Board (FRB) shall be established to determine the relevancy of failures, review failure trends, determine the need for and the depth of root cause failure analyses, and ensure that adequate corrective actions are taken in a timely manner utilizing the FRACAS process described in Section 21.1.7.
- 21.1.6.2. The activities of the FRB shall begin with the factory acceptance test and conclude at the end of the warranty associated with the item failed or any extension thereof.
- 21.1.6.3. The core members of the FRB shall include the Contractor's Reliability Engineer, Warranty Manager, and NYCT assigned Reliability and Warranty representatives. Other members from NYCT, Contractor, and Subcontractors shall participate, as necessary, to facilitate thorough review of failure data.
- 21.1.6.4. All equipment failures that occur during the warranty period shall be classified as relevant or non-relevant failures by the FRB.
- 21.1.6.5. The FRB shall analyze all failures, whether occurring in revenue service or not, and shall classify relevant failures into train delay, service, safety-critical, and/or a component failure. This classification shall then be used for reliability calculations.
- 21.1.6.6. If the FRB is unable to reach consensus on the relevancy or categorization of failures or any other disputes within the purview of FRB, NYCT's Project Manager shall be notified of the issue. The Project Manager will review the issue and formally communicate NYCT's position to the Contractor.
- 21.1.6.7. The Contractor shall maintain a database of all failures (both relevant and non-relevant) reviewed by FRB and shall provide to NYCT in approved electronic format with the monthly Reliability Demonstration Report [CDRL].
- 21.1.6.8. NYCT reserves the right to specify the frequency of FRB meetings.

21.1.7. Failure Reporting, Analysis and Corrective Action System

- 21.1.7.1. The Contractor shall establish a FRACAS process in accordance with MIL-STD-2155.
- 21.1.7.2. The FRACAS shall be a closed-loop system that collects, analyzes, and records all relevant failures; analyzes to the Lowest Level Replaceable Unit (LLRU) level to determine cause; and provides documentation for recording corrective action taken.
- 21.1.7.3. The FRACAS shall commence at the start of factory acceptance testing of the first car and continue through the completion of reliability demonstration period.
- 21.1.7.4. The Contractor shall submit a Failure Analysis Report (FAR) to NYCT for each failure occurrence within 30 days of each incident. The FAR shall identify the Unit and car affected, equipment and cause(s) of failure, and shall indicate what corrective action is necessary, and the extent of such action.

- 21.1.7.5. The Contractor shall maintain an electronic FRACAS database and provide analysis of FRACAS data to identify failure trends and fleet defects.
- 21.1.7.6. The FRACAS database shall have a status of the FAR associated with each incident.
- 21.1.7.7. FRACAS data shall be submitted to NYCT with the monthly Reliability Demonstration Report and as requested by NYCT. [CDRL]
- 21.1.7.8. The Contractor's failure data evaluation shall promptly identify every failure trend and determine its cause. A failure trend is defined by failure within a 90-day reporting period of three or more identical components or functions employed in identical or equivalent applications, where the failures are caused by the same failure mechanism.
- 21.1.7.9. With NYCT approval, the Contractor shall implement corrective or preventive action for each such trend. The Contractor shall summarize these findings and actions in the monthly Reliability Demonstration Report. [CDRL]
- 21.1.7.10. The FRACAS data shall include the failure rates of components that have a failure ratio equal to half that for declaring a Fleet Defect as per Section 21.1.2.10 and Article 910 of the Contract Terms and Conditions.

21.2. Maintainability

21.2.1. General

- 21.2.1.1. The vehicle shall incorporate designs that reduce maintenance, substantially improving service intervals and component replacement beyond those described within NYCT's document entitled "SMS Generic Car Workscope and Time Intervals" (see Appendix C-36).
- 21.2.1.2. The designs shall also minimize Mean Time to Repair (MTTR), including all access time and costs throughout the design life.
- 21.2.1.3. The objectives of the maintainability program, including corrective and preventive maintenance, shall provide for:
 - a) Enhancement of vehicle availability.
 - b) Minimization of maintenance costs.
 - c) Minimization of vehicle downtime.
- 21.2.1.4. Specific maintainability design requirements are contained in Section 2.14.4.

21.2.2. Maintainability Requirements

- 21.2.2.1. The Contractor shall provide estimates of the MTTR for preventive and corrective maintenance tasks for all major subsystems to NYCT's review and approval. [CDRL]
- 21.2.2.2. Estimates shall be updated whenever a design change affects MTTR.
- 21.2.2.3. Compliance with the MTTR requirements shall be illustrated during the Maintainability Demonstration required within Section 21.2.4.

21.2.3. Maintenance Plan

- 21.2.3.1. The Contractor's maintainability program shall include submittal of a detailed Maintenance Plan outlining all schedules and activities for vehicle corrective and preventive maintenance. [CDRL]
- 21.2.3.2. The Maintenance Plan, along with the proposed Maintenance Manuals and associated drawings, shall be included in the Master Program Schedule (refer to Section 20.2.5).

- 21.2.3.3. The Maintenance Plan shall outline each maintenance task, time schedules, recommended tools, personnel, and skill levels required.
- 21.2.3.4. Maintenance recommendations shall be based upon those of the Contractor and of the equipment suppliers.
- 21.2.3.5. The Maintenance Plan shall be coordinated with, and shall agree with, the Maintenance Manuals.

21.2.4. Maintainability Demonstrations

Demonstration at Equipment First Article Inspections

- 21.2.4.1. Each equipment First Article Inspection (FAI) shall include evaluations and demonstrations of maintainability.
- 21.2.4.2. Maintainability demonstrations at equipment FAI shall be video recorded and the recording submitted as part of the meeting minutes. [CDRL] (See Section 22.5.5.9)

Car Level Demonstration

- 21.2.4.3. At the car level, a formal demonstration shall be performed based on MIL-STD-471 with a minimum sample size of one Unit.
- 21.2.4.4. Actions necessary to enable train movement under disabling conditions shall also be demonstrated (Sections 22.3.3 and 22.3.5).

General Requirements

- 21.2.4.5. The Contractor shall submit a Maintainability Demonstration Plan for NYCT approval. [CDRL]
- 21.2.4.6. As part of the training program for maintenance personnel, selected servicing, preventive maintenance (Section 21.2.5), troubleshooting, change-out of components, corrective maintenance, and use of special tools shall be demonstrated where special emphasis, instruction, or proficiency is needed.
- 21.2.4.7. The procedures used in the demonstration shall be the same as those within the manuals delivered per Section 22.3.
- 21.2.4.8. The formal maintainability demonstration shall use production Units on NYCT property, which shall be documented by video recordings and shall be submitted to NYCT for review and approval as part of the training aids (see Section 22.5.5). [CDRL]

21.2.5. Preventive Maintenance

- 21.2.5.1. Preventive maintenance shall comprise the tasks that are performed to defer or prevent an anticipated failure occurrence and to manage conditions of wear.
- 21.2.5.2. All preventive maintenance tasks, as defined in the Maintenance Manual, shall have fewer activities and greater intervals than the NYCT standard minimum maintenance interval (see "SMS Generic Car Workscope and Time Intervals" document in Appendix C-36).

21.3. System Assurance

21.3.1. General

- 21.3.1.1. The cars shall be designed and constructed to be safe to passengers, persons near the cars, and employees, both under normal operating conditions and in the event of equipment failure.
- 21.3.1.2. The Contractor shall ensure that all safety aspects are considered for all individual systems and subsystems, and for integrated systems (i.e., brakes and propulsion) to complete the car design.

- 21.3.1.3. Conflicts between performance and safety requirements will be addressed on a case-by-case basis. The guidelines for resolution of conflicts will be as follows:
- a) Applications that, in accordance with the requirements of this section, are determined to have a significant impact on passenger safety, shall conform to applicable safety requirements defined in this Specification. Requirements for other material characteristics or properties shall conform to that of materials typically used for the application that are available at the time of award of Contract. Typical examples of this application are materials used in the interior of the car body.
 - b) Applications that do not meet the criteria described in the previous paragraph will require conformance to all operational, performance, service, and maintenance requirements of this Specification.
- 21.3.1.4. All equipment shall comply with applicable codes, standards, and regulations cited in Section 21.3.1.5 and elsewhere in this Specification.
- 21.3.1.5. All equipment shall comply with applicable local, state, and federal rules and regulations. These include, but are not limited to:
- a) Military Standard, MIL-STD-882 E: "System Safety Program Requirements." (U.S. Department of Defense).
 - b) National Fire Protection Association (NFPA) 130 – "Standard for Fixed Guideway Transit and Passenger Rail Systems, 2014 Edition".
 - c) American Public Transportation Association (APTA)'s PS-RP-005-00, "Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment."
 - d) Institute of Electrical and Electronics Engineers (IEEE) Standard 1483-2000, "IEEE Standard for the Verification of Safety for Processor-Based Systems Used in Rail Transit Control".
 - e) 49 Code of Federal Regulations (CFR) 238.105, "Train Electronic Hardware and Software Safety".
 - f) Federal Transit Administration (FTA)'s "Handbook for Transit Safety and Security Certification, FTA MA-90-5006-02-01, Final Report, November 2002".
 - g) NYCT's System Safety Assurance Plan.

21.3.2. System Safety Program Plan

- 21.3.2.1. Contractor shall develop, implement, and maintain a comprehensive System Safety Program Plan (SSPP) conforming to the guidelines and requirements of MIL-STD-882 E, Section 4, all tasks within MIL-STD-882 E, Sections 100 and 200, and NYCT's System Safety Assurance Plan. The SSPP shall be submitted for NYCT approval. [CDRL]
- 21.3.2.2. The SSPP shall document the system safety methodology for the identification, classification, and mitigation of all vehicle hazards and shall impose design requirements and management controls, which prevent mishaps by eliminating hazards or reducing risk to levels acceptable to NYCT.
- 21.3.2.3. The SSPP shall be developed in the earliest phases of the Contract and shall be continuously maintained throughout as design and construction evolves.
- 21.3.2.4. Safety requirements, defined in this section and elsewhere in this Specification, shall be incorporated into the SSPP and the Contractor's designs.

- 21.3.2.5. Specific portions of MIL-STD-882E are referenced herein. These references shall not be construed as limiting the applicability of any portions of MIL-STD-882E, whether referenced or not. Requirements may be waived or amended only where approved by NYCT.
- 21.3.2.6. Formats for reports, listings, analyses, and other required submittals shall be jointly determined between NYCT and the Contractor.
- 21.3.2.7. The term Program Manager appearing within MIL-STD-882E shall be interpreted as meaning NYCT. The Contractor is solely responsible for development of the SSPP.
- 21.3.2.8. The term Government Furnished Equipment (GFE) appearing within MIL-STD-882E shall be interpreted to mean NYCT-furnished equipment.

21.3.3. Hazard Identification

- 21.3.3.1. The Contractor shall identify all failure-induced and normal operating (non-failure condition) hazards falling into severity Categories I, II, III and IV. Hazards shall be compiled into a Preliminary Hazard List (PHL) and submitted for approval to NYCT. [CDRL]
- 21.3.3.2. In addition to those hazards identified by the Contractor, the following hazards shall be included in the listings and shall be considered hazards of Category I or II severity:
- a) Emergency brake fails to apply when requested.
 - b) Service brakes fail to apply when requested.
 - c) Propulsion fails to cease when requested.
 - d) No-motion detection system indicates no motion when train is moving.
 - e) Door opens spontaneously when not commanded.
 - f) Door opens on wrong side of car.
 - g) Door closes on person's limb and indicates door closed and locked to the control system.
 - h) Door interlocks erroneously indicates door is closed and locked.
 - i) Excessive currents or overheated equipment cause fire hazard.
 - j) Indication of uncoupled when not uncoupled.
 - k) Train moves in wrong direction.
 - l) Train speed and track curvature combine in such a manner as to cause a train to derail or a car to overturn.
 - m) Onboard equipment causing EMI affecting wayside signaling system or other onboard systems.
 - n) Wayside equipment causing EMI affecting wayside signaling system through vehicle or onboard systems.
 - o) Uncoupled train assumed to be coupled.
 - p) Emergency brake fails to stop at required distance(s) per specification.
 - q) Service brake fails to provide requested braking rate.
 - r) Loss of safety grounds, or other failure, that exposes persons to injurious voltages.
 - s) Train regenerates into dead section of third rail.
 - t) CBTC equipment related hazards.
 - u) Platform Edge CCTV system for One Person Train Operation (OPTO) and related hazards.

21.3.4. Hazard Analysis

- 21.3.4.1. As required by MIL-STD 882E Task 202, 204,205, and 206 Preliminary Hazard Analysis (PHA), Subsystem Hazard Analysis (SSHA), System Hazard Analysis (SHA), and Operating and Support Hazard Analysis (O&SHA) shall be prepared and submitted for NYCT approval. [CDRL]
- 21.3.4.2. Per-hour failure rates shall be established for each category of hazard severity. Analyses shall demonstrate that the vehicle conforms to the requirements of this Specification and that all identified hazards are either eliminated or reduced to levels of risk acceptable to NYCT.
- 21.3.4.3. Hazards shall be resolved according to the precedence rules listed in Paragraph 4.3.4 in MIL-STD-882E, with the restriction that hazards with Category I and II severity (as defined in MIL-STD-882E) shall be resolved only by methods 4.3.4a or 4.3.4b of Paragraph 4.3.4, and as mandated by this Section 21.3.
- 21.3.4.4. All hazard analyses shall be adjusted or amended as the vehicle design and construction progresses.
- 21.3.4.5. The analysis methods shall be selected by the Contractor as appropriate for the system under evaluation and the category of hazard severity. Hazards of Category I and II severity shall receive analyses sufficiently rigorous to demonstrate that the hazard cannot occur under any reasonable conditions.
- 21.3.4.6. The Contractor shall be prepared to demonstrate by test the validity of any portion of, or all, analyses of Category I or II severity hazards. Failure rate for Category I and II hazards must be less than 10^{-8} per hour of operation. Failure rate for Category III hazard must be less than 10^{-6} per hour of operation.
- 21.3.4.7. Standard failure and safety analysis methods, and published failure rates for components shall be utilized wherever possible.
- 21.3.4.8. A capability Level 2 Sneak Circuit Analysis (SCA) in accordance with ANSI S-102.2.5 shall be applied to all safety-critical vehicle functions. The proposed analyzed functions and SCA methodology shall be submitted to NYCT for approval. [CDRL]
- 21.3.4.9. Existing hazard analyses of subsystems may be submitted, provided the analyzed subsystem is identical in all respects to that proposed, including the operating environment, and the analysis method is sufficiently rigorous. Analyses or tests required by other sections of this Specification, such as structural analyses or fire penetration tests, may also be submitted for consideration by NYCT where appropriate.
- 21.3.4.10. Analyses shall examine the vehicle in all possible configurations, and shall include circuit faults within the coupler electrical circuits.
- 21.3.4.11. Analyses shall identify all maintenance errors that could result in unsafe conditions, such as incorrect adjustment of sensors, and incorrect adjustments of the door obstruction sensing system to cite two, but not all, examples.
- 21.3.4.12. Analyses shall also include design errors that could produce unsafe conditions, such as improper breaker type or rating and temperature, or environmental dependence on proper operation for use in checking designs.

Fire Hazard Analysis

- 21.3.4.13. The Contractor shall conduct and submit for approval a Fire Hazard Analysis (FHA) of the vehicle in accordance with the guidelines of NFPA 130, Annex E and APTA's PS-RP-005-00 "Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment." [CDRL]

- 21.3.4.14. The purpose of the FHA is to provide a reasonable understanding of the fire performance of car materials and assemblies in the context of actual use.
- 21.3.4.15. All hazards identified during the FHA shall be documented on the Hazard Tracking Log (HTL) and shall be tracked until closure.

Operating and Support Hazard Analysis

- 21.3.4.16. An O&SHA shall be conducted and submitted for approval per Task 206 of MIL-STD-882E to identify and assess hazards introduced by operational and support activities and procedures, and to evaluate the adequacy of operational and support procedures, facilities, processes, and equipment used to mitigate risks associated with identified hazards. [CDRL]

21.3.5. Failure Mode Effects and Criticality Analysis

- 21.3.5.1. The Contractor shall perform and submit for approval a Failure Modes, Effects and Criticality Analysis (FMECA) to identify weaknesses in safety critical system hardware and software design, and to analyze the modes and effects of failures whenever these details are not established by historical records of equipment operation. [CDRL]
- 21.3.5.2. The FMECA shall provide input to system designs and to the safety analyses for theoretical circuit behavior, random component failures, electrical interference, systematic component failures, and software errors in software-based logic.
- 21.3.5.3. The analysis shall assume that each single item failure, as its effects are analyzed, is to be considered the only failure in the system. Where a single item failure is non-detectable, the analysis shall be extended to determine if the effects of a second failure, which in combination with the first undetectable failure, could result in a catastrophic or critical failure condition.
- 21.3.5.4. The FMECAs developed by the Contractor and systems and subsystem suppliers shall use a MIL-STD-1629A or other standard format. The Contractor shall submit a template for the FMECA within the System Safety Program Plan for approval.
- 21.3.5.5. The FMECA shall be updated throughout vehicle design development.

21.3.6. Safety Certification Program

- 21.3.6.1. The Contractor shall provide a comprehensive Safety Certification of the design of the vehicle based on quantifiable analysis prior to the vehicle being conditionally accepted by NYCT.
- 21.3.6.2. The Contractor shall develop and submit for approval a Safety Certification Plan (SCP), which shall detail how safety certifications of each sub-system and the vehicle as a whole will be achieved. [CDRL]
- 21.3.6.3. The SCP shall describe the process that will be followed during the entire procurement phase to identify, track, and maintain these certificates.
- 21.3.6.4. The Safety Certification shall be conducted in accordance with the guidelines presented in the FTA's Handbook for Transit Safety and Security Certification, FTA MA-90-5006-02-01, Final Report, November 2002.
- 21.3.6.5. The Safety Certification shall ensure that all known hazards have been mitigated to a risk acceptable to NYCT.
- 21.3.6.6. A Hazard Tracking Log shall be maintained by the Contractor as the primary tool to track all identified hazards and recommended control measures to mitigate them.
- 21.3.6.7. Safety Certification requirements for the CBTC and SIR Cab Signaling systems are discussed in Sections 14 and 25, respectively.

21.3.7. Software Safety

- 21.3.7.1. The Contractor's System Safety Program Plan shall include a software safety section that applies to any embedded or external software or firmware that controls or monitors safety-critical functions.
- 21.3.7.2. The requirements for software safety, which shall be in addition to the requirements of Section 18, Software Systems, shall meet or exceed the requirements of 49 CFR 238.105, "Train Electronic Hardware and Software Safety, and IEEE Standard 1483-2000, IEEE Standard for the Verification of Safety for Processor-Based Systems Used in Rail Transit Control".
- 21.3.7.3. It shall be the responsibility of the Contractor to ensure that software is subjected to these requirements continuously through the evolution of the program, including any software revisions made by the Contractor up to and including the passage of the last car out of warranty.
- 21.3.7.4. The Contractor shall provide and submit for approval a standalone Software Safety Program Plan that specifically addresses the requirements of 49 CFR 238.105. **[CDRL]**
- 21.3.7.5. Software safety requirements shall treat software as an integral part of a hardware/software system. A Software Configuration Item (SCI) shall be considered safety critical if it contains vital or safety related software functions, unless an independent redundant hardware means is also provided to accomplish the same functions and the hardware/software design has been analyzed and proven to be fail-safe.
- 21.3.7.6. Features of the software safety program shall include a description of how the following shall be accomplished:
 - a) Definition.
 - b) Implementation and oversight of the software design and verification process.
 - c) Integrity of the documentation.
 - d) Software hazard analysis.
 - e) Software safety reviews.
 - f) Software hazard monitoring, reporting and tracking.
 - g) Software integration with hardware at each stage of the design and testing process for components, subsystems, systems, cars, consists, and trains incorporating software for safety-critical functions.

21.4. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
21-1	21.1.3.1	Reliability Prediction Summary	PDR
21-2	21.1.3.6	Reliability Prediction Summary Updates	Quarterly or upon NYCT request
21-3	21.1.4.2	Reliability Program Plan	Notice to Proceed (NTP) + 60 days
21-4	21.1.4.2	Reliability Program Plan Updates	CDR
21-5	21.1.5.1	Reliability Demonstration Plan	90 days before delivery of first Unit
21-6	21.1.6.7, 21.1.7.7, 21.1.7.9	Monthly Reliability Demonstration Report with failures	Monthly after start of FRACAS process
21-7	21.2.2.1	Estimates of the MTTR for preventive and corrective maintenance tasks for all major subsystems	CDR
21-8	21.2.3.1	Maintenance Plan outlining all schedules and activities for vehicle corrective and preventive maintenance	CDR
21-9	21.2.4.2, 21.2.4.8	Maintainability Demonstration video	30 days after completion of demonstration
21-10	21.2.4.5	Maintainability Demonstration Plan	90 days before delivery of first Unit
21-11	21.3.2.1	System Safety Program Plan	PDR
21-12	21.3.3.1	Preliminary Hazard List	PDR
21-13	21.3.4.1	Preliminary Hazard Analysis (PHA)	CDR
21-14	21.3.4.1	Subsystem Hazard Analysis (SSHA)	CDR
21-15	21.3.4.1	System Hazard Analysis (SHA)	CDR
21-16	21.3.4.8	Sneak Circuit Analysis (SCA) Process Plan	CDR
21-17	21.3.4.13	Fire Hazard Analysis	CDR
21-18	21.3.4.16	Operating and Support Hazard Analysis (O&SHA)	CDR
21-19	21.3.5.1	Failure Modes Effects and Criticality Analysis	CDR

CDRL	Ref	Deliverable	Timing
21-20	21.3.6.2	Safety Certification Plan	CDR
21-21	21.3.7.4	Software Safety Program Plan	PDR

Section 22

System Support

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22. SYSTEM SUPPORT

22.1. Introduction

- 22.1.1. This section defines the requirements for the development and delivery of project documentation including manuals, drawings, and implementation of post-delivery training programs to familiarize the operations, maintenance, supervisory, and administrative personnel with all aspects of in-service support related to operations, inspections, maintenance, repair, and supply of parts for the cars.
- 22.1.2. This section also provides requirements for parts identification and supply of spare parts, special tools, and test equipment.
- 22.1.3. The requirements related to in-service support are divided into operations and maintenance manuals, training program guides and aids, spare parts, special tools, diagnostic test equipment, special tools, and technical support service categories.

22.2. Scope

22.2.1. General Requirements

Software

- 22.2.1.1. All publications required by this Specification shall be generated using a commercially available publishing or open source software. The final selection of the software shall be proposed by the Contractor and approved by NYCT.
- 22.2.1.2. Software applications for the viewing of technical submittals and drawings shall use commercially available software or open source software, subject to approval by NYCT.

Format

- 22.2.1.3. The final format of each manual, parts catalog, schematics, and drawings shall be approved by NYCT.
- 22.2.1.4. Chapter numbers and associated material in all manuals, Illustrated Parts Catalogs, Overhaul Process Manuals, and training guides shall be organized and sequenced with a numbering system that is consistent from one type of document to another and that allows cross referencing between different documents.
- 22.2.1.5. Sharp and clear drawings and graphics shall be used for illustrations as appropriate. Photographs and video may be used only where explicitly approved by NYCT.
- 22.2.1.6. A complete table of contents shall be included at the beginning of each publication, and a complete page numbered index at the end.
- 22.2.1.7. All publications, especially those prepared by suppliers, shall be thoroughly reviewed by the Contractor to confirm completeness and accuracy of information, and the quality of publications prior to submittal to NYCT.
- 22.2.1.8. Plastic coated tabs shall be used to separate sections within each publication.

Document Updating

- 22.2.1.9. All publications shall be kept up-to-date during the full period of the Contract. Each updated submittal shall be accompanied by a file containing a revised list of affected pages for the publications being changed.
- 22.2.1.10. The Contractor shall incorporate proposed changes to subject documents, and provide updated submittals to NYCT for review and approval, in both editable and non-editable electronic format.

- 22.2.1.11. Engineering changes that affect original design, or have significant impact on operations or safety, shall meet the requirements specified in Section 20.3.4.

22.2.2. Contractor Responsibilities

- 22.2.2.1. The Contractor shall ensure that technical submittals such as two-dimensional (2-D) drawings and three-dimensional (3-D) computer aided design (CAD) models, wiring schematics and associated wiring lists, diagnostic test equipment, special tools and gauges, and operating, service and training manuals, contain the level of detail and information necessary to properly operate and maintain all car equipment.
- 22.2.2.2. The Contractor shall ensure that all technical submittals and documents related to car systems, subsystems, components, maintenance, operations, and training are written in simple and concise English; and contain information that is complete, current, thoroughly organized, and accurate. The Contractor shall make every effort to eliminate ambiguous and irrelevant information.
- 22.2.2.3. The Contractor shall be responsible for the coordination, validation, completion, and delivery of the document submittals, from draft to final issuance.
- 22.2.2.4. The Contractor shall be responsible for development and delivery of a training program, training aids and associated courses, including proper setup of training aids as specified by NYCT.
- 22.2.2.5. The Contractor shall develop a Master Plan and schedule for development, compilation, and submittal of all publications in compliance with the schedule outlined in Section 22.2.4.
- 22.2.2.6. The Contractor shall demonstrate to NYCT that all tasks described in the supplied documentation can be performed safely and efficiently by the specified levels of NYCT personnel.
- 22.2.2.7. All maintenance activities shall conform to the SMS #08-002, "NYCT Generic Workscope", see Appendix C-36. The Contractor shall submit any deviations to NYCT for approval.

22.2.3. Deliverables

The Contractor shall provide printed copies of the volumes of manuals and training guides in the quantities indicated in Table 22-1 for each course offered.

The Contractor shall also provide digital copies of these documents in both editable and non-editable electronic formats, as part of the Interactive Electronic Technical Manuals (see Section 22.3.2). All documents shall be prepared using commercially available or open source software.

The Contractor shall provide training aids and parts and test equipment in the quantities indicated in Table 22-2.

Table 22-1: Manuals Quantities

Description	Draft	Final
22.3.2 Interactive Electronic Technical Manuals	1	1
22.3.3 Train Operator's Manual (pocket size, plasticized)	10	750
22.3.4 Train Operator Quick Reference Guide	5	1 per A car + 10
22.3.5 Road Car Inspector's Pocket Manual	10	300
22.3.7 Work Manual/ Inspection Procedures	5	20
22.3.8 Overhaul Process Manual	5	10
22.3.9 Illustrated Parts Catalog	3	3
22.3.10 Maintenance and Engineering Instruction Manual	5	40
22.3.11 Software User Manuals	1	11
22.3.12 Software Maintenance Manuals	1	11
22.3.13 Special Tools and Test Equipment Manuals	1	11
22.4.2 Instructor's Guide (ten sets for each course)	1	10
22.4.3 Participant's Training Guide (each course)	1	100
22.4.4 As-Built Drawings (digital copy for use on workstations)	0	8

Table 22-2: Hardware Deliverable Quantities

Description	Quantity
22.3.6 Handhelds	60
22.5.5 Training Aids, two sets for each course	2
22.5.6 Multimedia HD LED Projectors (min. 2100 lumens)	5
22.22.6.7.4 Shipping Boxes for Equipment (SMS Parts)	See PF-3
22.7.1 Special Tools	See PF-4
22.22.7.2.3 Special Tools for Training	2 sets
22.22.7.2.9 Shipping Boxes for Special Tools	See PF-4
22.22.7.2.11 Coupler Adapters	One per Unit
22.8.5 Portable Test Equipment	See PF-5
22.8.9 Bench Test Equipment	See PF-5
22.8.17.4 General Purpose Workstations	5

22.2.4. Schedule of Submittals and Deliverables

- 22.2.4.1. The Contractor shall maintain and update all technical documents, manuals, training guides, and training aids to reflect up-to-date changes in the car design.
- 22.2.4.2. The Contractor shall update all documents including those previously approved as final, to incorporate all changes that are identified until the end of the warranty period of the last Unit. The specific provisions for BTE and warranty provisions are contained in Section 22.8.1.10.
- 22.2.4.3. Submittal schedule requirements for manuals and training guides shall be as shown in Table 22-3.

Table 22-3: Submittal Schedule for Documents [NTP = Notice To Proceed]

Ref	Document type	Table of Contents	First Draft	Final Draft	Final Issue
22.3.2	Train Operator’s Manual	180 days from NTP	150 days before delivery of first Unit.	Upon delivery of first Unit.	Acceptance of First Unit.
22.3.4	Train Operator Quick Reference	180 days from NTP	150 days before delivery of first Unit.	Upon delivery of first Unit.	Acceptance of First Unit.
22.3.5	Road Car Inspector’s Pocket Manual	180 days from NTP	150 days before delivery of first Unit.	Upon delivery of first Unit.	Acceptance of First Unit.
22.3.7	Work Manual	180 days from NTP	Upon delivery of first Unit.	Upon delivery of 20th Unit.	30 days before end of warranty on first Unit.
22.3.8	Overhaul Process Manual	365 days from NTP	Upon delivery of first Unit.	300 days before end of warranty on first Unit.	End of the warranty period.
22.3.9	Illustrated Parts Catalog	180 days from NTP	150 days before delivery of first Unit.	180 days before end of warranty on first Unit.	120 days before end of warranty on first Unit.
22.3.9.8	Asset ID and Bar Coded Component List	365 days from NTP	At First Article Inspection	Upon delivery of first Unit.	120 days before end of warranty on first Unit.
22.3.10	Maintenance and Engineering Instruction Manual	180 days from NTP	Upon delivery of first Unit.	120 days before end of warranty on first Unit.	30 days before end of warranty on first Unit.
22.3.11	Software User Manual	180 days from NTP	150 days before delivery of first Unit.	Upon delivery of first Unit.	30 days before end of warranty on first Unit.
22.3.13	Special tools and Test Equipment Manuals	365 days from NTP	120 days before delivery of test equipment.	Upon delivery of test equipment.	Due date on the start time of class.
22.4.2 22.4.3	Training Guides, Instructor & Participant	180 days from NTP	30 days prior to pilot class.	After session 2, upon NYCT acceptance of content.	30 days after final draft.
22.5.7	Train Operator Course Material	180 days from NTP	150 days before delivery of first Unit.	After the pilot class before session 1.	30 days after session 2.
22.5.7	Conductor Course Material	180 days from NTP	150 days before delivery of first Unit.	After the pilot class before session 1.	30 days after session 2.
22.5.8	Road Car Inspector Train-the-Trainer Course Material	180 days from NTP	60 days before each pilot class.	After the pilot class before session 1.	30 days after session 2.
22.5.9	Car Inspector Maintainer Program (Phase I) - Maintenance	180 days from NTP	60 days before each pilot class.	After the pilot class, before session 1.	30 days after session 2.
22.5.9	Car Inspector Maintainer Program (Phase II) - Overhaul	180 days from NTP	60 days before each pilot class.	After the pilot class, before session 1.	30 days after session 2.
22.5.9	Electronics Repair & BTE Course Material	180 days from NTP	60 days after acceptance of first Unit.	After the pilot class, before session 1.	30 days after session 2.
22.5.9.4	Maintenance Training Program -Train-the-Trainer	180 days from NTP	30 days prior to pilot class.	300 days before end of warranty on first Unit.	30 days before end of warranty on first Unit.
22.5.10	Management Familiarization Course	180 days from NTP	Upon delivery of first Unit.	After the pilot class, before session 1.	30 days after session 2.
22.22.8.1.9	PTE Design description	n/a	6 months after NTP.	n/a	n/a
22.22.8.1.13	PTE source code	n/a	n/a	n/a	End of Warranty.
22.8.3	Software Maintenance Manuals	180 days from NTP	120 days before delivery of test equipment.	Upon delivery of test equipment.	On acceptance of test equipment.
22.9.2	Workstation Equipment Manuals	365 days from NTP	150 days before delivery of equipment.	90 days before delivery of first Unit.	On delivery of first Unit.

22.2.4.4. Submittal schedule requirements for training aids and special tools and test equipment shall be as shown in *Table 22-4*.

Table 22-4: Schedule for Hardware Deliverables

Ref	Deliverable	First Delivery	Deliveries Complete
22.3.2	Interactive Electronic Technical Manuals editing hardware/software	30 days before delivery of first Unit	30 days before end of warranty on first Unit
22.3.6	Handhelds	90 days before delivery of first Unit	Due date on the start time of class
22.5.5	Training Aids (two sets for each course)	30 days before each course	After all courses start
22.5.6	Multimedia HD LED Projectors (min. 2100 lumens)	30 days before first course	After all courses start
22.6.7.4	Shipping Boxes for Equipment	With equipment	With equipment
22.7.1	Special Tools	30 days before delivery of first Unit	Acceptance of first Unit
22.22.7.2.3	Special Tools for Training	30 days before first course	After all courses start
22.22.7.2.9	Shipping Boxes for Special Tools	With special tools	With special tools
22.22.7.2.11	Coupler Adapters	With Units	All Units delivered
22.8.5	Portable Test Equipment (PTE)	With delivery of first Unit	Acceptance of first Unit
22.8.8.6	PTE Cables	With delivery of first Unit	Acceptance of first Unit
22.8.9	Bench Test Equipment (BTE)	With delivery of second Unit	With delivery of 31 st Unit
22.9.2.1	Workstations (loaded with commercially available or open source office software)	With delivery of first Unit	Acceptance of first Unit
13.6.5	Automatic Announcement System Workstations	With delivery of second Unit	With delivery of 31 st Unit

22.3. Operations and Maintenance Manuals

22.3.1. General Requirements

- 22.3.1.1. This Section specifies the requirements for Operations and Maintenance Manuals (OMM).
- 22.3.1.2. The content of manuals shall be limited to the information necessary to complete the stated task as it pertains to operation, function, inspection, testing, maintenance, and repair of the relevant car system, subsystem, equipment, and components.
- 22.3.1.3. The format of manuals shall be logically organized with systems and elements sorted in ascending order of importance. All statements shall be clear, positive, and accurate with no possibility of incorrect implication or inference.
- 22.3.1.4. The manuals shall be prepared using a commercially available publishing software featuring text processing and integration of scalable vector graphics for illustrations, as required by Section 22.2.1.5.
- 22.3.1.5. All manuals shall be submitted in both printed and electronic format, including submittals at the draft, final draft, and final approval stages.
- 22.3.1.6. All submitted documentation shall be considered as “Interim Documents” until approved by NYCT.
- 22.3.1.7. The title, content, and volume sequence of each OMM shall be clearly noted on the cover page.

22.3.1.8. Final hard copy versions of manuals shall be of high quality, reproducible format, and single-sided printed on a three-hole pre-punched paper.

Except for the Train Operator and Road Car Inspector Manual, all other publications shall be produced on a standard 8.5 × 11-inch letter size, 70-lb offset paper, and bound in a 3-inch lockable metal ring, heavy duty view binder with loose leaf format to allow page revisions.

22.3.1.9. A new status sheet listing the effective date of each page shall be included for each manual at the time the updates are forwarded to NYCT. Each updated page shall be annotated with a vertical bar in the margin to indicate where material has been added, deleted, or revised.

22.3.1.10. Final sets of all manuals shall be serialized with permanently marked serial numbers on the spine of the cover, using numbers provided by NYCT.

22.3.1.11. NYCT shall be granted the right to use, reproduce, and modify any content of any OMM as it deems necessary.

22.3.1.12. Maintenance Manuals, procedures, and Training Guides shall clearly identify all hazardous materials, equipment, and situations that may be encountered during maintenance, and shall indicate the proper handling, storage, and disposal of hazardous materials in compliance with corresponding Material Safety Data Sheet (MSDS).

22.3.1.13. All maintenance procedures involving potential hazards shall contain clear identification of the hazard and instructions to minimize or eliminate hazards during the procedure.

22.3.2. Interactive Electronic Technical Manuals

22.3.2.1. The Contractor shall prepare and provide interactive electronic versions of the following manuals:

- a) Work Manual.
- b) Overhaul Process Manual.
- c) Maintenance and Engineering Instructions Manuals.
- d) Illustrated Parts Catalog.

22.3.2.2. The Interactive Electronic Technical Manuals (IETM) shall structurally integrate and correlate, as appropriate, all relevant information pertaining to the car equipment and/or any of its components, using text, tables, graphics, flowcharts, functional flow diagrams, schematics, troubleshooting, repair and overhaul procedures, videos, sound files, photographs, functional descriptions, and parts catalog data.

22.3.2.3. In general, the IETM shall include the information and content required by the respective manuals noted in 22.3.2.1.

22.3.2.4. The IETM shall be a web-based online tool that allows user to view, scroll, navigate, search by key words or part number, explode, pan, zoom, and print graphics, print text, or tables.

22.3.2.5. The text, graphics, schematics and drawings, shall be presented in accordance with the requirements of NYCT Specification 8012-GENL-89, see Appendix C-39.

22.3.2.6. The IETM shall feature user interface dialogue prompts, as appropriate, so that user is required to respond (i.e. enter data) before any subsequent processes are undertaken.

22.3.2.7. The IETM shall feature content dependent filtering, capable of returning and presenting only the information that applies to the specific configuration or situation.

22.3.2.8. The data filtering shall be accomplished by linking the related information elements within the data. Data linking shall be used to minimize redundant information elements wherever practicable.

- 22.3.2.9. Technical information shall be supplemented with warnings, cautions, and notes in such way as to attract the user's attention to safe practices, procedures, and conditions. Such warnings shall comply with existing NYCT procedures and OSHA standards.
- 22.3.2.10. The IETM shall feature a help function describing how to use the IETM.
- 22.3.2.11. The IETM shall feature functions that allow NYCT to update individual data modules that make up the content of respective manual(s).
- 22.3.2.12. The IETM shall contain administrative information such as
- a) Identification of the technical manual title, assigned technical manual number, and document version.
 - b) Date - baseline date including the dates of latest and all previous changes as applicable.
 - c) Verification, changes, or revision status as applicable.
 - d) Preparation activity.
 - e) Activity with technical control of the IETM.
 - f) Activity responsible for configuration management of the equipment/system.
 - g) Information for forwarding deficiency reports, or other evaluative comments.
 - h) Distribution statement.
 - i) Export control notice, as applicable.
 - j) Summary list of reference documents, including their data links.
- 22.3.2.13. Data prepared and contained within the IETM shall be formatted using XML tags consistent with S1000D-I9005-01000-00, "International Specification for Technical Publications" using a common source database.
- 22.3.2.14. Off the shelf software, such as Asymetrix Multimedia Tool Box, Borland's Delphi, or Microsoft Visual Basic and Borland's dBase V or Visual Basic, or Microsoft Access shall be used to develop the IETM.
- 22.3.2.15. NYCT shall be granted the all copyrights to use, reproduce, and modify any content of any IETM, as deemed necessary.
- 22.3.2.16. The Contractor shall demonstrate the functions and content of the IETMs to NYCT for review and approval. [CDRL]

22.3.3. Train Operator's Manual

- 22.3.3.1. The Contractor shall provide a Train Operator's Manual (TOM) for use by train operating personnel.
- 22.3.3.2. The pocket sized TOM shall be reproduced on a page size approved by NYCT, bound in covers approximately 1/16-inch (2-mm) thick, printed on glossy waterproof paper that is resistant to oil, grease, tearing and fading.
- 22.3.3.3. The Contractor shall ensure that TOM is consistent with NYCT's existing operating rules, regulations, procedures, and bulletins.
- 22.3.3.4. The TOM shall contain all information needed by NYCT operating personnel to safely, correctly, and efficiently carry out the operation of the train in all possible consist configurations.
- 22.3.3.5. The TOM shall contain information about the location, function, and operation of car controls, gauges, indicators, switches, and cutouts needed to operate the train in a safe manner.

- 22.3.3.6. The TOM shall contain procedures and information related to preparation of a train for operation in manual and CBTC operating modes, including One Person Train Operation (OPTO) and two person operation, and procedures for laying-up trains from service. All operating conditions shall be accounted for, including coupling and uncoupling.
- 22.3.3.7. The TOM shall include illustrations, referenced in the text, to show locations of the undercar equipment, and other features of the car which Train Operator may not be in position to control or adjust directly, but of which the Train Operator should have some basic knowledge.
- 22.3.3.8. The TOM shall include a brief description about the operation of all car systems, including trucks, couplers, air springs, leveling valves, lights, HVAC, cutouts, bypasses, CBTC/AWS equipment operated by the Train Operator, and key circuit breakers.
- 22.3.3.9. The TOM shall include a brief description about the functions, features, and failure modes of OBCU equipment.
- 22.3.3.10. Block diagrams and schematic drawings shall be used to augment the description of assemblies and the relationship of components, assemblies, and systems.
- 22.3.3.11. The TOM shall contain a Troubleshooting Guide, including the description of error codes and diagnostic methods, to enable the Operator to identify operational problems, isolate faults and recover a train in case of in-service failure(s).
- 22.3.3.12. The TOM shall also include information relating to specific safety cautions, special procedures, warnings, emergency recovery, recovery of a dead train procedures, and other information needed to maintain safe operating conditions.

22.3.4. Train Operator Quick Reference Guide

- 22.3.4.1. The Contractor shall provide the Train Operator Quick Reference Guide (TOQRG) in the form of an abbreviated version of the TOM.
- 22.3.4.2. The pocket sized TOQRG shall be bound in covers and reproduced on a regular paper of page size as approved by NYCT.
- 22.3.4.3. The final sets of TOQRG shall be serialized with permanently marked serial numbers on the spine of the cover, using numbers provided by NYCT.
- 22.3.4.4. An amendment shall be prepared to make limited modifications to TOQRG. Amendments shall be in the form of inserts of revised pages, and shall be cumulative and supersede prior amendments. A guide may be amended a maximum of five times after which it shall be reissued as a complete new document.

22.3.5. Road Car Inspector's Pocket Manual

- 22.3.5.1. The Contractor shall develop and supply the Road Car Inspector's Pocket Manual (RCIPM) for use by field maintenance personnel.
- 22.3.5.2. The format of RCIPM shall be similar to that of TOM, with the addition of systematic troubleshooting and fault handling procedures, corrective actions, and recovery instructions to cover both normal operating and emergency conditions.
- 22.3.5.3. The RCIPM shall contain all pertinent information needed by Road Car Inspectors to correctly troubleshoot, identify, repair, and recover a train in case of in-service failures.
- 22.3.5.4. The content of RCIPM shall also include the information provided by the Train Operator Display (TOD), and augmented with a list of unusual fault occurrences that may not display as alarms.

- 22.3.5.5. The pocket sized RCIPM shall be reproduced on page size as approved by NYCT, bound in covers approximately 1/16-inch (2-mm) thick, with glossy waterproof paper that is resistant to oil, grease, tearing and fading.
- 22.3.5.6. The final sets of RCIPMs shall be serialized with permanently marked serial numbers on the spine of the cover, using the numbers provided by NYCT.
- 22.3.5.7. An amendment shall be prepared to make limited modifications to the RCIPM. Amendments shall be in the form of inserts of revised pages, and shall be cumulative and supersede prior amendments. A pocket manual may be amended a maximum of five times after which it shall be reissued as a complete new document.

22.3.6. Handheld Devices

- 22.3.6.1. The Contractor shall provide handheld devices in the quantities specified in Table 22-1.
- 22.3.6.2. The handheld devices shall be sufficiently durable to withstand drops and knocks associated with normal use within the NYCT operating environment, and compliant with MIL-STD 810G.
- 22.3.6.3. The net weight of handheld device shall be less than 15 oz. (0.5 kg).
- 22.3.6.4. The handheld device shall have an active viewing screen area of no less than 6 inches measured diagonally, color 640 × 480 resolution, high visibility backlit LCD, capable of portrait or landscape orientation.
- 22.3.6.5. The handheld device shall be battery operated, with a minimum standby time of 150 hours, run time of no less than 8 hours, and shall be capable of rapid charging.
- 22.3.6.6. The handheld device shall be capable of accessing all intelligent microprocessor based car subsystems' real-time status information, fault logs, and trouble messages via the Monitoring and Diagnostic System (MDS) wireless interface specified in Section 17.3.1.3. The device should have available and consistent connectivity.
- 22.3.6.7. The handheld devices shall be serialized with permanently marked serial numbers, using numbers provided by NYCT.
- 22.3.6.8. Security of access to the handheld devices, including communication protocols, shall be as specified in Section 18, Software Systems.
- 22.3.6.9. The handheld device shall be equipped with a means such as string, strap or a clip, to allow attachment to a user's body or belt.

22.3.7. Work Manuals

- 22.3.7.1. The Contractor shall provide Work Manuals (WM) as part of the IETM, see Section 22.3.2. The WM shall allow cross referencing between the Illustrated Parts Catalog (IPC), Overhaul Process Manual (OPM), and other Maintenance Manuals. The WM shall provide provisions for revision, revision control, printing, reporting, troubleshooting, queries, searches, etc.
- 22.3.7.2. The Contractor shall demonstrate the use of WM procedures during the corresponding pilot training classes.
- 22.3.7.3. The content of the WM shall comply with NYCT specification 8003-GENL-87, "Work Manual", see Appendix C-38. The format shall comply with Section 22.3.2.
- 22.3.7.4. A draft copy of the relevant WM chapter(s) shall be made available for use and validation during the First Article Inspection of respective system (see Section 23.7.1).

22.3.7.5. As applicable to individual systems, the WM shall contain:

- a) All pertinent information needed by the car maintenance personnel to inspect, service, troubleshoot the car, and to maintain its safe operation.
- b) Information needed to perform running repairs and adjustments for each car subsystem, including a quick reference guide to test, troubleshoot, service, and replace equipment down to the lowest replaceable level.
- c) Information about maintenance inspections, and details pertaining to inspection intervals and criteria.
- d) Preventative maintenance tasks for each car subsystem and details pertaining to service intervals and criteria for replacement in compliance with existing standard NYCT maintenance schedule unless otherwise approved by NYCT.
- e) Instructions for using PTE and procedures for maintenance, adjustment, testing, and troubleshooting.
- f) Block diagrams and illustrations to augment the relationship between components, assemblies, and systems.
- g) Troubleshooting flowcharts and interactive troubleshooting guides to augment the repair of complex systems.
- h) A sequence of illustrations may be used in order to simplify, clarify, and shorten the narrative.

22.3.7.6. When a procedure calls for removal and replacement of a component, the instruction shall reference to the appropriate location in the respective manual. The relevant sections shall be cross-linked, referenced to, and accessible within the WM.

22.3.8. Overhaul Process Manuals

22.3.8.1. As part of the IETM, the Contractor shall develop and provide an OPM that allows cross referencing between various Maintenance Manuals, for use by car maintenance personnel.

22.3.8.2. The content of OPM shall comply with NYCT specification 8012-GENL-89, "General Requirements for Overhaul Process Manual", see Appendix C-39. The format shall comply with Section 22.3.2.

22.3.8.3. The OPM shall include detailed procedures to allow Maintenance and Overhaul Shop personnel to effectively service, inspect, maintain, replace, adjust, repair, and overhaul all aspects of the vehicle and its subsystems and components.

22.3.8.4. The OPM shall include all pertinent information needed to perform a comprehensive overhaul on all mechanical, electrical, and electronic assemblies and subassemblies.

22.3.8.5. The OPM shall also include step-by-step setup and test instructions for using the PTE, bench testers, special tooling, and shop-test stands needed to correctly test, verify, and adjust the overhauled equipment.

22.3.8.6. Illustrations, exploded views, and video-based aids/guides shall be used to augment the relationship between components, assemblies, and systems.

22.3.9. Illustrated Parts Catalog

22.3.9.1. As part of the IETM, the Contractor shall provide an Illustrated Parts Catalog (IPC) that allows cross referencing between various Maintenance Manuals.

22.3.9.2. The content of the IPC shall comply with NYCT specification #1000-MMD-89, "Multivolume Illustrated Parts Catalog", see Appendix C-40. The format shall comply with Section 22.3.2.

- 22.3.9.3. The IPC shall enumerate, describe, illustrate, and provide information about every assembly used on a car, including related modules (Lowest Replaceable Units [LRU] and Lowest Level Replaceable Units [LLRU]), subassemblies, individual parts, PTE, Bench Test Equipment (BTE), and special tools.
- 22.3.9.4. The IPC sections shall coincide with chapters of the other Maintenance Manuals.
- 22.3.9.5. Illustrations shall be used to clearly portray the location of a component as related to an end item. Components on the illustration shall be linked (indexed) to the parts list, description, and commodity number.
- 22.3.9.6. A 3-D exploded view and/or cut-away drawings shall be used to clearly portray the disassembly sequence, and identify parts and their relationship within the assembly. Where practical, digital photographs and/or renderings shall be permitted.
- 22.3.9.7. This IPC shall allow a drillup and drilldown from high-level assembly to its individual items and include cross references between part description, number, unit of measure, quantity per car and assembly, original manufacturer part number and its commercial equivalent (where available), name of manufacturer or supplier and its contact information, space for NYCT commodity number, special handling instructions, and the reference IPC page and illustration.
- 22.3.9.8. The Contractor shall submit for NYCT review and approval an Asset ID and Bar Coded Component List (ABCCL) for the cars.

22.3.10. Maintenance and Engineering Instruction Manual

- 22.3.10.1. The Contractor shall provide a Maintenance and Engineering Instruction Manual (MEIM).
- 22.3.10.2. The MEIM shall contain a general overview of the entire car, including the information on all car systems, and equipment's operating and performance characteristics, dimensions, weights, and ratings.
- 22.3.10.3. The illustrations shall be used to show, in perspective, interior and exterior layouts, roof, ceiling, floor, and underfloor structure to clearly note the physical location of each system.
- 22.3.10.4. The use of 2-D drawings shall be minimized.
- 22.3.10.5. The MEIM shall also provide a general description of all tests, inspection equipment, and tools used to maintain the cars.
- 22.3.10.6. A draft copy of the relevant MEIM chapter(s) shall be made available for use and validation during the First Article Inspection (FAI) of the respective car subsystem (see Section 23.7.1).

22.3.11. Software User Manuals

- 22.3.11.1. The Contractor shall provide Software User Manuals (SUM) for all intelligent and microprocessor controlled subsystems having software that is run by the user and has a user interface requiring on-line user input or interpretation of displayed output.
- 22.3.11.2. The SUM shall contain sufficiently comprehensive information to allow any qualified software engineer or programmer to make parameter, or program, and/or system modifications, without recourse to the Contractor.
- 22.3.11.3. The format of SUM shall include, but not be limited to, general information about the respective system and its software modules, functional description including parameter descriptions and ranges, linkage to other modules, error routines, and any special consideration lists for input/output data.

- 22.3.11.4. The SUM shall contain memory maps for both internal and peripheral memory with descriptions for all the programs, data files, overlay areas, and memory available for expansion.
- 22.3.11.5. Data flow diagrams, truth tables, state diagrams, equations shall be used to augment the relationship between different software functions and operation.
- 22.3.11.6. The SUM shall contain a revision index recording software modifications including date, reason for change, description of change, and required approvals.
- 22.3.11.7. The SUM shall contain the information about the development method, convention, and tools employed for development and programming of software.
- 22.3.11.8. The SUM shall contain the information about the initialization and program loading requirements, test records, and use of test software.
- 22.3.11.9. The software documentation shall be prepared in accordance with the latest revision of IEEE 1558 standard, "Software Documentation for Rail Equipment and Systems".
- 22.3.11.10. For additional requirements related to software validation and documentation, see Section 18.4.

22.3.12. Software Maintenance Manuals

- 22.3.12.1. The Contractor shall provide Software Maintenance Manuals (SMM) for all intelligent and microprocessor controlled subsystems.
- 22.3.12.2. The SMM shall contain recommended procedures, processes, and tools needed to administer and maintain all diagnostic files, parameter files, software modules of microprocessor based subsystems. Refer to Section 22.9 for software workstation requirements.
- 22.3.12.3. The SMM shall include a system operation description (hardware and software) as it relates to the user's tasks.
- 22.3.12.4. The SMM shall be prepared specifically for the systems delivered to NYCT, and shall not include standard descriptions that do not apply to the delivered equipment.
- 22.3.12.5. The SMM shall discuss processes for performing version control and configuration management procedures as described in the approved Software Configuration Management Plan.
- 22.3.12.6. The SMM shall define processes pertaining to software risk management, and how to monitor, identify, assess, and manage the risk during the operations and maintenance phase.
- 22.3.12.7. The SMM shall describe how to perform routine maintenance and how to recover from system problems.
- 22.3.12.8. The SMM shall include descriptions of system notifications for routine maintenance and alarm conditions.
- 22.3.12.9. The SMM shall describe software configuration management, processes to monitor software performance, and track, verify and load software versions using the tools and utilities provided.
- 22.3.12.10. The SMM shall describe recovery procedures to facilitate system restarts and failures. The manual shall have sufficient information to guide the operator through starting and configuring the subject system, initiating diagnostics, and interpreting diagnostic and error output, and the procedure for reloading the executable and parameter file(s) should it be necessary.
- 22.3.12.11. The SMM shall include a functional explanation and description of application programs, modules and their roles.
- 22.3.12.12. The SMM shall not be written as a programmer's document.
- 22.3.12.13. For additional requirements related to software maintainability, see Section 18.3.

22.3.13. Special Tools and Test Equipment Manuals

- 22.3.13.1. The Contractor shall provide a Test Equipment Manual for all special tools, gauges, and test equipment provided by the Contractor.
- 22.3.13.2. The Contractor shall provide manuals and procedures to use, maintain, repair, calibrate and troubleshoot all Diagnostic Test Equipment (DTE), including:
 - a) Portable Test Equipment (PTE).
 - b) Bench Test Equipment (BTE).
 - c) Testing Gauges.
- 22.3.13.3. The Contractor shall provide complete schematic diagrams for all DTE, and automatic test stands including all custom test fixtures and auxiliary power supplies needed to test each LRU, LLRU, or Printed Circuit Board (PCB).
- 22.3.13.4. The Contractor shall supply Software Maintenance Manuals to support the maintenance of microprocessor based DTEs, in accordance with the requirements noted in Section 22.3.12.

22.4. Training Manuals

22.4.1. General

- 22.4.1.1. The content of each training manual, and Participant's and Instructor's Training Guide, shall fully describe the operation, testing, troubleshooting, maintenance, assembly, disassembly, and recommended repair methodology for all car systems, subsystems, equipment, and components.
- 22.4.1.2. The interim documents shall be submitted for final record, after review and acceptance by NYCT, in accordance with the schedule in Table 22-3 and prior to completion of the contract.

22.4.2. Instructor Guides

- 22.4.2.1. The Contractor shall provide an Instructor Guide for each training course.
- 22.4.2.2. The format of Instructor's Guide shall comply with existing NYCT Operations Training Manuals. A sample of the format will be made available to the Contractor upon request.
- 22.4.2.3. The Instructor Guide shall contain all the information and material to allow an NYCT instructor to effectively teach and deliver any training program at a later time.
- 22.4.2.4. The Instructor's Guide shall include notes explaining course agenda, objective, and course delivery methodology.
- 22.4.2.5. The Instructor's Guide shall include:
 - a) Instructions for preparing and managing training sessions.
 - b) List of training materials and required resources and facilities.
 - c) Lesson plans and instructions on how to present any working models or advanced technology training aids.
 - d) Duration of teaching modules.
 - e) Target audience.
 - f) Prerequisites for each course.
- 22.4.2.6. The Instructor's Guide shall include a lesson plan for each course, indicating which training aids will be used, or referred to, during the course instructions.

- 22.4.2.7. The Instructor's Guide shall note references to locations in the Participant's Guide where answers to the post-test questions are contained.
- 22.4.2.8. The Instructor's Guide shall include notes explaining all safety concerns and applicable NYCT policies.
- 22.4.2.9. The Instructor Guide for the Car Inspector and Maintainer Program shall include existing NYCT car Inspection Checklists and relevant sections of Work and Overhaul Process Manuals as an addendum.
- 22.4.2.10. The Instructor Guide for Train Operator and Conductor's Training courses shall include color (only) photographs to emphasize the information presented in the guide.
- 22.4.2.11. The Instructor's Guide shall identify the evaluation criteria and methods for measuring participant's performance in the classroom and in the shop/ field for each course. Some courses may use course components (pre-course test, class participation, unit test, and exams) to aggregate the passing score.

22.4.3. Participant Guides

- 22.4.3.1. The Contractor shall provide a Participant Training Guide for each training course.
- 22.4.3.2. The Participant Guide shall include notebook size copies of any and all training aids used by instructor.
- 22.4.3.3. The format of Participant Training Guide shall comply with existing NYCT Operations Training Manuals. A sample of the format will be made available to the Contractor upon request.
- 22.4.3.4. The Participant Training Guide shall contain all the information needed by a trainee to successfully complete the training program, including pre- and post-test questions without answers.
- 22.4.3.5. The Participant Guide shall include the up-to-date training course schedule and latest revisions of training and reference material, training aids used by instructor, and other applicable manuals that might be provided for training.
- 22.4.3.6. The Participant Guide for the Car Inspector and Maintainer Program shall include copies of existing NYCT Inspection Checklists, and applicable sections of the Work and Overhaul Process Manuals approved by NYCT.
- 22.4.3.7. The Participant Guide for Train Operator and Conductor's Training shall include color (only) photographs to emphasize the information presented in the guide.

22.4.4. Contractor's Specifications and As-Built Drawings for Training

- 22.4.4.1. When used as a reference material to facilitate training, as-built drawings and wiring diagrams, shall be simplified to the maximum extent possible, to allow easy comprehension of the subject matter.
- 22.4.4.2. Complex drawings shall be simplified into single line functional diagrams as appropriate, to illustrate the operation, function, and/or troubleshooting of complex systems.
- 22.4.4.3. Reference schematic diagrams shall include sufficient detail about each component in the systems and subsystems to allow easy comprehension.
- 22.4.4.4. Assemblies or parts identified by initials or reference numbers on the subject drawings, shall be supported by a key to permit precise identification.

22.4.5. Electronic Format Submittals

- 22.4.5.1. All drawings, including integrated schematics, shall also be submitted in electronic format using an NYCT approved means of transmittal.

- 22.4.5.2. Drawings shall be in AutoCAD and PDF formats. Alternate editable drawing formats may be proposed to facilitate the display, review, mark-up, editing, and printing of electronic drawings as part of the acceptance process, see Section 20.5.1.
- 22.4.5.3. Documents submitted in PDF format shall have a security level enabled to prevent annotation of the files. Multiple PDF documents submitted in a single file shall be bookmarked to facilitate file navigation.

22.5. Training Program

22.5.1. General Requirements

- 22.5.1.1. The Contractor shall develop and deliver a comprehensive and professional Training Program to provide an adequate skill and knowledge base to NYCT about the configuration, operations, maintenance, repairs, and overhaul of the car and its carborne equipment.
- 22.5.1.2. The training program shall accurately and completely reflect the requirements of the Operations and Maintenance Manuals, and be structured and implemented so that the designated operations, maintenance, supervisory, and administrative personnel can gain access to all necessary resources needed to safely, properly, and successfully operate, repair, and maintain the cars.
- 22.5.1.3. The Contractor shall provide the Training Program to NYCT personnel consisting of operations and maintenance, supervisory, and engineering staff as per the schedule listed in Table 22-3.
- 22.5.1.4. The Contractor shall assume that NYCT personnel have no prior knowledge of the new cars, but have the skills pertinent to their craft.
- 22.5.1.5. The Contractor shall submit an Educational Program Outline (EPO) for NYCT review and acceptance, in accordance with timeline noted in the Section 22.5.2.
- 22.5.1.6. The EPO shall include a proposed schedule for training, identifying each training module topic and the order in which they will be presented.
- 22.5.1.7. The training courses that require hands-on training shall include both classroom and shop training sessions. The expected shop time shall be 50 percent or more of the total training time, through the use of actual equipment, tools, and interactive training modules.
- 22.5.1.8. The Contractor shall ensure that all maintenance procedures used in the training sessions have been approved by NYCT prior to delivery of such sessions.
- 22.5.1.9. The Contractor shall be responsible for the content and condition of all training material and shall update and replace all superseded or damaged material for the duration of the Training Program.
- 22.5.1.10. All training material such as training aids and lesson plans shall become the property of NYCT following the completion of the Training Program.
- 22.5.1.11. All training programs and sessions shall be held Monday through Friday, and including weekends as needed, with start and finish times to be determined and provided by NYCT's Operation Training.
- 22.5.1.12. The Contractor shall provide an adequate supply of high quality, professionally developed training materials on paper, and ensure that all necessary training equipment is available for use. A copy of all materials shall also be provided electronically.
- 22.5.1.13. The Training Program shall include steps to test and determine the proficiency of the trainees.
- 22.5.1.14. All training courses shall be prepared and presented in English.
- 22.5.1.15. The duration of each training session shall be in accordance with the Training Schedule and Class Size requirements.

- 22.5.1.16. The Contractor shall attend a one day mandatory Track Safety class (TS3) and a one day Shop and Yard class (CO14) at NYCT’s training facility to learn about NYCT’s safety regulations and facilities.
- 22.5.1.17. The Training Program shall be based on NYCT’s Train-the-Trainer philosophy to allow future training programs to fully benefit from the training materials provided.
- 22.5.1.18. The Contractor shall supervise all training courses.

22.5.2. Training Schedule and Class Sizes

- 22.5.2.1. The class size shall be from 5 to 10 people.
- 22.5.2.2. The Contractor shall first provide training to the Car Inspectors and Maintainers to enable them to inspect, maintain, troubleshoot, and repair the equipment during the warranty period.
- 22.5.2.3. The Contractor shall then provide a train-the-trainer program to designated Operations Training personnel to enable them to train personnel on how to inspect, operate, maintain, troubleshoot, repair, and overhaul the car equipment throughout its life.
- 22.5.2.4. The Contractor shall provide train and equipment familiarization training to NYCT Supervisors.
- 22.5.2.5. The course schedule shall be as outlined in Table 22–5.

Table 22-5: Training Courses Schedule

Session	No of Sessions	Course Schedule	Course Location	Count of Participants
Management Familiarization	2	60 days before scheduled acceptance of the first Operating Unit	NYCT premises	20
Train Operator, Pilot Class	1	6 weeks before scheduled delivery of the first Operating Unit	Contractor’s property	10
Vehicle Supervisor Familiarization	2	6 weeks before scheduled delivery of the first Operating Unit	Contractor’s property	10
Train Operator Class	3	1 month after delivery of the first Operating Unit	NYCT premises	30 (10 per class)
Conductor’s Pilot Course	1	6 weeks before scheduled delivery of the first Operating Unit	Contractor’s property	10
Conductor’s Course	3	1 month after delivery of the first Operating Unit	NYCT premises	30 (10 per class)
Road Car Inspector Pilot Class	1	6 weeks before scheduled delivery of the first Operating Unit	Contractor’s property	10
Road Car Inspector Class	3	1 month after delivery of the first Operating Unit	NYCT premises	30 (10 per class)
Car Inspector and Maintainer, Pilot Class, Phase I	1	60 days before acceptance of the first Operating Unit	NYCT premises	10
Car Inspector and Maintainer Class, Phase I	2	After successful completion of Phase I	NYCT premises	20 (10 per class)
Overhaul Procedures, Pilot Class, Phase II	1	4 months prior to the end of warranty on the first Operating Unit	NYCT premises	10
Overhaul Procedures Class, Phase II	2	4 months prior to the end of warranty on the first Operating Unit	NYCT premises	20 (10 per class)
Electronic Repairs and BTE, Pilot Class	1	At the delivery of the first Operating Unit	NYCT premises	10
Electronic Repairs and BTE Class	2	8 months prior to the end of warranty on the first Operating Unit	NYCT premises	20 (10 per class)
Session	No of Sessions	Course Schedule	Course Location	Count of Participants
Special tools and gauges Course	3	1 month after delivery of the first set of tools and gauges	NYCT premises	30 (10 per class)

Network Training Level 1	3	1 month after delivery of the first Operating Unit	NYCT premises	30 (10 per class)
Network Training Level 2	1	4 months prior to the end of warranty on the first Operating Unit	NYCT premises	20

22.5.3. Instructor Qualifications

- 22.5.3.1. All classroom and shop training shall be presented by training facilitators with in-depth experience and knowledge about the design and functional characteristics of the car systems.
- 22.5.3.2. The Contractor shall provide a detailed resume for each instructor to NYCT for review and approval, 60 days prior to the beginning of the scheduled course.
- 22.5.3.3. NYCT will recognize the instructor as qualified once it is confirmed that the instructor can effectively communicate in English, has training and experience in teaching technical training courses, and possesses an in-depth knowledge of the subject.
- 22.5.3.4. All training instructors shall be experienced in the subject matter, trained in adult education training techniques, technically knowledgeable, and fluent in English.
- 22.5.3.5. All training instructors shall be familiar with NYCT Policies and Procedures, especially those concerning train operation and maintenance.

22.5.4. Train-the-Trainer Program

- 22.5.4.1. The Contractor shall provide a “Train-the-Trainer” component for each training module.
- 22.5.4.2. The Contractor shall deliver up to three “Train-the-Trainer” sessions for each training module. The first module is considered a pilot course.
- 22.5.4.3. The Contractor shall conduct a pilot course for each module to demonstrate the effectiveness of Instructor’s Guide, training material, and training aids. Each pilot session shall be attended by an NYCT-appointed committee to evaluate the training module and recommend changes as required.
- 22.5.4.4. The Contractor shall incorporate all NYCT’s feedback, comments, and requested changes from both pilot and other subsequent instructor training sessions within 30 days. Should any significant change be required, NYCT reserves the right to request a repeat of a pilot course.
- 22.5.4.5. The “Train-the-Trainer” pilot course shall be twice the duration and content of the corresponding regular training session module.
- 22.5.4.6. The instructor trainees shall have the right to record video of any training session that is presented by the Contractor.
- 22.5.4.7. Before submittal to NYCT for review and approval, the Contractor shall ensure that all final versions of instructor training sessions include material that is directly related to applicable subject; is accurate, complete, and logically organized; and is easily understood by trainees.
- 22.5.4.8. All the material and hardware, training aids or special tools shall become the property of NYCT upon the start of Train-the-Trainer program.

22.5.5. Training Aids

General Requirements

- 22.5.5.1. The Contractor shall be responsible for preparing and providing copies of all training manuals, Bill of Materials (BOMs), drawings, schematics, troubleshooting guides, and distribution of any other training handouts.

- 22.5.5.2. The Training Aids shall contain, as applicable, an interactive technology, audiovisual instructional media and/or other applicable hardware needed to support the subject training session.
- 22.5.5.3. Presentations depicting hydraulic, pneumatic, and air-conditioning systems shall be animated and include direction of flow for the particular medium.
- 22.5.5.4. The Contractor shall provide 3-D drawings and renderings of car arrangement in electronic format, to illustrate the location of major car equipment, subassemblies, and components.
- 22.5.5.5. All illustrations and diagrams shall display the equivalent 3-D animation or isometric views, as approved by NYCT, as they would be seen from the viewpoint of a person actually operating, troubleshooting, or repairing the equipment.
- 22.5.5.6. Contract spare parts or assemblies shall not be used for training purposes. In cases where an actual piece of equipment is required to support training, the Contractor shall supply adequate quantities of fully functional demonstration units, marked with suitable type label stating "FOR TRAINING USE ONLY." Units for training purposes shall be serialized per NYCT specification #8023-GENL-01, see Appendix C-34.
- 22.5.5.7. Final versions of proposed training aids shall be delivered and demonstrated to NYCT for approval 90 days prior to the start of training. The Contractor shall ensure that applicable calibrations have been performed, all functions verified, and training objectives can be fulfilled as intended by the demonstrated item.
- 22.5.5.8. Final versions of all training aids shall become the property of NYCT upon the completion of the training program.

Video Recordings

- 22.5.5.9. The Contractor shall arrange to record professional quality videos (minimum HD and 16:9 aspect ratio) to illustrate the key concepts of maintainability for all major subsystems including [CDRL]:
 - a) CBTC carborne equipment (See Section 25 for Cab Signaling for SIR Units).
 - b) Propulsion.
 - c) Side Doors and Controls.
 - d) CCTV.
 - e) Braking System.
 - f) All Auxiliary Power Equipment.
 - g) HVAC.
 - h) Communications.
 - i) Air Compressor Unit.
 - j) Monitoring and Diagnostics System
- 22.5.5.10. These videos shall become the property of NYCT, distributed on digital storage media and used during the training program.
- 22.5.5.11. The Contractor shall arrange to record professional quality video of all final training sessions for each course. These video records shall become the property of NYCT.

Interactive Technology Modules

- 22.5.5.12. Interactive technology based training modules shall be provided for all major subsystems such as CBTC carborne equipment, OPTO, Propulsion, Side Doors and Controls, car CCTV (including protocol

for access and chain of custody) and Platform Edge CCTV, Brakes System, Air Compressor, Auxiliary Power, HVAC, Communications, and Open Gangway.

- 22.5.5.13. The interactive technology based training modules shall be self-contained, with a runtime limited to 30 minutes each. All modules shall incorporate voice-over instructions, audio that simulates equipment operations, and quiz/exercises with interactive responses to answers including the follow-up questions for incorrect responses.
- 22.5.5.14. The interactive technology training modules shall contain either a video clip or an animated simulation demonstrating how the system or subsystem behaves and fails when operating in the intended environment, and how to diagnose, isolate, and repair typical defects.
- 22.5.5.15. The interactive modules shall include troubleshooting exercises to score students' responses based on the time used to remedy typical type of fault or defect.
- 22.5.5.16. The interactive computer based training modules covering operation and layout of the cab controls shall be provided to facilitate the training of Train Operators (T/O).
- 22.5.5.17. The T/O interactive training modules shall have the same specifications as above.
- 22.5.5.18. The T/O training modules shall contain diagnostics and isolation procedures to teach T/Os how to facilitate multiple malfunction scenarios, including the following:
 - a) Brake Pipe Rupture.
 - b) Coupler Pipe Rupture.
 - c) Brake In Emergency (BIE) Carborne Tripping Device-Train Recharges/Train Does Not recharge.
 - d) Stuck Brakes-Service Brakes, Parking Brakes.
 - e) Recovery of Dead Train.
 - f) Passenger Emergency Handle Unit – Pulled in Station or Pulled Between Stations.
 - g) Emergency Brake Handle – Train Does Not Charge.
 - h) Door Obstruction, Cutting Out Doors.
 - i) Defective Door, No Obstruction Found/Obstruction Found.
 - j) Isolating a car.
 - k) Programming of Train Operator's Display.
 - l) Procedure for Installation of Coupler Adapter.
 - m) Brake Release Bypass Operation.
 - n) Main Reservoir Rupture.
 - o) Side Door Bypass.
 - p) Special Charge Feature.
 - q) Train Operators Display (TOD) for Troubleshooting.
- 22.5.5.19. Any modifications to the car design during the warranty period shall be incorporated into the corresponding interactive computer-based training modules.
- 22.5.5.20. All interactive, computer-based training modules shall be approved by NYCT prior to delivery. The modules should be minimum Sharable Content Object Reference Model (SCORM) 1.2 compliant with full integration capability to Oracle's Enterprise Learning Management System.

22.5.6. Hardware Associated with Training Aids

- 22.5.6.1. All hardware based Training Aids shall be delivered to NYCT's Operations Training prior to the beginning of corresponding pilot session, and shall become the property of NYCT.
- 22.5.6.2. The Contractor shall supply mock-ups, scale models, and sample hardware as required to support the training efforts at the Maintenance and Overhaul Shops.
- 22.5.6.3. The Contractor shall provide diagnostic test equipment, desktop and laptop computers, and media projectors in the quantities specified in the Table 22-2.
- 22.5.6.4. Laptops shall be loaded with applicable PTE diagnostic tools and computer-based training software applications, including the electronic version of technical manuals.
- 22.5.6.5. The Contractor shall supply workstations in quantities specified in Table 22-2, to support general training purposes. The workstations shall be loaded with commercially available publishing software featuring text processing and integration of scalable vector graphics for illustrations.
- 22.5.6.6. Supplied laptops, media projectors, and workstations shall comply with the requirements of Section 22.9.1.
- 22.5.6.7. The Contractor shall supply two complete sets of Special Tools and Gauges furnished with carrying cases or fixtures as appropriate, to support the Training Program, in quantities specified in Table 22-2.
- 22.5.6.8. These tools and gauges shall be marked using suitable type labels populated with letters at least 1 inch (2.5 cm) high, stating "FOR TRAINING USE ONLY." Items for training purposes shall be serialized per NYCT Specification #8023-GENL-01, see Appendix C-34.

22.5.7. Train Operator and Conductor Training

- 22.5.7.1. The Contractor shall provide training courses for Conductors (C/R) and Train Operators (T/O).
- 22.5.7.2. The Train Operator and Train Conductor training course shall consist of appropriate theory and practical application, and shall enforce the material presented in the TOM.
- 22.5.7.3. The training course structure shall include operating sessions, in Manual and CBTC mode under ATO/ATPM, to enable trainees to obtain a proper knowledge about the actual train operations and operating cab experience in maintenance yards and on the mainline.
- 22.5.7.4. The training course shall include Side Door Operation for crew operating in both two-person and OPTO scenarios.
- 22.5.7.5. The training course shall also include sessions on troubleshooting procedures and recovery operations.
- 22.5.7.6. An NYCT-qualified instructor or supervisor shall accompany the Contractor's instructor to ensure compliance with existing NYCT safety regulations and procedures.

22.5.8. Road Car Inspector Training

- 22.5.8.1. The Contractor shall provide a Road Car Inspector Training course.
- 22.5.8.2. The Road Car Inspector Training course shall consist of appropriate theory and practical application, to enforce the material presented in the Road Car Inspector's Pocket Manual.
- 22.5.8.3. The training course structure shall include inspection, service, maintenance, and troubleshooting sessions broken down into modules for each system, to enable trainees to obtain an in-depth knowledge about the actual train functions and operations.

- 22.5.8.4. An NYCT-qualified instructor or supervisor shall accompany the Contractor's instructor to ensure compliance with the existing NYCT safety regulations and procedures.

22.5.9. Maintenance Training

- 22.5.9.1. The Contractor shall provide the Maintenance Training courses in two phases, in accordance with requirements of Section 22.5.2.
- 22.5.9.2. The first phase of maintenance training shall include theory of operation, system and equipment description, on-car demonstrations, use of tools and test equipment to train a designated group of NYCT Instructors, Car Inspectors, and Maintenance personnel to maintain, inspect, troubleshoot, and operate cars through the warranty period.
- 22.5.9.3. The second phase of maintenance training course shall include theory of operation and in-depth shop demonstrations concerning heavy maintenance repairs, overhaul and rebuild procedures, use of recommended tools, and portable and bench test equipment, intended to train a group of designated car equipment maintenance personnel to maintain cars and carborne equipment through the car's life.
- 22.5.9.4. In addition, as part of the second phase of maintenance program, a training course shall also be provided to a group of designated instructors and maintenance personnel to teach materials related to functionality, troubleshooting, repair, reprogramming, calibration, and alignment of electronics modules and BTEs, and use of test tools and associated BTE. This program shall consist of theory and shop demonstrations at NYCT's Central Electronics Shop.
- 22.5.9.5. Classroom instruction for maintenance courses shall include the relevant details related to function and upkeep of components and materials, lubrication schedule, tolerance limits, recommended test frequency, test methods, and required tools and instruments as applicable.
- 22.5.9.6. When methods of access, removal, dismantling, reassembly, or application are not self-evident, the instruction shall cover these matters.

22.5.10. Management Familiarization Training

- 22.5.10.1. The Contractor shall provide a "Familiarization of New Equipment" course to a group of designated Management, Operations Control, and Materials Coordination staff.
- 22.5.10.2. This course shall cover all subjects taught in other training courses.
- 22.5.10.3. The content of this course shall be scaled down to an Executive Summary format.

22.5.11. Parts Catalog Seminar

- 22.5.11.1. The Contractor shall provide a Parts Catalog Seminar to a designated group of NYCT Material Coordinators and Operations Support personnel.
- 22.5.11.2. This course shall cover car, subsystem, equipment, and component familiarization.
- 22.5.11.3. This course shall be held during regular working hours at a location(s) designated by NYCT.

22.5.12. Field Instructions and Warranty Field Instructions Training

- 22.5.12.1. In addition to formal training during the warranty period, the Contractor shall also provide field training for a selected group of NYCT's qualified maintenance personnel.

- 22.5.12.2. The format of this training shall be a hands-on apprenticeship type instruction, presented by skilled instructors having a thorough knowledge and experience in maintenance, service, and operations as required.
- 22.5.12.3. The focus of this training shall be on the actual car operations, car equipment controls, maintenance, inspections, troubleshooting and repair tasks, reporting procedures, and corrective measures.
- 22.5.12.4. The actual field work shall be done by NYCT maintenance personnel, supervised by the Contractor, and performed in accordance with NYCT's operating rules and regulations.
- 22.5.12.5. The Contractor's instructor shall be accompanied by NYCT's qualified instructor or supervisor to ensure that all NYCT rules and procedures are properly followed.
- 22.5.12.6. At the Contractor's expense, the Contractor may request to provide a portion of field instructions at its own or subcontractor's facilities, for special training and in accordance with the Training Schedule.

22.5.13. Network Training

- 22.5.13.1. The Contractor shall provide comprehensive, student paced, "hands-on" network IT training classes complete with full documentation. Two series of classes shall be provided:
 - a) The first series shall cover basic network theory, operation, function and standard networking techniques for monitoring and diagnosing the car's networks.
 - b) The second series shall be specifically to train authorized NYCT personnel on how to modify, upgrade, and add new network devices to the car networks.

22.6. Spare Parts

22.6.1. General Requirements

- 22.6.1.1. The Contractor shall supply Capital and Non Capital spare parts in the quantities specified on the Form PF-3, R211 Contract Terms and Conditions.
- 22.6.1.2. In addition, the Contractor shall provide recommended spare parts lists summarizing the warranty spares, consumable, replacement, repairable, and overhaul parts. The lists shall also include the recommended quantities, Original Equipment Manufacturer (OEM) part numbers and description, pricing, estimated lead-times, and anticipated consumption rates.
- 22.6.1.3. The recommended quantities shall be based on the estimated reliability of the part or system, the lead-time for delivery, and the cost of replacement versus repair for each part.
- 22.6.1.4. Consumable parts are defined as parts or materials that require routine change-out as part of planned maintenance. These parts are not expected to be used again.
- 22.6.1.5. Replacement parts are defined as parts that are not replaced on a regular basis and that can be expected to fail randomly.
- 22.6.1.6. Overhaul parts are defined as parts which are expected to be replaced at scheduled intervals, typically as part of NYCT's Scheduled Maintenance System (SMS), and which, once replaced, are expected to be remanufactured, overhauled, or reconditioned for future use.
- 22.6.1.7. Repair parts are defined as parts that are not expected to be replaced on a regular basis, but which may require a replacement from time to time due to accidents, vandalism, abuse, or random failure.

- 22.6.1.8. The recommended spare parts list should include information about dual sourcing where practicable.
- 22.6.1.9. The Contractor shall provide a draft of each list for NYCT's review and approval, at least 90 days prior to delivery of the first Unit.
- 22.6.1.10. The parts lists shall be updated as required through the duration of the Contract.
- 22.6.1.11. The final version of each spare parts lists shall be delivered with the completion of warranty of the first production Unit.
- 22.6.1.12. All replacement parts, including those for SMS and repair, shall be commercially available for a minimum of 20 years.

22.6.2. Parts and Device Identification

- 22.6.2.1. The Contractor shall utilize the Asset Identification System as specified in NYCT Specification #8023-GENL-01, Appendix C-34, to tag and uniquely identify all LRUs, and all other replaceable components on the cars, all portable test equipment, gauges, special tools, and spare parts.
- 22.6.2.2. Paper labels shall not be used.
- 22.6.2.3. For non-serialized components, the bar code labels shall uniquely identify the manufacturer and part number.

22.6.3. Warranty Spares

- 22.6.3.1. The Contractor shall supply Warranty Spare Parts to support car maintenance during the warranty period without any additional cost to NYCT.

22.6.4. Recommended Consumable Parts

- 22.6.4.1. The Contractor shall provide a list of recommended consumable parts necessary to maintain the cars on an annual basis coordinated to the regular inspection cycles within this 1-year period. The list shall be consistent with the Contractor's recommended maintenance practices. The list shall include the OEM name and part number. **[CDRL]**
- 22.6.4.2. The recommended quantities of consumable parts shall be based on the estimated service life of the part or system, the lead-times for delivery, and the cost of replacement versus repair for each part.
- 22.6.4.3. To mitigate supply chain risks, the Contractor shall identify, and NYCT shall approve, as necessary, second sources of supply of consumable components so that they can seamlessly, and with applicable configuration change control, allow for interchangeability of one supplier's functionally equivalent component with an alternative supplier's component.
- 22.6.4.4. Dual sourcing requires identification of two completely independent suppliers or manufacturing facilities with no overlap in their supply chains. Both suppliers shall offer equivalent parts with respect to both physical properties and functional performance.

22.6.5. Recommended Replacement Parts

- 22.6.5.1. The Contractor shall provide a list of recommended replacement parts necessary to maintain the cars, based on the Contractor and subcontractor's prior experience with the equipment and on the maintenance requirements of NYCT defined in NYCT document SMS #08-002 "Generic Passenger Car Worksopce", see Appendix C-36. The list shall include the OEM names and part numbers. **[CDRL]**

22.6.5.2. The replacement parts shall be used after the completion of the warranty period.

22.6.6. Recommended Repairable Parts

22.6.6.1. The Contractor shall provide a list of recommended repairable parts necessary to maintain the cars, based on the Contractor and subcontractor's prior experience with the equipment and on the maintenance requirements of NYCT defined in NYCT document SMS #08-002 "Generic Passenger Car Workscope"; see Appendix C-36. The list shall include the OEM names and part numbers. **[CDRL]**

22.6.7. Recommended Overhaul Parts

22.6.7.1. The Contractor shall provide an overhaul parts list, identifying the parts necessary to support a continuous, ongoing overhaul program for each subsystem. The list shall include the OEM names and part numbers. **[CDRL]**

22.6.7.2. The overhaul parts list shall be consistent with the Contractor and subcontractors' recommended maintenance practices, and align with NYCT's scheduled maintenance requirements defined in NYCT document SMS #08-002 "Generic Passenger Car Workscope", see Appendix C-36.

22.6.7.3. Overhaul part kits shall be provided for each system or subsystem as applicable.

22.6.7.4. The Contractor shall design and supply individual shipping boxes, in accordance with Form PF-3, to be used by NYCT to transport SMS parts between NYCT Maintenance and Overhaul Shops.

22.7. Special Tools and Test Equipment

22.7.1. General Requirements

22.7.1.1. The Contractor shall provide all special tools and gauges in compliance with Form PF-4, R211 Contract Terms and Conditions.

22.7.1.2. The Contractor shall survey NYCT's existing supply of special tools. Following the survey, the Contractor shall provide a list of proposed special tools, with justification, for use as part of the Critical Design Review (CDR) process, for NYCT review and approval. **[CDRL]**

22.7.1.3. The Contractor shall provide all the tools on the approved list, in noted quantities, per the schedule defined in *Table 22-4*.

22.7.1.4. The Contractor shall secure its own gauges and special tools necessary to maintain delivered cars during the warranty period. Gauges and tools delivered to NYCT will not be available to the Contractor.

22.7.2. Gauges and Special Tools

22.7.2.1. Special tools shall include, but shall not be limited to, production and test jigs, gauges, fixtures, hand tools, power tools, wire and cable crimp tool, PCB extenders, or other equipment necessary to inspect, calibrate, adjust, maintain, repair, disassemble, and assemble a car or its subsystems, that are not commonly available from commercial tool suppliers.

22.7.2.2. All special tools shall be supplied along with complete manuals explaining their use, care, and maintenance. The drawings shall include all dimensions, material, parts list, and condemning limits.

22.7.2.3. To support the training courses, two sets of gauges and special tools shall be provided to NYCT prior to delivery of pilot training sessions.

- 22.7.2.4. Gauges and special tools needed for maintenance and inspections shall be those devices that the Contractor refers to in the Work Manual. See Section 22.3.7.
- 22.7.2.5. Gauges and special tools needed for repair and overhaul of the cars shall be those devices that the Contractor refers to in the Overhaul Process Manual. See Section 22.3.8.
- 22.7.2.6. Documentation and drawings related to gauges and special tools shall be included in the Contractor's CDR documents, and shall be reviewed as part of the CDR.
- 22.7.2.7. The Contractor shall supply user manuals for all supplied tools and gauges, containing explanations about the use of tools, and testing methods where applicable.
- 22.7.2.8. The Contractor shall supply manufacturing drawings and parts lists for all special tools and gauges, to enable NYCT to order additional quantities of special tools beyond those required by the Contract.
- 22.7.2.9. The Contractor shall also provide shipping containers and fixtures for all gauges and special tools in accordance with Form PF-4, R211 Contract Terms and Conditions. These containers shall be designed to last a minimum of 20 years, and suitable for transporting, shipping, and storing the equipment and LRUs.
- 22.7.2.10. Details of shipment provisions shall be presented as part of the CDR. NYCT may grant a waiver for equipment that is designed to be shipped without any special treatment.
- 22.7.2.11. The Contractor shall provide coupler adapters as required by Section 4.4.4.
- 22.7.2.12. Any special tools required for proper maintenance and calibration of the BTE shall be supplied as part of the BTE deliverables.

22.8. Diagnostic Test Equipment

22.8.1. General Requirements

- 22.8.1.1. The Contractor shall provide Diagnostic Test Equipment (DTE) in compliance with Form PF-5, R211 Contract Terms and Conditions. The DTE shall be capable of comprehensive testing and diagnosis of the car and all of its on-board systems, to aid the maintenance staff in maintaining, troubleshooting, software parameter modification, and calibration of car equipment.
- 22.8.1.2. A complete parts list, drawings, and user manuals relating to testing, inspection, troubleshooting, and repair of test equipment, including PTE and BTE, shall be included in Contractor's CDR documents, and shall be reviewed as part of CDR.
- 22.8.1.3. At the time of Preliminary Design Review (PDR), the Contractor and NYCT shall determine and agree upon the final specifications for the workstations and PTE laptops. The approved equipment shall be the most recent generation, in the top 10 percent of performance available on the market at the time of the purchase in terms of durability, processing power, capacity, capable of running the latest software packages on NYCT's approved Operating System (OS).
- 22.8.1.4. Peripheral hardware such as printers, external drives, scanners, etc., are one per workstation (PC) setup unless otherwise stated. The workstation computer shall be equipped with a high resolution video card and large screen monitor.
- 22.8.1.5. The delivered systems shall conform to the industry standard at time of delivery to ensure they are capable of running software packages current at the time of delivery.

- 22.8.1.6. The manufacturers of the PC, monitor, and external components shall be approved by NYCT and supported by NYCT's system-wide PC maintenance contractors at the time of delivery.
- 22.8.1.7. Any commercial packages (such as the operating system, Microsoft Office or open source equivalent, etc.) shall be NYCT approved versions.
- 22.8.1.8. As a minimum, the computer performance of the workstations shall meet or exceed the following preliminary requirements:
- a) Delivery year equivalent of an Intel Core i7-4790, 8M cache, 4.00 GHz computer.
 - b) 32 GB of RAM Dual Channel DDR3 1600 MHz and 2 TB 7200 rpm SATA hard drive 6.0Gb/s + 256 GB SSD. The memory needs (RAM and hard drive) of the installed software shall not utilize more than 50 percent of the installed RAM memory or 35 percent of the hard drive space.
 - c) Secondary internal 2 TB backup hard drive for RAID (Redundant Array of Inexpensive Disks) or equivalent to backup primary hard drive.
 - d) Two TB external portable hard drive with backup software.
 - e) PC backup and restore software such as Norton Ghost with system restore technology.
 - f) Ethernet 10/100/1000 Network Interface Card.
 - g) 802.11 ac Wi-Fi Wireless networking capability, IEEE 802.11a/b/g/n compatible.
 - h) HD R9 270 GDDR5 video card with 2GB dedicated RAM.
 - i) 101-key keyboard.
 - j) Scrolling optical USB mouse.
 - k) Card Readers for various types of commonly available Media Cards.
 - l) Two internal Blu-ray Combo Drives (able to read Blu-Ray Disc and write to DVD/CD).
 - m) 27-inch wide Ultra HD screen with a resolution of 2560 × 1440.
 - n) Professional laser printer (networkable) that prints at least 23 pages per minute (PPM). Paper size capacity (letter, legal, or tabloid) and ability to print in color is determined by requirements of basic documents to be printed. All printers shall be able to automatically perform two sided printing. PPM rate may be waived for specialty printers.
 - o) Scanner capable of duplex scanning at 50 images per minute with Optical Character Recognition (OCR) and PDF or applicable open source capture software.
 - p) Software required or used by supplier during development to run the applications on the system, including the latest NYCT approved version of Microsoft Office or open source equivalent, and all required media and software to support the applications and re-initialize the workstation. The PTE and BTE software shall have a straight-forward install and setup procedure similar to COTS software.
 - q) Appropriate cables, and accessory software shall be provided for all ancillary equipment. In lieu of CDs or DVDs, other storage media may be furnished subject to NYCT approval.
- 22.8.1.9. The detailed functions of all test equipment shall be presented during the subject system design review. The capabilities and functions of all test equipment shall be as approved by NYCT.

- 22.8.1.10. If at any time during the project, up to the end of the general warranty on the last car and the Specific Guarantees/Warranties under Article 908 (4), it is determined that the test equipment does not properly log or isolate faults, or fails to perform any of its intended functions, the Contractor shall reprogram or modify the equipment as necessary at its own expense. The warranty for DTE shall be extended by the time period required to resolve these issues.
- 22.8.1.11. The Contractor shall make any and all modifications to the test equipment defined by this Specification, if at any time during the project, up to the end of the general warranty on the last car and the Specific Guarantees/Warranties under Article 908 (4), it is determined that changes and modifications need to be made to the car, or any of its subsystems, the Contractor shall make any and all modifications to the test equipment as defined by this Specification.
- 22.8.1.12. The Contractor shall submit for review and approval, a description of the PTE for each system, listing interfaces, hardware configuration, user manual, and recommended operation of PTE.
[CDRL]
- 22.8.1.13. At the end of the warranty period, the Contractor shall provide to NYCT the development tools and licenses necessary to modify all BTE and automated test application software.
- 22.8.1.14. All software for BTEs shall allow NYCT to make future upgrades.
- 22.8.1.15. The Contractor shall arrange for First Article Inspection (FAI) and Factory Acceptance Test (FAT) for both BTEs and PTEs at a location to be agreed upon by NYCT and the Contractor, and shall provide notice to NYCT as defined in Section 23.7.1.3.
- 22.8.1.16. Prior to delivery of BTE(s) to NYCT, the Contractor shall arrange for Pre-Acceptance Inspection at the respective facilities, to validate that the BTE meets all stated requirements.
- 22.8.1.17. During the Unit Qualification Testing of first production Unit, the Contractor shall arrange for an FAI to validate that the PTE meets all stated requirements.

22.8.2. Definitions

- 22.8.2.1. For the purpose of this Section, **Level 1 Type Maintenance** shall be defined as activities involving troubleshooting and maintenance of car equipment down to the LRU level. Such activities may include diagnostics and recovery of system data, repair by replacement of LRUs, and functional testing of the car system or subsystem.
- 22.8.2.2. **Level 2 Type Maintenance** shall be defined as activities involving troubleshooting and maintenance of car equipment down to the LLRU level (i.e. PCB or subassembly). Such activities typically require full functional testing and corresponding corrective action(s).
- 22.8.2.3. **Level 3 Type Maintenance** shall be defined as troubleshooting and maintenance of car equipment down to a discrete or integrated circuit component level, including but not limited to LLRU repair, replacement of components, testing, and validation of the repair or installation.
- 22.8.2.4. Level 2 and Level 3 Type Maintenance shall be conducted independently.

22.8.3. DTE Software Documentation and Maintenance Manuals

- 22.8.3.1. The Contractor shall provide DTE Software Maintenance Manuals (SMM) as needed to administer and maintain the software based diagnostics and inspections equipment. The DTE SMMs shall meet the general requirements for SMMs described in Section 22.3.12.
- 22.8.3.2. The format and content of DTE SMM shall be limited to the information necessary to complete the stated task as it pertains to operation, function, maintenance, repairs, and recovery of the equipment.

- 22.8.3.3. The content of DTE SMM shall contain procedures needed to perform version control and configuration management of the system.
- 22.8.3.4. The DTE SMM shall contain sufficient level of information to help operator perform operations such as initiating and interpreting of diagnostics, starting and configuring of system, reinstalling, and recovery.
- 22.8.3.5. The DTE SMM shall include description and functions of application programs, respective modules and their roles.
- 22.8.3.6. The Contractor shall provide a development and maintenance utility tool to support software installation, interface, debugging, monitoring, and system recovery.

22.8.4. Data Rights and Source Code Listings

- 22.8.4.1. At the end of the warranty period, the source code for the PTE and BTE software applications shall be provided to NYCT to retain, per Contract Terms and Conditions Article 105 B, and Section 18.3.
- 22.8.4.2. The data rights relating to PTE/BTE source codes and software applications, including software modules, file structures, database records, tables, internal lists and test scripts shall comply with terms of Section 18, Software Systems.

22.8.5. PTE Functional Requirements

- 22.8.5.1. The Contractor shall supply Portable Test Equipment (PTE) capable of accessing all carborne intelligent microprocessor based subsystems over the car network via a centralized MDS Ethernet port in the Cab, wirelessly via the MDS (see Section 17.3.2), or directly from the subsystem's local Ethernet port. Also see Section 18 – Software Systems for related cyber security requirements.
- 22.8.5.2. At minimum, the PTE shall include all functions required to support Level 1 Type Maintenance.
- 22.8.5.3. The interconnecting carborne intelligent microprocessor subsystem shall be capable of recording data from all its sensors and actuators. A record of related activities and conditions shall be stored in memory whenever a particular fault or event is set, to allow diagnosis of intermittent problems via the respective PTE application.
- 22.8.5.4. The PTE shall allow access to systems via a main screen. Access to system functions shall be from menus resident within the PTE software, allowing interaction with subsystem's control process, real-time monitoring, displaying of fault, downloading, and configuring of parameters.
- 22.8.5.5. The PTE shall be capable of downloading and verifying a system application software. A password protected mode shall be provided when downloading or configuring parameters.
- 22.8.5.6. The PTE shall have a graphical user interface using plain English language and consistent with car terminology, e.g., valves are open or closed, contactors are ON or OFF. Look-up tables or references to translate the error codes are not permitted.
- 22.8.5.7. The PTE shall be capable of providing a sufficient level of information to enable a test technician to perform Level I type maintenance, including diagnosis and functionality checks of a system, and locating and replacing any component that is fully or partially failed.
- 22.8.5.8. All PTE user manuals shall be included on the PTE device.
- 22.8.5.9. PTE software manipulation shall be adequately protected against the inadvertent parameter changes that might adversely affect the safe operation of equipment or car.
- 22.8.5.10. The Contractor shall supply all PTE software modules, and a master copy and license for each PTE application.

- 22.8.5.11. The Contractor shall supply the PTEs and cables in quantities noted in Table 22-2.
- 22.8.5.12. Each PTE shall support and be equipped with an industrial quality Bar Code Reader to allow tracking of replacement parts.
- 22.8.5.13. PTE shall be capable of operating using the built-in battery or via AC power adapter. The minimum run time for battery shall be 6 hours.
- 22.8.5.14. It shall not be necessary to remove, dislodge, dismount, or disconnect any component, card, wire, chassis, terminals, or cable in order to perform periodic calibration or diagnostics using the PTE.
- 22.8.5.15. The Contractor shall develop a general PTE interface requirement for all subsystems that is consistent with the details below and including all relevant sections of the Technical Specification. This general PTE interface specification shall be used to ensure a “common layout” for all PTE applications regardless of the supplier, and shall be submitted to NYCT for approval as part of the Preliminary Design Review (PDR).
- 22.8.5.16. At the minimum, the PTE shall be capable of performing the following functions as applicable:
- a) Recover system data.
 - b) Download, view, and analyze fault events and data logs collected from the respective system.
 - c) Read and playback any memory storage units removed from the car.
 - d) In real-time, safely generate test commands, set initial test conditions, read statuses, measure, view, and log signals necessary to fully exercise and assess the functions of the system under test.
 - e) Measure, gauge, and indicate all of the signals, responses, and outputs generated by the system under test via graphical user interface(s).

22.8.6. PTE Physical Requirements

- 22.8.6.1. The PTE shall perform under the environmental conditions imposed by activities of the car inspection and repair shops, with temperatures ranging from 20°F to 115°F (-7°C to 46°C) in the test area.
- 22.8.6.2. The PTE shall be a completely portable, state-of-the art, high performance military grade terminal, suitable for rough handling during use on the shop floor, pit location, car, or in the yard.
- 22.8.6.3. The approved equipment shall be the most recent generation, in the top 10 percent of performance available on the market at the time of the purchase in terms of processing power and capacity, capable of running the latest software packages on the NYCT-designated OS, and software applications required to view or run all the downloaded information from any car system.
- 22.8.6.4. The laptop PC PTEs shall meet or exceed the following preliminary requirements:
- a) Toughbook, or suitable equivalent.
 - b) Delivery year equivalent of an Intel Core i7-4790, 8M cache, 4.00 GHz laptop computer.
 - c) 32 GB of RAM Dual Channel DDR3 1600 MHz.
 - d) Solid state hard drive, with a minimum capacity of all software plus 7 days’ worth of stored data and 100 percent free data processing space and no less than 2 TB. The hard storage shall

also be capable of storing all system and subsystem test software and fault log downloads from an entire work shift.

- e) Secondary internal 2 TB backup hard drive for RAID (Redundant Array of Inexpensive Disks) or equivalent to backup primary hard drive.
- f) 2 TB external portable hard drive with backup software.
- g) PC backup and restore software such as Norton Ghost with system restore technology.
- h) Ethernet 10/100/1000 Network Interface Card.
- i) 802.11 ac Wi-Fi Wireless networking capability, IEEE 802.11a/b/g/n compatible.
- j) Internal Blu-ray Combo Drive (able to read Blu-Ray Disc and write to DVD/CD).
- k) USB and FireWire ports.
- l) Anti-theft lock.

22.8.6.5. The laptop PTE shall comply with the MIL-STD-810G, certification for 3 feet drop or equivalent, and IEC 60529 IP53 Dust and Moisture protection requirements.

22.8.6.6. The laptop PTE shall be protected and housed in a lightweight suitcase-type enclosure with removable cover suitable for use in a shop environment, and equipped with custom built lightweight interface backplate, unless otherwise approved by NYCT.

22.8.6.7. All meters supplied as part of the PTE shall be of variety capable of withstanding industrial service.

22.8.6.8. The weight of a portable computer based PTE shall not exceed 8.5lb (3.8 kg) without prior approval by NYCT.

22.8.6.9. For PTE that does not consist of a PC, the response and output indicators, including input generators shall be of industrial grade, and weight shall not exceed 30 lb. (13.6 kg).

22.8.6.10. An existing PTE design that has been used on previous contracts that does not exceed the weight limit by more than a factor of 1.2 may be proposed for consideration and NYCT approval.

22.8.7. PTE Interface Connections

22.8.7.1. A local PTE interface connection port shall be provided for each subsystem.

22.8.7.2. In addition, a centralized PTE interface plug shall be located on the left side of the cab interior on an A car (see Section 5.7.7), and one behind a secured panel in the passenger area of the B car, as a means to access a subset of PTE functions.

22.8.7.3. A subset of PTE functions shall be accessible through the MDS for each subsystem (Section 17.3.7).

22.8.7.4. All connections shall be hand operated, robust, weather-tight, quick disconnect, and military grade, meeting the requirements of Section 19.25.5.

22.8.7.5. The PTE access ports shall have recessed pins to prevent bending and breakage.

22.8.7.6. A quick disconnect type connector shall be used for all pressure test fittings.

22.8.8. PTE Cables and Hoses

22.8.8.1. The PTE cable shall be compatible with the network interfaces specified in Section 16.5.2 to allow PTE connection to car systems.

22.8.8.2. A minimum number of cable connections shall be used to connect the test equipment to the Unit Under Test (UUT).

- 22.8.8.3. The connection cables shall be flexible, abrasion and oil resistant, and shall allow connection of PTE to the subsystem connector without the use of power converter.
- 22.8.8.4. The cable design shall protect cables and wiring from breakage by providing strain relief so that the weight of cable assembly, or connector does not damage the UUT, PTE, or Bench Test Equipment (BTE).
- 22.8.8.5. The cable connectors shall be molded.
- 22.8.8.6. The Contractor shall supply 40 cables to connect the PTE to the subsystem connector without the use of a power converter.
- 22.8.8.7. The connection cables and test hoses shall be stored inside the PTE case or backpack.

22.8.9. PTE Acceptance Testing

- 22.8.9.1. The PTE Acceptance Testing shall follow the criteria defined in Section 22.8.16, BTE Acceptance Testing.
- 22.8.9.2. The Contractor shall demonstrate all PTE features on a fully operational Unit, including the capability to detect and isolate the correct "faulty LRUs" following "fault insertion" exercises.

22.8.10. Bench Test Equipment

- 22.8.10.1. The Contractor shall supply Bench Test Equipment (BTE) as specified in Table 22-2, to support the back shop repairs and maintenance activities at Central Electronics Shop (CES), Overhaul Shops, and Maintenance Facilities.
- 22.8.10.2. At the minimum, the BTE shall feature all functions required to support Level 2 and Level 3 Type Maintenance.
- 22.8.10.3. For the purposes of this Specification, the terms Consolidated Automated Bench Test Equipment (CABTE) and Bench Test Equipment (BTE) shall be interchangeable.
- 22.8.10.4. The Contractor shall propose a single BTE platform that supports testing of multiple car subsystems to the maximum extent. The Contractor shall propose different variations of BTE to NYCT for review and approval.
- 22.8.10.5. The CABTE shall be based on an integrated test system known as a Core Tester. The Core Tester shall comprise one or more 19 inch racks containing a Computer Control Processing Unit, Human Interface System, power supplies, signal distribution, basic measurement instruments, Interface Test Adapter (ITA) and Unit Under Test (UUT) interface connection panel(s).
- 22.8.10.6. The baseline CABTE shall feature provisions to allow addition of specialized racks and reconfiguration into different types of testers to support testing of Communications and Controls, Radio Frequency and electro-optics, high power, electro-mechanical and pneumatics equipment.
- 22.8.10.7. The CABTE shall not utilize any electronic module, LRU, LLRU, PCB, or assembly that is part of the car system it is intended to test.
- 22.8.10.8. The BTE shall be designed primarily for operation at repair facilities and installation on Overhaul Shop benches, constructed to occupy the minimum space.
- 22.8.10.9. The BTE shall be designed to operate from a controller, computer, or an integral programming medium.
- 22.8.10.10. The BTE shall be designed as a tool for use by a maintenance specialist, and shall permit accurate and efficient servicing and maintenance of respective car subsystem and its components.

- 22.8.10.11. The BTE design shall follow the requirements of Section 19, Materials, Processes, and Workmanship where they are applicable. Alternative, industry accepted, standards for BTE may be proposed during design review.
- 22.8.10.12. Controls, displays, markings, coding, labeling, and arrangement scheme of BTE shall be uniform for common functions of all equipment and systems.
- 22.8.10.13. BTE design shall reflect ergonomic engineering to minimize factors that degrade human performance or increase error, to protect from acoustic noise, vibration, shock, and other hazards.
- 22.8.10.14. Fail-safe design principles shall be incorporated for those BTEs where a failure can cause catastrophic damage to equipment, injury to personnel, or inadvertent operation of critical equipment.
- 22.8.10.15. The BTE shall represent the simplest design consistent with requirements and expected operational conditions.
- 22.8.10.16. The BTE shall be capable of being operated and maintained in its operational environment by NYCT personnel with minimal training.
- 22.8.10.17. The Contractor shall survey NYCT's facilities (for space, power and air supplies and cleanliness etc.), to ensure the compatibility of the BTE design with NYCT's Overhaul Shop facilities.
- 22.8.10.18. The BTE shall be designed on the basis of available operating power in the Overhaul Shop in which the bench tester will be used, typically 120/208 Vac, 60 Hz with shop air pressures at 110 psi.
- 22.8.10.19. The BTE design shall incorporate provisions to allow future expansions and upgrades to be added to extend its test capacities as required.
- 22.8.10.20. Instrumentation or test equipment required to perform troubleshooting that cannot be designed into the BTE shall be provided as part of ancillary equipment and may include portable carts and commercially available test equipment such as an oscilloscope, function generator, frequency counter, digital multi-meters, and other hand tools and gauges as applicable. Ancillary equipment shall be subject to NYCT approval.
- 22.8.10.21. The connection cables and test hoses shall be easily repairable by the end user using standard shop tools. Any special tool required shall be provided as part of the BTE.
- 22.8.10.22. The Contractor shall provide User Manuals, troubleshooting, and repair procedures for each BTE, including the complete IPC, drawings, and schematic diagrams.
- 22.8.10.23. The BTE software documentation shall be prepared in accordance with the latest revision of IEEE 1558 standard, "Software Documentation for Rail Equipment and Systems".
- 22.8.10.24. The Contractor shall perform feasibility studies for submittal to NYCT, to determine if existing NYCT BTEs can be upgraded to be compatible with R211 equipment.
- 22.8.10.25. NYCT reserves the right to conduct FAIs on a complete BTE in accordance with requirements of Section 23.7.1.

22.8.11. BTE Functional Requirements

- 22.8.11.1. The BTE design shall feature functions to enable maintenance specialists to perform Level 2 and Level 3 maintenance of LRU and LLRUs.
- 22.8.11.2. The BTE shall be designed to facilitate the repair and calibration of mechanical, electrical, electronic, electromechanical, and pneumatic assemblies down to the LLRU level.

- 22.8.11.3. The BTE shall hold, position, electrically, and mechanically connect, cool as necessary, protect from electrical and mechanical damage, and provide suitable electrical test points to allow operation and facilitate testing and maintenance of the UUT for which it is designed.
- 22.8.11.4. The BTE for mechanical, electromechanical, and pneumatic equipment shall be a stand-alone specialized equipment capable of simulating the operating conditions of the UUT, testing and maintenance of high power, pneumatic and hydraulic equipment, and devices.
- 22.8.11.5. The BTE for electrical and electronics equipment shall generate, monitor, log, and display interface signals, and provide suitable functions and provisions to allow operation, facilitate testing and maintenance of individual electronic PCBs, and control and interface modules and assemblies.
- 22.8.11.6. The BTE shall feature functions to facilitate upload of fault and/or event logs from all intelligent systems for review, analysis, or troubleshooting.
- 22.8.11.7. Dials, indicators, and controls shall be of direct reading type, not requiring the use of calibration charts or curves.
- 22.8.11.8. The BTE diagnostic software shall detect failures in the UUT that result in any carborne equipment or system performance degradation. The UUT shall not require disassembly, or removal of conformal coating, to perform functional testing, unless approved by NYCT.
- 22.8.11.9. The BTE shall be based on a commercially available hardware platform provided by a BTE manufacturer, including all necessary firmware for full operation.
- 22.8.11.10. The UUT shall connect to the BTE using the local electrical connector(s) that are used for connection to a higher-level assembly; otherwise, appropriate test signal port-interfaces shall be provided.
- 22.8.11.11. In cases where a Joint Test Action Group (JTAG) interface is available on an LLRU, it shall be used to the extent possible for component testing, diagnosis and fault isolation.
- 22.8.11.12. Other than interfacing with existing UUT connectors, test probes shall not be used.
- 22.8.11.13. The BTE program shall feature automatic End-to-End (GO/NO-GO) functional type tests, diagnostic and fault detection tests, and rapid troubleshooting tests. Manual testing shall be allowed for items embedded within an LRU (i.e. switches, LEDs, displays, etc.) that require user intervention.
- 22.8.11.14. For End-to-End type tests, the BTE test program shall allow user to select a preferred "test entry point" from which to start the initial test sequence.
- 22.8.11.15. The test BTE program shall feature a "loop testing" mode for all test types (End-to-End, entry point, etc.). The user shall manually enter a number of loop-tests to be performed.
- 22.8.11.16. The BTE program shall feature a function to allow the user to manually repeat or abort the test sequence, and an option to bypass a failed test and continue with remaining test sequences.
- 22.8.11.17. An individual test report shall be generated for all LRU/LLRU/BTE/ITA self-tests, and displayed to the operator as the test progresses.
- 22.8.11.18. The test report for BTE and ITA self-tests shall include status and date of calibration measurement instruments. An option to save a test report shall be provided.
- 22.8.11.19. The BTE shall feature a function to save all generated test report(s) under a uniquely named file within the BTE. The test report format and file naming convention shall be approved by NYCT.
- 22.8.11.20. The BTE Operating System and Test Program Environment shall feature a client login option, hosting three levels of access including Administrator, Calibrator, and Operator type users.

- 22.8.11.21. An Administrator login shall allow user to gain full access rights to install, delete, modify, and compile all software files on the BTE computer.
- 22.8.11.22. The Calibrator login shall allow user to run executable UUT test programs, execute BTE and ITA self-tests programs, and update all test program calibration parameters.
- 22.8.11.23. An Operator login shall allow user to run executable UUT test programs, access to view and print test reports only (i.e. no write access).
- 22.8.11.24. The BTE shall include a network printer.
- 22.8.11.25. The BTE design shall allow loading of application firmware, network interface, and operational software(s) to all target (including in-circuit) programmable devices, at both LRU and LLRU levels.
- 22.8.11.26. The BTE design shall feature tools that allow calibration/validation of UUT to specified limits.
- 22.8.11.27. The BTE subsets shall reside at different NYCT Overhaul Shops, and shall be configured accordingly.

22.8.12. BTE Self-Test Capability

- 22.8.12.1. The BTE design shall feature an automated self-test program, capable of diagnosing its resident instrumentation and internal components.
- 22.8.12.2. The BTE self-test program shall exercise all its resident instrumentation and internal components within the operating ranges as used during the UUT testing.
- 22.8.12.3. Testing of BTE interface cabling shall be achieved via a wrap-around self-test feature to verify the operational integrity of all BTE instrumentation.
- 22.8.12.4. In the event that the BTE is configured as a passive device (wiring only), a wrap-around self-test feature must be incorporated into the BTE design.
- 22.8.12.5. The BTE self-test procedure shall determine if the bench test equipment is functioning properly, (GO/NO-GO) to the extent that the designated functions of the BTE will support UUT testing.
- 22.8.12.6. In the instance where the BTE self-test fails, the possible failed BTE instruments or individual components and associated internal cabling shall be listed by probability of failure.
- 22.8.12.7. The failed components shall be identified by the component designation defined in the schematic for the BTE.
- 22.8.12.8. The results of the BTE self-test shall always be displayed to the operator, saved by auto feature, and printed upon command.
- 22.8.12.9. Upon encountering a failure during BTE self-test, the diagnostic testing shall continue testing so that the malfunctioning instrumentation or component is defined.
- 22.8.12.10. The BTE Self-Test shall meet the fault isolation requirements and ambiguity group sizes for its instrumentation and individual, stand-alone components as noted in Table 22–6.

Table 22–6: BTE Instrumentation and Component Level Fault Isolation

Ambiguity Group Size	Percentage
3 or less	100%
2 or less	90%
1	80%

- 22.8.12.11. In the event that the maximum quantity of instruments and/or components in the BTE equals one of the listed ambiguity group sizes, the next lower ambiguity group size and associated percentage shall become the design goal.

- 22.8.12.12. Complete details (diagnostic flowcharts, test procedures, illustrated parts breakdown, application and test software and user manuals) shall be provided to facilitate upkeep and repair of BTE.
- 22.8.12.13. Complete parts lists and schematic diagrams of the bench test equipment shall be provided to enable its repair (with the execution of the BTE self-test program).
- 22.8.12.14. The results of the self-test shall always be displayed, saved by auto feature, and with an option to print.
- 22.8.12.15. Should the BTE encounter a failure during a self-test, the diagnostic self-test shall not stop until fully completed. The test result shall clearly indicate specific component(s) or major assembly failure, and list the recommended corrective action(s).

Test points required for monitoring or adjustments shall be properly marked and readily accessible.

22.8.13. BTE Performance Requirements

- 22.8.13.1. The BTE shall be capable of testing both intelligent microprocessor based and non-intelligent systems to support off-car repair and maintenance activities.
- 22.8.13.2. The BTE having an audible noise source shall not exceed the levels allowed by Occupational Safety and Health Administration (OSHA) 1910.95 Standard, "Occupational Noise Exposure".
- 22.8.13.3. The performance of BTE shall not be adversely affected when exposed to sea-salt atmosphere, dust particles, or humid and harsh operating conditions as may be encountered in NYCT's shops.
- 22.8.13.4. The BTE shall have a hook-up time of not greater than 10 minutes for any UUT.
- 22.8.13.5. The BTE shall have features that allow reprogramming of intelligent microprocessor based systems, and verification of installed software version(s) on the subject UUT.
- 22.8.13.6. The BTE shall feature a selection of automatic sequenced tests, continuous cycle tests, and/or manually selected specific loop-test modes to facilitate troubleshooting of the UUT.

The BTE shall feature Level 1, Level 2, and Level 3 diagnostic capabilities, as needed to detect and display test results in real-time, of all failures in the Unit-Under-Test (UUT) that result in degradation of equipment performance, and faulty components.

- 22.8.13.7. The BTU shall be capable of emulating the normal and threshold operating ranges of the UUT.
- 22.8.13.8. The BTE shall be capable of performing an automatic GO/NO-GO (End-to-End) and diagnostic tests to determine whether an UUT is functioning properly.
- 22.8.13.9. The hierarchical level of UUT testing shall begin from the LRU of the car subsystem.
- 22.8.13.10. The BTE shall allow the operator to fully exercise all functions by injecting signals into the UUT.
- 22.8.13.11. The BTE shall allow the operator to observe in real-time all signals and statuses of the UUT.
- 22.8.13.12. The BTE shall automatically generate and store a test report for each individual test instance and shall be capable of performing measurements, analyses, and verification of the test results against the expected values or acceptance criteria.
- 22.8.13.13. The BTE diagnostic software shall initially execute a GO/NO-GO test sequence to determine whether the UUT is functioning properly.
- 22.8.13.14. The GO/NO-GO test results shall be displayed to the operator, saved by auto feature, and with an option to print.
- 22.8.13.15. Following a successful detection of failure, a use of guided systematic manual probing of UUT, as part of the diagnostic test routines, shall be permitted.

- 22.8.13.16. As part of the manual probing sequence, the BTE instrumentation shall automatically acquire all test measurements, and evaluate the ensuing test results in terms of a pass/fail criterion.
- 22.8.13.17. In the event that LRU does not pass the diagnostic GO/NO-GO test, the BTE program shall continue testing of the UUT until the malfunctioning LLRU is identified.
- 22.8.13.18. In cases where a faulty LLRU cannot be uniquely identified, the BTE test program shall isolate all possible failed subassemblies according to the fault isolation requirements and ambiguity group sizes noted in Table 22-7.

Table 22-7: Level-2 maintenance, LLRU level fault isolation

Ambiguity Group Size	Percentage
3 or less	100%
2 or less	90%
1	80%

- 22.8.13.19. LRUs with common bus-structured architectures may not be bound by the percentage cited, but failures shall be detected and isolated to the smallest possible ambiguity group. Such LRUs shall include a troubleshooting guide and procedure to allow the most efficient means of fault isolation.
- 22.8.13.20. In the event that the maximum quantity of LLRUs within the UUT equals to one of the listed ambiguity group sizes, the next lower ambiguity group size and associated percentage shall become the design goal.
- 22.8.13.21. Upon the identification of suspect LLRU(s), the BTE shall feature an option to allow the operator to halt the test loop in order to facilitate the LLRU ambiguity group isolation.
- 22.8.13.22. The BTE diagnostics shall feature an independently executable test program to facilitate a stand-alone diagnostic testing of PCBs or subassemblies down to the component level. Such assemblies shall be tested as a standalone device disconnected from the higher level assembly.
- 22.8.13.23. The BTE test program shall continue testing until the malfunctioning discrete component is identified.
- 22.8.13.24. In the instances where discrete component cannot be uniquely classified, all possible suspected failed components, both active and passive, shall be identified.
- 22.8.13.25. The active components within the suspect list of overall failed components shall meet the fault isolation requirement and ambiguity group sizes as noted in Table 22-8.

Table 22-8: Level-3 maintenance, Active Component Level Fault Isolation.

Ambiguity Group Size	Percentage
4 or less	100%
3 or less	95%
2 or less	90%

- 22.8.13.26. The ambiguity group size shall never contain more than one Very Large Scale Integrated (VLSI) circuit (e.g., microprocessor, or controller) or one programmable (e.g. PAL or PGA) component.
- 22.8.13.27. PCBs with common bus-structured architectures will not be bound by the percentages listed above; however, failures shall be detected and isolated to the smallest possible ambiguity group.

22.8.13.28. Manuals for equipment using PCB with common bus-structured architecture shall include a troubleshooting guide indicating the most efficient means of isolating such bus faults.

22.8.14. BTE Interface Test Adapters

- 22.8.14.1. Each external connector on Interface Test Adapter (ITA) shall be equipped with an attachable or affixed protective cover.
- 22.8.14.2. ITA placement shall not require connecting or disconnecting any adjacent connector(s) during mate/de-mate action.
- 22.8.14.3. Power connector contacts supplying power shall have socket contacts, whereas those receiving power shall have pin contacts.
- 22.8.14.4. The BTE utilizing the ITA shall be capable of self-testing any attached test fixtures, adapters, or test cables and of isolating any shorts or opens.
- 22.8.14.5. The BTE shall be capable of isolating faults of the ITA. The possible failed components shall meet the fault isolation requirements and ambiguity group sizes as specified in Table 22-8.
- 22.8.14.6. The ITA shall be connectable to the Interface Connector Assembly (ICA) of the BTE.
- 22.8.14.7. The ITA shall capture and hold the UUT and shall utilize the I/O connector(s) of the UUT.
- 22.8.14.8. The total connection capability from the individual ITA to the ICA shall be of sufficient quantity to meet the requirements of the Level-2 Fault Isolation Ambiguity Group Size and Percentage (see Table 22-7).
- 22.8.14.9. The UUT shall be easily connected and disconnected from the ITA.
- 22.8.14.10. The physical configuration for testing of component boards when mounted to an ITA is dependent upon the accessibility of the components for the UUT and shall be determined by mutual agreement between the Contractor and NYCT.
- 22.8.14.11. The ITA shall be capable of receiving and operating with all of the BTE generated signals and generate the drive and timing requirements to fully exercise the UUT.
- 22.8.14.12. The ITA design shall not utilize any electronic module, LRU, LLRU, PCB, or assembly that is part of the car systems it is intended to support.
- 22.8.14.13. The BTE, under software control, shall generate and receive signals from and to the UUT I/O connector(s) and then to the ITA and ICA.
- 22.8.14.14. The ITA design shall feature self-test capabilities to validate all of its internal components. In the event that ITA is configured as passive device (wiring only), a wrap-around self-test feature shall be incorporated into the ITA design.
- 22.8.14.15. The ITA self-test routine shall identify all possible suspect internal components, both active and passive, and report them following the completion of the test routine.
- 22.8.14.16. The active components within this suspected list of overall failed components shall meet the following fault isolation requirements and ambiguity group sizes as noted in Table 22-9.

Table 22-9: ITA Component Level Fault Callout

Ambiguity Group Size	Percentage
4 or Less	100 %
3 or Less	95 %
2 or Less	90 %
1	85 %

22.8.14.17. Prior to applying the main power to the UUT, the program shall take appropriate steps to ensure that BTE, all ITAs and correct UUT(s) are properly connected (UUT Signature Test) and that the main power can be applied (UUT Safe-To-Turn-On Test).

22.8.15. BTE System Support Assessment

22.8.15.1. A System Support Assessment (SSA) of the LRUs and LLRUs shall be performed at FAI in order to assign a preliminary categorization and repair feasibility analysis of the system subassemblies.

22.8.15.2. To support the SSA, the Contractor shall provide one complete and fully operational set of LRUs which are intended to be supported by proposed BTE.

22.8.15.3. For all LRUs and LLRUs, the Contractor shall provide a preliminary documentation package in electronic format, including but not limited to, wiring schematics, diagrams, mechanical drawings, BOMs, and estimated unit price ranges.

22.8.15.4. NYCT will use the SSA to define the capability of the BTE with respect to PCB and component level fault isolation testing.

22.8.15.5. The result of SSA analysis and the physical characteristics of the LRUs and LLRUs shall be used to define one of the following categories for all PCBs and subassemblies.

- a) **Category A:** The PCBs and subassemblies containing low to medium component density (including component types and component mounting) that allow semi-automatic and/or manual probing during fault isolation and troubleshooting down to the component level.
- b) **Category B:** The PCBs and subassemblies containing high component density such as multi-layer construction, surface mounted technology, ICs with close-spacing of pins, specialized ICs (processors, programmable logic devices, ASIC devices, and other type of custom components) that may prevent effective fault isolation and manual troubleshooting down to component level.
- c) **Category C:** The PCBs and subassemblies commercially available off-the shelf, purchased from Original Equipment Manufacturers (OEM).
- d) **Category D:** The PCBs and subassemblies that are non-repairable due to extremely low or high complexity but have destructive nature of failure, or are classified as vital, or have system safety implications.

22.8.15.6. The reparability of the UUT (LRUs and LLRUs) shall not be solely driven by the criteria cited above, as initially it is assumed that all subassemblies are defined as "repairable".

22.8.15.7. In cases where a UUT may be defined as Category D as a result of various factors (expenditure, availability, complexity level, physical limitations, etc.), the Contractor shall provide an appropriate supporting documentation to NYCT for review and approval.

22.8.15.8. In the event that NYCT defines a PCB or subassembly as Category D, the Contractor shall furnish the BTE program with a functional GO/ NO-GO testing capability for the corresponding UUT.

22.8.15.9. In cases where NYCT defines a PCB or subassembly as Category D, NYCT reserves the right to request for a revision of Contract's deliverable spare parts quantities accordingly.

22.8.16. BTE Acceptance Requirements

22.8.16.1. The BTE shall be qualified in accordance with NYCT Specification TSS-W1065, "NYCT Test Program Set Validation/Verification Procedure", see Appendix C-41.

22.8.16.2. Upon delivery and installation of BTE equipment at designated NYCT location(s), all applicable paragraphs of TSS-W1065 Section 5.0 shall be repeated as part of the acceptance/commissioning.

22.8.17. BTE Safety Requirements

22.8.17.1. The BTE when connected and operated (in any operational mode), and disconnected shall comply with the safety requirements of IEC-61010-1, and use the electrostatic discharge protection.

22.8.17.2. Appropriate protective measures are defined in Table 22-10.

Table 22-10: Equipment Voltage ratings and recommended protection

Voltage Range	None	Guards	Enclosure	Markings			Interlock		Discharge Device	
				Caution	Warning	Danger	Bypass	No Bypass	Automatic	Shorting rods
0-30	X			X						
30-70		X		X			X		X	
70-500		X			X		X		X	X
>500		X	X			X		X	X	X

Notes:

- a) Voltage range applies to the total differential voltage.
- b) Under marking "CAUTION", identify maximum voltage.
- c) Under marking "WARNING", identify maximum voltage.
- d) Under marking "DANGER", add the words "HIGH VOLTAGE" and identify maximum voltage.
- e) For voltages of 70V to 500V or greater, both automatic and shorting rod discharge devices shall be used.

22.8.17.3. Prior to applying main power to the UUT, the program shall make sufficient measurements to ensure that the BTE, the ITA, and the correct UUT are connected properly (UUT Safe-To-Turn-On test). This philosophy should be implemented within the ITA design.

22.8.17.4. Status indicating lights, arranged in a tower stack, shall be used to identify the status of BTE, i.e., green shall be illuminated when BTE is in standby; amber shall be illuminated to indicate that the test program is running; blue shall be used to signal the user input; and red shall be used to warn of high voltage presence.

22.8.18. BTE Warranty Requirements

22.8.18.1. The Contractor shall provide warranty which guarantees the proper operation of each item of the equipment delivered, including BTE hardware, software, peripheral and ancillary equipment.

22.8.18.2. The duration of warranty shall be three years. The warranty shall commence following the completion of all required BTE maintenance training, and once the BTE is accepted for use by NYCT.

22.8.18.3. The Contractor shall be responsible for upkeep and calibration of all BTE articles during the BTE warranty period.

22.9. Workstation Equipment

22.9.1. General Requirements

22.9.1.1. The Contractor shall provide workstations for the subsystems cited below, configured with approved OS and peripherals, including licenses for all software applications, as specified in Table 22-2.

- Automatic Announcement System
- Monitoring and Diagnostic System
- Event Recorder
- Communications System
- Signs
- Door System
- HVAC system
- CCTV system

22.9.1.2. The Contractor shall provide workstations to support tasks such as development and upkeep of interactive manuals and training aids, examination and analysis of fault logs, editing and setting of Ethernet, Programmable Logic Controllers (PLC), and other programmable memory devices.

22.9.1.3. The Contractor shall provide specific workstations, previously used by software contractors to develop R211 application software, complete with its peripherals and documentation, such that the requirements of Section 18.3.1.13 can be accomplished and witnessed by NYCT.

22.9.1.4. Six months prior to workstation delivery, the Contractor and NYCT representatives shall meet to determine the final requirements of the workstations.

22.9.1.5. The Contractor shall provide a list of proposed software packages, including the OS, software development tools, and hardware with justification for use, to NYCT for review and approval.

22.9.2. Workstation Equipment

22.9.2.1. The Contractor shall deliver, install, test, and commission all workstation equipment for the subsystems cited on Form PF-5, R211 Contract Terms and Conditions, to the schedule in Table 22-4.

22.9.2.2. All general purpose workstations, peripherals and interconnections, shall meet current NYCT cyber security (encryption) standards, see NYS Information Technology Policies, Standards, and Best Practice Guidelines at <https://www.its.ny.gov/tables/technologypolicyindex>, whether or not connected to the NYCT network. All workstations shall meet the requirements of Section 22.9.1.3.

22.9.2.3. The Contractor shall supply workstations for the subsystems cited on Form PF-5, R211 Contract Terms and Conditions, equipped with applicable software applications and interface adapters in quantities specified in Table 22-2, to support maintenance functions described in Section 22.9.1.2.

22.9.2.4. The Contractor shall supply workstations equipped with appropriate publishing and other software applications that were originally used by the Contractor in the design of the equipment, complete with external backup hard-drives (2 TB minimum), network based laser printers and related accessories in the quantities specified in Table 22-2 to support the upkeep and replication of Technical Support and Engineering documentation, and training materials, drawings and schematics, and Operations and Maintenance Manuals.

22.10. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
22-1	22.3.2.16	Demonstration of the features and content of IETMs	1st Car Delivery
22-2	22.5.5.9	Professional quality videos to illustrate the key concepts of maintainability for all major subsystems	30 days before applicable training course
22-3	22.6.4.1	List of recommended consumable parts	CDR
22-4	22.6.5.1	List of recommended replacement parts necessary to maintain the cars	CDR
22-5	22.6.6.1	List of recommended repairable parts	CDR
22-6	22.6.7.1	Overhaul parts list	Acceptance of First Unit
22-7	22.7.1.2	List of proposed special tools with justification for use	CDR
22-8	22.8.1.12	A description of the PTE for each system, listing interfaces, hardware configuration, user manual, and recommended operation of PTE	CDR

Section 23

Quality Assurance

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23. Quality Assurance

23.1. Introduction

23.1.1. Scope

- 23.1.1.1. This section establishes NYCT's requirements and criteria for the development and implementation of the R211 Quality Assurance Program.
- 23.1.1.2. NYCT's Quality Assurance requirements generally follow ISO 9001:2008, FTA Quality Assurance and Quality Control Guidelines, and established NYCT quality assurance practices and preferences.

23.2. Quality Management System

23.2.1. General

- 23.2.1.1. The Contractor shall establish, document, implement, and maintain a quality management system for work performed under this Contract.
- 23.2.1.2. The Contractor shall:
 - a) Determine the processes needed for the quality management system and their application throughout the organization.
 - b) Determine the sequence and interaction of these processes.
 - c) Determine criteria and methods needed to ensure that both the operation and control of these processes are effective.
 - d) Ensure the availability of resources and information necessary to support the operation and monitoring of these processes.
 - e) Monitor, measure where applicable, and analyze these processes.
 - f) Implement actions necessary to achieve planned results and continual improvement of these processes.
- 23.2.1.3. The Contractor shall be responsible for all of the quality assurance functions required by this Contract.
- 23.2.1.4. The Contractor shall assure contract compliance by subcontractors and suppliers. Surveillance of subcontractors shall include sampling and review of products, records, procedures, processes, manufacturing operations, and quality control methods.
- 23.2.1.5. The Contractor shall be certified to ISO 9001 or an approved equivalent.

23.3. Quality Assurance Program

23.3.1. General

- 23.3.1.1. The Contractor shall plan and implement a Quality Assurance (QA) Program to assure delivery of quality cars to NYCT under the terms of this Contract.
- 23.3.1.2. The QA Program shall apply to the Contractor's entire organization and all manufacturers, subcontractors, and suppliers that perform work under this Contract.
- 23.3.1.3. The QA Program shall assure that all aspects of the Contract are in conformance with the design, materials, and workmanship requirements provided in this Specification.
- 23.3.1.4. The QA Program shall require the Contractor to document the inspection of design and manufacturing operations.

23.3.1.5. The QA responsibilities required by this Specification include:

- a) Planning, establishing and maintaining a QA Program.
- b) Performing all work required by the QA Program.
- c) Conducting QA Program audits.

23.3.2. QA Manual

23.3.2.1. The Contractor's and major subcontractors' QA Manuals shall be submitted to NYCT for reference. [CDRL]

23.3.3. Quality Assurance Program Plan

23.3.3.1. The Contractor shall submit a Quality Assurance Program Plan (QAPP) for work performed under this Contract for NYCT approval. Any revisions of the QAPP shall be submitted for NYCT approval. [CDRL]

23.3.3.2. Contract work that is performed prior to NYCT's approval of the QAPP shall be at the Contractor's risk.

23.3.3.3. The QAPP shall regulate procedures, methods, and processes to ensure compliance with all Contract requirements.

23.3.3.4. The QAPP shall clearly define the authority of the QA Department and the quality responsibilities of every department. An organization chart shall be included to show the reporting relationships of all management staff.

23.3.3.5. The QAPP shall clearly indicate that QA personnel shall have sufficient authority and organizational freedom to ensure that nonconforming or discrepant product or service will not be delivered to NYCT.

23.3.3.6. The responsibility for the QA Department shall be placed in the Contractor's organization such that meeting schedule and cost projections will not compromise the quality of products or services delivered under the terms of the Contract.

23.3.3.7. The QAPP shall include work-specific quality organization charts for the Contractor and all major suppliers at various manufacturing and assembly operations for critical quality functions such as:

- a) Receiving inspection,
- b) Source inspection,
- c) In-process and final inspection,
- d) Nonconforming material,
- e) Material Review Board,
- f) Product testing,
- g) Contract compliance,
- h) Corrective action procedures, and
- i) Software QA requirements, which shall be included per Section 18.4.

23.3.3.8. The QAPP shall include, at a minimum, the descriptions of the following procedures regarding implementation of QA activities. The procedures shall also contain or refer to a comprehensive collection of forms for documentation of quality control activities. The Contractor shall submit these procedures to NYCT upon request:

- a) Design control, including technical documentation and engineering changes.
- b) Transmission of all quality assurance requirements to procurement sources.

- c) Receiving, source, in-process, and final inspections.
- d) Production and process control.
- e) Operator certifications and qualifications, including training.
- f) Functional testing.
- g) Discrepancy control.
- h) Measuring and test equipment calibration and certification.
- i) Drawing control.
- j) Quality Assurance records.
- k) Shipping, handling, and storing.
- l) Selection of qualified procurement sources.
- m) Evaluation and assessment of subcontractor's Quality Assurance program.
- n) Monitoring of subcontractor quality assurance performance.
- o) Evaluation of procured articles against purchase order requirements.

23.3.4. Master Test and Inspection Plan

- 23.3.4.1. The Contractor shall submit a Master Test and Inspection Plan (MTIP) for NYCT approval. Any revisions to the MTIP shall be submitted to NYCT for review and approval. [CDRL]
- 23.3.4.2. The MTIP shall identify all manufacturing, inspection and test stages of the major components and subsystems for the following plans, as applicable:
 - a) R211A NYCT Prototype Cars.
 - b) R211A NYCT Production Cars.
 - c) R211S Staten Island Railway (SIR) Prototype Cars (see Section 25).
 - d) R211S SIR Production Cars (see Section 25).
 - e) R211T Open Gangway Cars (see Section 26).
- 23.3.4.3. Each plan shall include a car work-flow block diagram of the manufacturing process, showing significant operations and related points for critical inspections, examinations, and tests.
- 23.3.4.4. Each plan will identify all inspection and test procedures required at the suppliers' or subcontractors' plants, the Contractor's plants, and on NYCT property prior to acceptance.
- 23.3.4.5. All inspection or test procedures shall contain the procedure number, location, and Specification reference, if applicable.
- 23.3.4.6. The MTIP shall identify Contractor and NYCT hold points. NYCT hold points will be established when the MTIP is submitted.
- 23.3.4.7. The MTIP shall identify all First Article Inspections located at the Contractor's plant(s).

23.3.5. QA Program Audits

- 23.3.5.1. The Contractor's QAPP shall include plans and processes for audit of the Contractor's Quality performance and compliance (see Section 23.9.3).
- 23.3.5.2. NYCT will conduct audits of the Contractor's Quality performance and compliance (see Section 23.9.2).

23.3.5.3. NYCT may request the Contractor to perform additional audits of the Contractor's QA (see Section 23.9.4).

23.3.6. Control of Documents and Records

23.3.6.1. Documents and records required by the QA Program shall be controlled and be available to NYCT upon request.

23.3.6.2. Procedures shall be established to define the controls needed to:

- a) Approve documents, including specific documents that require NYCT's approval as defined in this Specification.
- b) Review, update and re-approve documents.
- c) Ensure changes and the current revision status of documents are identified.
- d) Ensure documents are available at points of use, legible, and readily identifiable.
- e) Ensure all electronic documents and databases are updated and maintained, including their accessibility through a shared network drive.
- f) Ensure external documents necessary to the QA Program are identified and their distribution controlled.
- g) Prevent unintended use of obsolete documents, and apply suitable identification to them if they are retained for any purpose.

23.3.6.3. The Contractor shall establish procedures to verify that QA records demonstrate compliance with the requirements of the purchase specifications. These procedures shall define which QA records will be retained.

23.3.6.4. QA records shall include the results of examinations, inspections, tests, process controls, certification of processes and personnel, non-conformances (including disposition), calibrations, corrective action, audits, and any other quality requirements delineated by the Contract.

23.3.6.5. The Contractor shall establish procedures to define the controls needed for the identification, storage, protection, retrieval, retention and disposition of QA records.

23.3.6.6. QA records shall be retained for the duration of the Contract and 5 years after acceptance of the last deliverable item under this Contract, or expiration of the warranty period, whichever is longer.

23.4. Resource Management

23.4.1. Management Responsibility

23.4.1.1. The Contractor's management shall:

- a) Ensure NYCT's requirements are determined and complied with.
- b) Ensure quality objectives are established.
- c) Ensure availability of resources.

23.4.1.2. The Contractor shall appoint a member of management who shall have the responsibility and authority to ensure that the processes needed for the QA Program are established, implemented, and maintained, and to report to top management on the performance of the QA Program and any need for improvement, as related to the R211 Project.

23.4.1.3. The management representative responsible for quality shall liaise with external parties on matters relating to the quality and resources required for the R211 Project.

23.4.1.4. The Contractor's management shall review the QA Program at planned intervals to ensure its continuing suitability, adequacy, and effectiveness.

23.4.2. Personnel and Training

- 23.4.2.1. The Contractor shall determine and provide the resources needed to implement and maintain the R211 QA Program.
- 23.4.2.2. Personnel performing work, inspection or tests pertaining to Quality shall be qualified on the basis of education, training, certification, skills, and experience.
- 23.4.2.3. The Contractor shall establish a training program for personnel to learn the skills needed to perform the work for this Contract.
- 23.4.2.4. The Contractor shall establish a training program procedure and shall submit it to NYCT upon request.
- 23.4.2.5. Records of personnel certification and qualification shall be maintained and shall be submitted to NYCT upon request.

23.4.3. Infrastructure and Work Environment

- 23.4.3.1. The Contractor shall designate an area at the Contractor's facilities that is solely devoted to the work performed and material storage for this Contract to ensure that there is no interference from other projects.
- 23.4.3.2. The Contractor shall provide a safe and clean environment for the work performed for this Contract.
- 23.4.3.3. The floor plan and layout of the Contractor's facilities shall be made available to NYCT upon request.

23.4.4. Contractor Provisions for NYCT's Inspection

- 23.4.4.1. The Contractor shall provide offices for NYCT project staff and representatives at all Contractor facilities associated with this Contract as detailed in the Contract Terms and Conditions, Article 912.
- 23.4.4.2. The Contractor shall provide areas for convenient inspection of materials, work, and equipment pertaining to this Contract.
- 23.4.4.3. Copies of all drawings, diagrams, schedules, changes, deviations, documents, and data associated with the work shall be furnished or conveniently available to NYCT.
- 23.4.4.4. Data shall be adequate to verify design, construction, assembly, installation, workmanship, clearance, tolerance, and functionality of the cars and test equipment.
- 23.4.4.5. Upon request from NYCT, the Contractor shall provide facilities at its subcontractor(s) of major subsystems (such as propulsion, brakes, and HVAC) to enable convenient inspection of subsystem components and equipment.

23.5. Product Realization

23.5.1. General

- 23.5.1.1. The Contractor shall determine all requirements specified by NYCT, requirements not directly specified but necessary for the car's specified or intended use (where known), applicable statutory and regulatory requirements, and any additional requirements considered necessary.
- 23.5.1.2. These requirements shall be carefully reviewed by the Contractor to ensure that all car requirements are defined and any questions or issues pertaining to the requirements or compliance are resolved.

23.5.2. Design and Development Controls

- 23.5.2.1. The Contractor shall establish procedures to assure designs are clearly defined.
- 23.5.2.2. Design inputs from Technical Specifications, regulatory requirements, industry codes, and applicable standards shall be identified and documented.

- 23.5.2.3. Procedures shall be developed for translating these design inputs into design specifications and drawings. Design development procedures shall define the following:
- a) Stages of design (for example, Preliminary Design Review (PDR), Intermediate Preliminary Design Review (IPDR), and Critical Design Review (CDR)).
 - b) Activities that occur at each stage (for example, individual submittals, Contractor internal review by Engineering and by QA, systems integration review, NYCT review, verification, and validation).
 - c) Means to verify that the design complies with requirements.
 - d) Appropriate information is present for purchasing, production and inspection/testing.
 - e) Acceptance criteria.
 - f) Responsibility for each activity.
- 23.5.2.4. Design reviews shall verify the adequacy of designs.
- 23.5.2.5. Design documents shall be the basis for purchase, manufacture, fabrication, test, inspection, and quality standards of the Contractor and subcontractors.
- 23.5.2.6. Detailed records of design development and review(s) shall be maintained including identification of any problems and necessary actions.
- 23.5.2.7. Records of verification and validation activities, including any necessary actions, shall be maintained.
- 23.5.2.8. Design changes shall be made using the same design/drafting, review and approval procedures that control creation and presentation of the original design.
- 23.5.2.9. The Contractor shall establish inspections and tests based on the latest approved designs. The engineering change control system shall require controlled documents to be prepared, issued, and revised. This system shall assure that all materials, replacement parts lists, and operation and maintenance data reflect the latest configuration of parts and equipment.
- 23.5.2.10. The Contractor shall submit a Configuration Management Plan that maintains and assures the latest drawing and software configuration to NYCT for review. Engineering change procedures shall be included in the Configuration Management Plan. [CDRL]
- 23.5.2.11. The Contractor shall implement this plan upon approval by NYCT and ensure that requirements for the effectivity point of changes are met and that obsolete Contract drawings and requirements are promptly removed from the system.
- 23.5.2.12. Means of tracking the effectivity points shall be employed and made available to NYCT.
- 23.5.2.13. The Contractor shall establish and maintain objective evidence of compliance with all of the requirements of this Contract's Specifications and accepted design control procedures.

23.5.3. Purchasing Controls

- 23.5.3.1. The Contractor shall be responsible for ensuring that all supplies and services procured conform to Contract requirements.
- 23.5.3.2. The Contractor shall establish procedures for the selection and control of subcontractors/suppliers. These procedures shall include:
- a) Qualification and acceptance of subcontractors/suppliers through review of QA manuals,
 - b) Evaluation of production facilities,
 - c) Review/audit of adherence to procedures, and
 - d) Monitoring/assessing of quality performance consistent with product complexity and quality requirements.

- 23.5.3.3. All purchased materials, equipment, and services shall comply with all NYCT Specification requirements.
- 23.5.3.4. Purchasing documents shall transmit NYCT quality requirements, specifications, and standards to subcontractors and suppliers.
- 23.5.3.5. The Contractor shall meet with subcontractors and suppliers as needed to clarify provisions of the purchase contract(s).
- 23.5.3.6. Purchasing information shall describe the product to be purchased including, where applicable:
 - a) Requirements for approval of product, procedures, processes and equipment, such as First Article Inspection, source inspection and submittal of test procedures.
 - b) Requirements for qualification of personnel.
 - c) QA Program requirements.
- 23.5.3.7. The Contractor shall establish procedures to assure that purchased material conforms to the requirements of the NYCT Specification and design and test requirements including qualification testing, First Article Inspection, source inspection, receiving inspection, review of material certifications and requisite supporting documents, and other activities.
- 23.5.3.8. Evidence of compliance with the NYCT Specification shall be available for NYCT's review up to 5 years after the last Contract deliverable is furnished or expiration of the warranty period, whichever is longer.

23.6. Production and Service

23.6.1. Production and Service Controls

- 23.6.1.1. The Contractor shall establish procedures to control manufacturing and production processes required by the NYCT approved MTIP.
- 23.6.1.2. Hold points shall prevent out-of-sequence installation and ensure that no work will be hidden from inspection or test by subsequent assembly. If items are installed out of sequence or hidden by succeeding assembly work, the Contractor shall implement corrections so that inspection and testing can occur, providing the same assurance as the NYCT approved MTIP.
- 23.6.1.3. Certain special manufacturing and production processes shall be performed by certified personnel using qualified procedures under specified environmental conditions. These processes shall include welding, heat treatment, non-destructive tests, and wheel pressing, as a minimum.
- 23.6.1.4. Manufacturing procedures shall be controlled to assure compliance with Specification requirements. Applicable codes, standards, regulations, and acceptance criteria for special processes and tests shall be cited by procedures, drawings, and checklists.
- 23.6.1.5. The Contractor shall establish procedures for identification and control of cars and components. The procedures shall assure that materials and components are handled, stored, and shipped to prevent damage, degradation, and loss.
- 23.6.1.6. The Contractor shall ensure that instructions for part identification and serialization, precautionary signs, protection against weathering and corrosion, drying agents, moisture barriers, and control of shelf life are defined. Parts identification and serialization shall be as defined by Section 22.6.2.
- 23.6.1.7. Conditions that adversely affect the quality of the components shall be identified, controlled, and eliminated.
- 23.6.1.8. Evidence of corrective actions to prevent recurrence of such conditions shall be verified and documented.

- 23.6.1.9. If defective work has occurred or defective materials have been used, the Contractor shall furnish the appliances and labor to investigate.
- 23.6.1.10. Defective materials or construction that may be disclosed from the investigation shall be promptly corrected with all costs borne by the Contractor.
- 23.6.1.11. Parts and apparatus damaged during construction, testing, or shipment shall be repaired at the expense of the Contractor. Repair procedures shall be subject to approval by NYCT.

23.6.2. Validation of Processes for Production and Service

- 23.6.2.1. Inspection and verification of compliance to the Technical Specification shall be assured by the Contractor at the facilities of the car-builder, subcontractors, or other manufacturers.
- 23.6.2.2. All entities within the Contractor's organization shall enforce the QA Program. Schedule and cost decisions shall not compromise quality.
- 23.6.2.3. The Contractor shall employ sufficient staff to perform effective control of quality.
- 23.6.2.4. The Contractor shall implement procedures for enforcement of receiving, source, in-process, first article, final, and acceptance inspections and tests.
- 23.6.2.5. Enforcement shall assure that cars, components, and materials are manufactured correctly, marked with appropriate identification, successfully tested, and packed to preclude damage during shipment.
- 23.6.2.6. Preparation for shipment of each car shall be confirmed by completed checklists for each shipment.
- 23.6.2.7. Inspection at the Contractor's and NYCT's facilities to assess damage to cars or equipment following transportation shall also be required.
- 23.6.2.8. The Contractor shall establish formal documented inspection and test procedures. All inspections and tests shall be performed to demonstrate compliance with Specification requirements, confirm elimination of deficiencies, and provide information on car and test equipment technical characteristics.
- 23.6.2.9. Test procedures shall reference the test objectives and list prerequisites to be met. Test instrumentation requirements shall also be listed for each test procedure.
- 23.6.2.10. The Contractor's inspectors shall monitor tests and verify that specified conditions are satisfied.
- 23.6.2.11. NYCT may also make inspections of items, completed or in-process, with, without, or in addition to the Contractor's inspection. This shall in no way void, lessen, or take the place of the Contractor's obligation to conduct thorough inspections.
- 23.6.2.12. Inspection and testing will not be conducted by NYCT on Saturdays, Sundays, or holidays observed by NYCT, unless specifically approved beforehand; see Contract Terms and Conditions, Article 901.
- 23.6.2.13. Failure by the Contractor to recognize this restriction will be reason for disapproval of the equipment involved, and the inspection(s) shall be rescheduled at NYCT's convenience for normal daytime shifts.
- 23.6.2.14. Repeated rejections at either the Contractor's or subcontractor's facilities shall be cause to withdraw NYCT's inspection. In such case, the work in question shall be stopped until a satisfactory corrective action agreement is reached between NYCT and the Contractor.

23.6.3. Special Requirements for Service

- 23.6.3.1. In addition to the requirements of Section 23.6.2, the following specific requirements apply to provision of services.
- 23.6.3.2. The Contractor shall prepare and utilize written procedures to assure and demonstrate the quality of the Operations and Maintenance Manuals defined in Section 22.3.

- 23.6.3.3. The Contractor shall prepare and utilize written procedures to assure and demonstrate the quality of the Training Program defined in Section 22.5.
- 23.6.3.4. The Contractor shall prepare and utilize written procedures to assure and demonstrate the quality of software, as defined in Section 18.4.1.7.

23.7. Inspection and Testing

23.7.1. First Article Inspection

First Article Inspection Process

- 23.7.1.1. First Article Inspection (FAI) shall be performed jointly by NYCT and the Contractor on all major subassemblies and the fully assembled car (of each type).
- 23.7.1.2. Equipment shall be shipped from the point of manufacture only after the FAI has been either approved or waived by NYCT.
- 23.7.1.3. The Contractor shall provide an individual notice to NYCT of each FAI a minimum of 21 days prior to the FAI.
- 23.7.1.4. The Contractor shall not schedule more than two FAIs on the same date without prior approval by NYCT.
- 23.7.1.5. The Contractor shall perform pre-FAIs to confirm the subcontractor's readiness, except where this requirement has been waived by NYCT.
- 23.7.1.6. The Contractor shall submit the results of the pre-FAI, prior to the FAI, to NYCT upon request.
- 23.7.1.7. The FAI will evaluate component and system maintainability, including the use of Portable Test Equipment (PTE), Bench Test Equipment (BTE), special tools, and data download and fault diagnosis, if applicable. Video recording of these aspects shall be used.
- 23.7.1.8. Removal and replacement of parts to the Line Replaceable Unit (LRU) and Lowest Line Replaceable Unit (LLRU) designations will be reviewed for acceptability by NYCT.
- 23.7.1.9. After the completion of a FAI, the Contractor shall perform a new FAI if there is a change of design.
- 23.7.1.10. FAI pieces shall be retained for the duration of the manufacturing phase for reference as the quality baseline, and stored in a secure area at the manufacturer's facilities. These items may be utilized for production of the last cars with prior NYCT approval.
- 23.7.1.11. The following FAI pieces need not be retained for the duration of the manufacturing phase, but photographs and/or video shall be used as a reference to define the quality baseline for the Contractor:
 - a) Complete carbody structure, and carbody structure subassemblies.
 - b) Interior equipment installation.
 - c) Underfloor equipment installation.
 - d) Truck Frame.

First Article Inspection Scope

- 23.7.1.12. The FAI shall be performed on the manufacture and assembly of the following items, at a minimum, (for each car type, as necessary):
 - a) Car Body and Interior – Complete Carbody, Carshell, Underframe, End Underframes, Side Frames, End Frames, Roof, Ends, Floor, Windows and Windshields, Seats, and Doors.
 - b) Truck System – Wheels and axles, Primary Springs, Bolster, Truck Frame, and Completed Trucks.

- c) Coupler - Mechanical Coupler, Draft Gear, Drawbar, Linkbar, Radial Carrier, and Electric Coupler.
 - d) Cab Console and Controls – Master Controller, Train Operator’s Display, Doppler Speed Sensor, Speedometer.
 - e) CBTC System (limited to Contractor’s scope of work).
 - f) Monitoring and Diagnostic System – Monitoring and Diagnostic equipment, Car Network Controller, Trainline Network Controller, and Event Recorder.
 - g) Power Supply System – Current Collector, Batteries, Knife Switch, Auxiliary Power Unit, and LVPS.
 - h) Propulsion System – Traction Motors, Propulsion Inverters, Gear Units, Brake Resistors, and Inductors.
 - i) Door System – Crew Key Switches, Door Operators, Master Door Controller, Door Control Relay Panel, Mechanical Locks, Guard Lights, and Door Monitoring Control Unit.
 - j) HVAC System – Inverter, Controller, and HVAC Units.
 - k) Communications System – Intercoms, Speakers, Buzzer, Radio, Communication Control Panel, Communication Control Unit, Conductor Panel, Microphone, Side Destination Signs, Ceiling Interior Information Signs, Information Displays, End Route Signs, and CCTV.
 - l) Lighting System – Main Lights, End Door Lights, Cab Light, Head Light, and Tail Light.
 - m) Friction Brake System – Brake Operating Unit, Control Electronics (if provided), Brake Pipe Control Unit, Trip Cock, Air Compressor Unit, Reservoirs, Tread Brake Units, and Passenger Emergency Handle Unit.
 - n) Underfloor, Exterior, and Interior Equipment Installation.
 - o) Complete Car – all types.
- 23.7.1.13. The Contractor shall submit a Subcontractors and Suppliers List containing the name, scope of work, address, contact person, and contact information for each subcontractor or supplier. [CDRL]
- 23.7.1.14. The Contractor shall submit an FAI Schedule containing all proposed FAIs, FAI dates, and manufacturer’s name and locations to NYCT for review and approval. [CDRL]

First Article Inspection Requirements

- 23.7.1.15. The Contractor shall submit the FAI Package to NYCT a minimum of 10 business days prior to the FAI.
- 23.7.1.16. The FAI package shall contain the following items:
- a) Schedule and FAI Agenda.
 - b) Vendor Contact Information and Location of FAI.
 - c) FAI Components List.
 - d) Drawings List and Status.
 - e) Software Configuration and Status.
 - f) Qualification Test Procedures and Reports List and Status.
 - g) Routine Test and Inspection Procedures List and Status.
 - h) Special Processes Procedures List.
 - i) Certificate(s) of Conformance List.
 - j) Certificate of Compliance with R211 Technical Specification referring to Prohibited Materials.
 - k) CDRLs List and Status.
 - l) SAR/SCR/SWR List and Status.

- m) Design Review Open Items List and Status.
 - n) Purchase Order.
 - o) Complete listing of all design or material changes made since Critical Design Review (CDR).
- 23.7.1.17. The FAI will only be performed on a component that has been built using approved production processes and tooling.
- 23.7.1.18. The FAI will not be conducted until the design drawings, qualification test procedures and reports, and routine test and inspection procedures have been conditionally approved or approved. If conditionally approved drawings are used, NYCT's conditions for approval shall be satisfied at the FAI and represented by the inspection article.
- 23.7.1.19. Each FAI will be assigned a unique number by NYCT.

First Article Inspection Event

- 23.7.1.20. At the FAI, the following items shall be made available by the Contractor and Vendor:
- a) FAI Package.
 - b) Complete Set of Approved or Conditionally Approved Drawings and Software Documentation.
 - c) LRU and LLRU list approved by NYCT for the item(s) to receive FAI.
 - d) Vendor inspection forms that control and document acceptance of in-process work showing all deficiencies satisfactorily corrected and accepted.
 - e) Vendor and Contractor final inspection reports showing all deficiencies satisfactorily corrected and accepted.
 - f) Completed test documents showing that the unit has passed testing.
 - g) For purchased items, a copy of the vendor's purchase order (with commercial items excluded).
 - h) Certificate(s) of Conformance.
 - i) Material Safety Data Sheets (MSDS).
- 23.7.1.21. The inspection work space shall provide the proper environment for inspection of piece part, subassembly, or car final assembly.
- 23.7.1.22. The FAI piece shall be displayed on a stand or table in a well-lit work space with any handling aids to facilitate inspection, as applicable.
- 23.7.1.23. All inspection tools, GO/NOGO gauges, plug gauges, meters, fixtures, and other equipment, and labor to take mechanical or electrical measurements shall be provided.
- 23.7.1.24. Tools and labor for disassembly and removal of covers shall be provided.
- 23.7.1.25. Inspection and conformance testing shall be performed.
- 23.7.1.26. Maintainability Demonstration will be performed, if applicable.
- 23.7.1.27. Photographs and/or videos of FAI items shall be taken and retained by the Contractor as a record of the established quality standard.
- 23.7.1.28. Any failure of the FAI will require a FAI follow-up where the FAI process will be repeated.

- 23.7.1.29. Upon the conclusion of the FAI, the Contractor and NYCT shall prepare a list of action items that were established during the FAI. Each action item shall contain the following, at a minimum:
- a) Action Item Number.
 - b) Subject.
 - c) Description, including photographs when applicable.
 - d) Action Required.
 - e) Responsible Party.
 - f) Target Date.
 - g) Action Item Status.

First Article Inspection Report

23.7.1.30. The Contractor shall submit an FAI Report for review and approval within 21 days of the FAI.

23.7.1.31. The FAI Report shall contain the following information:

- a) Attendance Sheet.
- b) Name, Part Number and Serial Number of Component.
- c) Status of each FAI Component.
- d) Action Item Sheets.
- e) Contractor Inspection Sheets.
- f) Test Results, if applicable.

23.7.1.32. Upon the closure of all open items, the Contractor shall submit a FAI Closure Report to NYCT for review and approval. The FAI Closure Report shall contain all the Action Item Sheets and the evidence showing how each Action Item was resolved and verified.

23.7.2. First Piece Inspection

23.7.2.1. First Piece Inspection (FPI) shall be performed if the design of the equipment remains unchanged, but the manufacturing location has been changed or the manufacturer has stopped production for more than 6 months.

23.7.2.2. The FPI shall follow the same process as the FAI, except that qualification tests do not have to be performed.

23.7.3. Source Inspection

23.7.3.1. Purchased materials shall be inspected at their source to verify conformance to the pertinent acceptance criteria.

23.7.3.2. Inspections will be performed in accordance with Purchase Order, specification, and drawing requirements.

23.7.3.3. Material certifications, test reports, and other requisite supporting documents shall be retained.

23.7.3.4. The Contractor shall submit a sampling plan for all source inspections performed at the Contractor's subcontractor's or suppliers' facilities to NYCT for review and approval. Wheels, axles, and wheel, and axle assemblies shall be inspected at a sampling rate of 100 percent. [CDRL]

23.7.3.5. If the Contractor's subcontractor's or supplier's material is rejected repeatedly, NYCT reserves the right to have the Contractor inspect all materials at 100 percent frequency until the cause of the rejection is resolved.

- 23.7.3.6. NYCT reserves the right to conduct source inspection of any supplies furnished or services rendered under the Contract.
- 23.7.3.7. The Contractor shall give 14 calendar days' notice before each vendor shipment of major items as listed in Section 23.7.1.12, so NYCT can be present during the inspection. The Contractor shall not schedule more than two vendor inspections on the same date without prior approval by NYCT.
- 23.7.3.8. After notice by the Contractor, NYCT will advise within seven calendar days whether an inspector will be present for the inspection.

23.7.4. Receiving Inspection

- 23.7.4.1. The Contractor shall submit a sampling plan for all receiving inspections performed at the Contractor's facilities to NYCT for review and approval. [CDRL]
- 23.7.4.2. Statistical quality control procedures which determine Acceptable Quality Levels (AQL) and Average Outgoing Quality Levels (AOQL) shall be performed in accordance with MIL-STD-105E, MIL-STD-1916, ANSI/ASQC Z1.4, or other approved plan.
- 23.7.4.3. The Contractor shall maintain a system to identify acceptance, rejection, or non-inspection status of materials and components. Inspection status shall be clearly identified by tags, stamps, or other means.

23.7.5. In-Process Inspection

- 23.7.5.1. The Contractor's QA Department shall maintain and direct a team of qualified inspectors to verify that work in its shops is performed in compliance with the approved design drawings.
- 23.7.5.2. These inspections shall be identified in the MTIP.
- 23.7.5.3. Discrepancies in the work shall be recorded, and departments responsible for the work shall be notified of the need for corrections.
- 23.7.5.4. Repairs and corrections shall be inspected for conformance to drawings and NYCT approved rework instructions, as needed.
- 23.7.5.5. Re-inspection acceptance status shall be indicated by the Contractor's inspectors by stamp or initials on the original discrepancy report.
- 23.7.5.6. Responsible manufacturing supervision shall be notified of rework that is rejected.
- 23.7.5.7. Exceptions to the quality of workmanship taken by NYCT on any car, system, component, or piece of test equipment shall be posted conspicuously and in a location convenient for review.
- 23.7.5.8. The Contractor's inspection personnel shall keep these notices current so rejection or approval status of each exception may be readily determined throughout the manufacturing process.

23.7.6. Hold Point Inspection

- 23.7.6.1. The Contractor shall establish hold points in the manufacturing process to provide critical inspections. Work cannot proceed beyond the hold point until NYCT's approval is achieved.
- 23.7.6.2. 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 subsequent assembly operations.
- 23.7.6.3. The Contractor shall notify NYCT of upcoming hold point inspection(s), with a minimum of 24 hours' notice.
- 23.7.6.4. The Contractor shall use inspection forms to record the list of discrepancies noted.
- 23.7.6.5. Nonconforming products shall not be released from a hold point until all discrepancies have been corrected.

- 23.7.6.6. The inspection forms shall be posted at or near the point of inspection for each car and included with the Car History Book when all discrepancies have been eliminated.

23.7.7. Final Inspections

- 23.7.7.1. After all work is completed to the latest NYCT approved configuration, the Contractor shall perform final inspection prior to NYCT's inspection.
- 23.7.7.2. Workmanship items covered by prior inspection reports shall be corrected and documented before final inspection begins.
- 23.7.7.3. The Contractor shall notify NYCT at least 24 hours before each final inspection and schedule no less than one full day for NYCT's inspection of each car before each shipment.
- 23.7.7.4. The Contractor shall provide a supervisor to accompany NYCT during final inspection to assure that deficiencies are understood and proper corrective action is taken.
- 23.7.7.5. The Contractor shall provide labor and appropriate tools to remove or open and reapply covers and access doors. During final inspection, all systems shall be operational with use of approved types of special equipment and/or power supplies.
- 23.7.7.6. All discrepancies found during final inspection shall be corrected and re-inspected.
- 23.7.7.7. If a corrective action affects a previously conducted pre-shipment test, the affected system shall be re-tested to verify correct operation of the affected equipment.

23.7.8. Shipping Inspection

- 23.7.8.1. The Contractor shall establish procedures to ensure completion of manufacture prior to shipment from each manufacturing facility and that all shipments shall be adequately prepared to preclude damage during shipment.
- 23.7.8.2. These procedures shall include car shipping preparation instructions and inspection procedures to verify the readiness of cars for shipment to the next manufacturing facility or acceptance site.

23.7.9. Pre-Shipment Testing

- 23.7.9.1. The Contractor shall test car functions and performance at the Contractor's facilities to assure compliance with all technical requirements of this Contract, as described in Section 24, Test Program.
- 23.7.9.2. Conformance tests shall be performed using approved procedures.
- 23.7.9.3. The results shall be documented and included in the Car History Book.
- 23.7.9.4. Corrective measures shall be made and tests shall be repeated until successful. Final car inspection shall not be permitted until testing is completed and accepted.
- 23.7.9.5. The Contractor shall give a minimum of 24 hours' notice to NYCT of any testing performed at the Contractor's facilities.

23.7.10. Retrofit Inspections

- 23.7.10.1. The Contractor shall establish procedures to inspect retrofits or changes made to cars at the Contractor's acceptance site.
- 23.7.10.2. The Contractor shall meet the requirements of FMI-001 New Car Field Modification and Capital Spare Parts Procedure, in Appendix C-33, when retrofits or changes are made to cars on NYCT property.
- 23.7.10.3. When a retrofit or change is made by the Contractor, it shall be applied to the entire fleet, unless specified by the Contractor and approved by NYCT.
- 23.7.10.4. The Contractor's QA Department shall verify and document the completion status of all changes.

23.8. Control of Materials

23.8.1. Identification and Traceability

- 23.8.1.1. Materials used in the manufacturing of cars and test equipment for this Contract shall be identified and controlled throughout receipt, storage, fabrication, repair, installation, and shipment.
- 23.8.1.2. Items for which traceability is a requirement shall be controlled by means of unique identification and documentation traceable to manufacturing sources. Markings shall be transferred to each part of an identified item when subdivided. Markings shall be in compliance with the applicable provisions of Section 22.6.2.
- 23.8.1.3. Markings shall not be obliterated or hidden by surface treatments.
- 23.8.1.4. The Contractor shall maintain identification and traceability documents so that specific parts may be able to be recalled in the case that a deficiency is discovered after delivery from the supplier to the Contractor, installation, or delivery to NYCT.
- 23.8.1.5. The Contractor shall establish procedures to identify the inspection and test status of work during production and installation. The procedures shall be capable of identifying the progressive status of components or materials as to their inspection and testing status, acceptance or rejection.
- 23.8.1.6. The manufacturing history of items shall be documented on forms that accompany parts and assemblies as they are processed. The procedures shall ensure that only work that has passed the required inspections and tests are accepted.

23.8.2. NYCT Property

- 23.8.2.1. The Contractor shall exercise care with any NYCT property that is under the Contractor's control or use for this Contract, and shall provide property insurance as required by the Contract Terms and Conditions, Article 605.
- 23.8.2.2. If any NYCT property is lost, damaged, or otherwise found to be unsuitable for use, the Contractor shall promptly document and report this to NYCT. This property can include intellectual property and data furnished by NYCT. See Contract Terms and Conditions, Article 602 for Contractor's responsibility.

23.8.3. Preservation of Product

- 23.8.3.1. Product for this Contract shall be preserved during the Contractor's internal processing and delivery to maintain conformity to requirements. This includes product processed by subcontractors/suppliers.
- 23.8.3.2. Preservation shall include identification, handling, packaging, storage and protection of product as applicable. Preservation shall also apply to the constituent parts of a product.
- 23.8.3.3. The Contractor shall comply with the specific requirements contained in Section 19.1.5 regarding storage of material.

23.8.4. Control of Inspection, Measuring and Test Equipment

- 23.8.4.1. The Contractor shall ensure that inspection, measuring, and test equipment shall be identified, marked, controlled, calibrated, and maintained in order to demonstrate the conformance of work to Specification requirements.
- 23.8.4.2. The Contractor shall establish procedures to assure tools and inspection and test equipment are calibrated. Gauges, instruments, tooling, fixtures, and other items used for inspection and testing shall be included in these procedures.

- 23.8.4.3. Calibrations and adjustments shall be performed at prescribed intervals. Calibration standards shall be traceable to the National Institute of Standards and Technology or approved equal.
- 23.8.4.4. Calibration status shall be labeled on the controlled item and recorded to assure adherence to calibration schedules. Calibration labels shall identify the date of current calibration, who calibrated it, and the date next calibration is due.
- 23.8.4.5. Records of calibration shall be maintained and available to NYCT upon request.
- 23.8.4.6. In the case that a calibrated item is found to be out of calibration, the Contractor shall assess and record the validity of previous measurements made by the item and take appropriate action to re-inspect and/or re-test components or equipment as necessary to confirm compliance. The Contractor shall be responsible for correcting or replacing any components or equipment found to be noncompliant.

23.8.5. Control of Nonconforming Product

- 23.8.5.1. The Contractor shall establish procedures for control of nonconforming material, including procedures for its identification, segregation, and disposition.
- 23.8.5.2. Nonconforming items shall be identified by status indicators such as markings, serialization, stamps, tags and/or inspection records, and physical segregation or other means preventing their use for production, shipment, or mixing with conforming material.
- 23.8.5.3. Bonded holding areas shall be established by the Contractor to isolate nonconforming items. If an item is too large or it is otherwise not feasible to be moved to the designated segregated holding area, it shall be positively marked or identified and isolated to prevent its use.
- 23.8.5.4. The Contractor shall maintain documentation of all nonconforming material including identification and disposition, corrective action, verification of compliance after implementing the disposition, and verification of effectiveness of corrective action. Corrective action shall extend to subcontractors and suppliers.

23.8.6. Material Review Board

- 23.8.6.1. A Material Review Board (MRB) with representatives from the Contractor's QA, Engineering, Production, and Procurement Departments (at a minimum) shall be established to evaluate nonconforming material and determine its disposition.
- 23.8.6.2. The MRB shall determine whether deficient items shall be reworked to achieve conformity with requirements, returned to the vendor, scrapped, repaired, or "use as-is." Disposition to "use as-is" or to repair nonconforming material (to any variation from full conformity with Specification requirements) shall require NYCT approval.
- 23.8.6.3. NYCT reserves the right to attend MRB meetings.
- 23.8.6.4. The MRB shall also investigate and identify the cause(s) of the noncompliance, recommend corrective actions to prevent recurrence, and follow-up to verify satisfactory implementation and results.
- 23.8.6.5. A summary report of MRB activities shall be issued at least monthly including a complete list of items received, and held in the nonconforming material holding area and description of deficiencies and dispositions.
- 23.8.6.6. The Contractor shall submit their MRB procedure to NYCT for review and approval as part of the QAPP.

23.9. Measurement, Analysis, and Improvement

23.9.1. QA Monthly Meetings

23.9.1.1. QA Monthly Meetings will be held at NYCT property and attended by the Contractor's and NYCT QA representatives.

23.9.1.2. The QA Monthly Meetings will discuss the following issues, at a minimum:

- a) Plant Schedules.
- b) Plant Staffing.
- c) Part Shortages.
- d) FAIs.
- e) Source Inspections (Pre-Shipment Inspections).
- f) Weekly Report Issues.
- g) Supplier Issues.

23.9.1.3. The Contractor shall record meeting minutes and submit them to NYCT for review.

23.9.2. NYCT Quality Assurance Audits

23.9.2.1. NYCT will audit the Contractor's quality assurance activities to evaluate compliance with the approved QAPP and QA procedures. NYCT audits may be conducted at the following times:

- a) Before production of the first car shell – this audit shall include the Contractor and subcontractors.
- b) After completion of the first complete car.
- c) Any time NYCT determines an audit to be appropriate.

23.9.2.2. NYCT will furnish the Contractor with an audit report within 30 calendar days following each audit. The audit report will describe the scope of the audit, procedures followed, observations, findings, and due dates for action.

23.9.2.3. The Contractor shall submit a formal written response to NYCT within 30 calendar days following the receipt of each audit report. The response shall request approval for the proposed remedial methods and timetables to achieve compliance with the audit report.

23.9.2.4. The Contractor shall correct noncompliances promptly and request approval of each implemented correction by NYCT.

23.9.2.5. Noncompliance with any part of the approved QAPP shall be cause for rejection of Contract work.

23.9.2.6. After corrective action of the noncompliance has been verified, NYCT will notify the Contractor and Contract work may be resumed.

23.9.2.7. Schedule delays caused by noncompliance with the approved Quality Assurance Program Plan shall not justify an extension of time under the Contract, see Contract Terms and Conditions Article 205.

23.9.2.8. NYCT shall have the right to visit facilities of the Contractor and subcontractors to assess their Quality Assurance programs. This assessment will determine if the Quality Assurance programs will assure product compliance with the Specification requirements.

23.9.2.9. During the assessment, NYCT may inspect production facilities, examine operations in progress, and review documentation.

23.9.3. Contractor Quality Assurance Audits

- 23.9.3.1. The Contractor shall audit all work performed in association with this Contract to ensure compliance with the approved QAPP and QA procedures.
- 23.9.3.2. The Contractor shall audit subcontractor QA Programs according to the following schedule, as a minimum:
 - a) As a condition of the subcontract or purchase order before start of work.
 - b) Within 1 month before the Contractor's First Article Inspection.
- 23.9.3.3. Audits shall be performed to approved procedures/checklists by personnel other than those who performed the work.
- 23.9.3.4. The Contractor shall notify NYCT in advance of any scheduled audit. NYCT reserves the right to witness audits of the Contractor, subcontractors, and suppliers.
- 23.9.3.5. The Contractor shall furnish an audit report to NYCT within 30 calendar days following each audit. The audit report will describe the scope of the audit and procedures followed. The report will identify deficiencies, corrective actions, and date when corrective action for each deficiency is required.
- 23.9.3.6. The Contractor shall verify that any noncompliance is promptly corrected, and submit a closing report to NYCT indicating the action that resolved each deficiency and the Contractor's QA acceptance.

23.9.4. Contractor's Quality Assurance Program Plan Audits

- 23.9.4.1. NYCT may request the Contractor to conduct periodic audits of implementation of the approved QAPP and supplemental manuals, procedures and instructions.
- 23.9.4.2. NYCT may request the Contractor to do an audit of areas of concern as determined by NYCT. Procedures, criteria and findings from these audits are subject to NYCT's approval.
- 23.9.4.3. The Contractor shall submit the results of the audit to NYCT upon request.

23.10. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

CDRL	Ref	Deliverable	Timing
23-1	23.3.2.1	Contractor's and major subcontractors' Quality Assurance Manuals	IPDR
23-2	23.3.3.1	Quality Assurance Program Plan (QAPP)	30 days after NTP
23-3	23.3.4.1	Master Test and Inspection Plan (MTIP)	IPDR
23-4	23.5.2.10	Configuration Management Plan	60 days after NTP
23-5	23.7.1.13	Subcontractors and Suppliers List	CDR
23-6	23.7.1.14	FAI Schedule List	CDR (with CDRL-23-5)
23-7	23.7.3.4	Source Inspection Sampling Plan	CDR
23-8	23.7.4.1	Statistical sampling plans	With QAPP (CDRL-23-2)

Section 24

Test Program

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24. Test Program

24.1. Introduction

- 24.1.1.1. This section defines the requirements for development and delivery of the Test Program. Test requirements are divided into Qualification, Routine, Pre-Shipment and Acceptance tests which are performed on components, systems, cars, Units and trains.
- 24.1.1.2. The Contractor shall establish and maintain an effective test program that details the methods and test procedures to assure that all design, materials, performance, and completed work conform to this Specification and other reliability and maintainability requirements, whether such items are manufactured by the Contractor, or procured from its subcontractors or vendors.

24.2. Scope and Responsibilities

24.2.1. General Requirements

- 24.2.1.1. The Contractor shall implement a comprehensive test program to perform inspection and testing of all items of work required by the Specification, including those performed by its subcontractors or vendors.
- 24.2.1.2. The Contractor shall perform comprehensive testing, as necessary, on all equipment, systems, and cars forming a complete Unit and train to meet the performance requirements set forth in the Specification. In some cases, testing shall be repeated separately for 4, and 5-car Unit configurations, and for trains of differing lengths.
- 24.2.1.3. The Contractor shall submit test procedures (Section 24.3.2) and corresponding test reports (Section 24.3.3) that are both technically correct and legible. All test procedures and test reports shall be subject to review and approval by NYCT.
- 24.2.1.4. The tests specified herein are considered to be an absolute minimum. The contractor shall generate test procedures in such a way that all necessary functions are tested and evaluated and that the specification requirements are met. In lieu of performing certain design qualification tests, the Contractor may request a waiver for NYCT pre-qualified equipment. See Section 20.2.7.
- 24.2.1.5. The Contractor shall be responsible for ensuring that each design and performance requirement of the R211 Specification is assigned to a specific test or other validation effort.

24.2.2. Contractor Responsibilities

Test Logistics

- 24.2.2.1. The Contractor shall conduct comprehensive testing on all raw materials, components, subsystems, cars, Units, and two Unit trains to validate the design and performance requirements, and to assure conformance to the Specification, inclusive of reliability and maintainability requirements.
- 24.2.2.2. Unless otherwise indicated, all costs associated with testing shall be borne by the Contractor, including tests that have failed, requiring retesting.
- 24.2.2.3. The Contractor shall provide all instruments, personnel, and apparatus required for testing. NYCT will be responsible for providing the CBTC test equipment as defined in Section 14, Train Control System, required to validate carborne CBTC installation and functionality. The Contractor is responsible for testing and verifying the functionality of all train interfaces to the carborne CBTC system.

- 24.2.2.4. The Contractor shall perform a complete retest of the subject item to demonstrate compliance to the Specification if the design of an item is changed after a test is conducted.
- 24.2.2.5. The Contractor shall give at least 21 days written notice to NYCT prior to the start of any qualification test.
- 24.2.2.6. All specified tests shall be arranged to facilitate witnessing and verification of parameters thereof by representatives of NYCT, unless NYCT directs the Contractor to proceed without them.
- 24.2.2.7. Before shipment and after delivery of each Unit to NYCT, the Contractor shall perform static and dynamic tests on each Unit. The dynamic tests shall be conducted while operating under power over a test track to demonstrate that the car systems operate in compliance with the Specification.
- 24.2.2.8. The Contractor shall provide a weekly schedule of the Contractor's work, inspection, and testing activities at the Contractor's facilities and on NYCT property. If there are changes to the weekly schedule, the Contractor shall give at least 24 hour notice to NYCT.

Staffing

- 24.2.2.9. The Contractor shall ensure appropriate staffing levels are provided to support all the test activities under this Contract.
- 24.2.2.10. The Contractor shall provide a resource labor profile showing proposed completion dates for tests and inspections in the timeframe allocated in the schedule. The staff scheduling and coordination of all inspections and testing shall match the type of test and pace of work activities.
- 24.2.2.11. The Contractor shall supply test personnel that are adequately trained and experienced to safely conduct and witness all tests and task activities under this Contract.
- 24.2.2.12. The Contractor shall ensure that staff are trained for tasks including, but not limited to instrumentation setup, data acquisition, and analysis.
- 24.2.2.13. The Contractor shall ensure that all personnel have completed the safety training appropriate for the work they will do, including NYCT's safety training (see Section 22.5.1.16) prior to access to NYCT facilities.
- 24.2.2.14. The Contractor shall become familiar with NYCT's operating rules and procedures concerning the operational testing in revenue and non-revenue service and overall process for approval of test procedures and reports. The Contractor shall be present during all qualification, routine, pre-shipment and acceptance tests.
- 24.2.2.15. Representatives of the manufacturers of equipment such as motors, traction control, friction brakes, door operating equipment, and other equipment specialties shall be available at the site of each test of such equipment as the Contractor and/or NYCT may require.

24.2.3. NYCT Responsibilities

- 24.2.3.1. NYCT will arrange access to the designated shops, test tracks, yards and mainline tracks as required. NYCT will arrange for the necessary crew to conduct the required preparation for static and dynamic tests under the conditions specified in the Contract.
- 24.2.3.2. NYCT has limited time and track availability on its system, and therefore, both the time and location for testing are subject to change at any time, without penalty to NYCT.

24.2.4. Third Party Test Facilities

- 24.2.4.1. In cases where the Contractor intends to use third party test facilities to perform static or dynamic tests, which may require the equipment or car to be moved to a specialized test center, those activities shall be declared in the Master Test and Inspection Plan (MTIP – see Section 23.3.4), where information about the third party, its test facilities and accreditation shall be provided.
- 24.2.4.2. This requirement shall apply to all tests necessitating the equipment or car to be moved to a specialized test center not belonging to either the Contractor or to NYCT.
- 24.2.4.3. Third party test facilities shall be accredited to ISO/IEC 17025, “General Requirements for the Competence of Testing and Calibration Laboratories”, or NYCT approved equivalent.

24.3. Testing Program

24.3.1. Classification of Tests

- 24.3.1.1. Tests performed on assemblies, subsystems, cars, Units and two Unit trains fall into the following test categories:
- a) Qualification Tests.
 - b) Routine Tests.
 - c) Pre-Shipment Tests.
 - d) Acceptance Tests.
- 24.3.1.2. All tests listed shall be included in the MTIP. See Section 23.3.4 for specific requirements.

Qualification Tests

- 24.3.1.3. Qualification Tests are typically one-time tests conducted to demonstrate compliance with Specification design requirements at operating and environmental extremes.
- 24.3.1.4. The required Qualification Tests are detailed in Section 24.4: Component Qualification Tests; Section 24.5: System Qualification Tests; Section 24.6: Car Qualification Tests; and Section 24.7: Unit and Train Qualification Tests.
- 24.3.1.5. The Unit and Train Qualification Tests shall be performed only on NYCT property.

Routine Tests

- 24.3.1.6. Routine Tests shall demonstrate that each equipment or item to be delivered operates within specified limits and is in compliance with its applicable design requirements.
- 24.3.1.7. The required Routine Tests are detailed in Section 24.8.

Pre-Shipment Tests

- 24.3.1.8. Pre-Shipment Tests shall demonstrate that each car, Unit and two Unit train has been fully assembled and is functional in accordance with the Specification prior to shipment to NYCT.
- 24.3.1.9. The required Pre-Shipment Tests are detailed in Section 24.9.

Acceptance Tests

- 24.3.1.10. Acceptance Tests shall validate that each Unit has been fully assembled and is functional in accordance with the NYCT Specification to demonstrate its use for revenue service.
- 24.3.1.11. Acceptance Tests shall be performed only on NYCT property.
- 24.3.1.12. The required Acceptance Tests are detailed in Section 24.10.

24.3.2. Test Procedures

- 24.3.2.1. The Contractor shall prepare a detailed procedure for each test described in the Specification.
- 24.3.2.2. The Contractor shall submit each test procedure to NYCT for review and approval no less than 30 days prior to the beginning of testing.
- 24.3.2.3. NYCT acceptance of test procedures does not free the Contractor of the responsibility of testing and complying with all the requirements of the applicable drawings and specifications.
- 24.3.2.4. Each test procedure shall include, as a minimum, the following:
 - a) Criteria, objectives, assumptions, and constraints.
 - b) Test setup, including calibration of test equipment.
 - c) Initialization requirements.
 - d) Input data.
 - e) Test instrumentation.
 - f) Expected intermediate test results, where applicable.
 - g) Requirements for recording output data.
 - h) Expected output data.
 - i) Minimum/maximum requirements for valid data to consider the test successful.
 - j) Pass/fail criteria for evaluating results.
 - k) Safety considerations and hazardous conditions.
 - l) Forms used to record data accumulated during the test.
- 24.3.2.5. Forms shall also contain a step-by-step format for data reduction, formulae used in deriving the data criteria for acceptability, and justification for the criteria set forth.
- 24.3.2.6. The test objectives, testing criteria, and pass/fail criteria shall be stated clearly in the test procedure and shall be stated in relation to design or operations specifications. The test procedure shall explain all steps with sufficient detail as to not create confusion during the test execution.
- 24.3.2.7. Traceability shall be provided from the specifications or requirements to the test procedure. Where practical, the individual procedural step that satisfies the requirement shall be identified.
- 24.3.2.8. Except as otherwise specified, all tests specified herein shall be performed by the Contractor and its subcontractors.
- 24.3.2.9. All tests shall be conducted using approved test procedures.
- 24.3.2.10. Errors in the test procedure found during the execution of the corresponding test shall be noted, verified, and corrected by the Contractor within 10 days. The Contractor shall submit the revised test procedure to NYCT for review and approval.

24.3.3. Test Reports

- 24.3.3.1. The Contractor shall prepare and submit to NYCT a copy of the report for each test, including copies of all test data, within 21 days of completion of testing for review and approval. Test reports are not required for component routine tests conducted at the supplier's facility.

- 24.3.3.2. Each test report shall include, as a minimum, the following:
- a) Description of the test.
 - b) Test equipment, including calibration dates.
 - c) All raw data collected in the test.
 - d) All data reduction forms.
 - e) Color photographs or any additional data necessary to support the test results.
 - f) A summary of the results in a manner that can be directly compared to the corresponding specification(s) without further calculations. The values corresponding to the Pass/Fail criteria shall be indicated in tabular form in the test reports.
- 24.3.3.3. Pertinent test data shall be maintained in a quantitative form to permit the evaluation of performance under the various specified test conditions. Test data shall be presented in the format approved by NYCT.
- 24.3.3.4. All Qualification Test reports shall be submitted to NYCT for review and approval.
- 24.3.3.5. Subcontractor produced test reports shall be approved by the Contractor before submittal to NYCT.
- 24.3.3.6. When qualification by similarity is proposed for the identical equipment supplied on other contracts, the Contractor may submit a Specification Waiver Request (SWR), including all supporting data and qualification reports. If the SWR is approved by NYCT, the qualification test does not need to be performed. Items that directly affect system safety shall not be submitted for a waiver. See Section 20.2.7.
- 24.3.3.7. Test reports for tests classified as commercial (Quality Assurance) tests shall not be submitted for approval but shall be made available to NYCT upon request.
- 24.3.3.8. The Contractor and supplier shall maintain test documentation and reports for a period of 12 years after the test was performed, except for truck routine tests which shall be included in the Car History Book. All test documentation and reports shall be available to NYCT, upon request, at any time during this 12-year period.
- 24.3.3.9. For pre-shipment and acceptance tests, the corresponding test reports shall be included in the Car History Book.

24.3.4. Test Components

- 24.3.4.1. Items to be used for testing shall be NYCT approved production items. Intelligent and microprocessor based equipment shall be loaded with NYCT approved production software.
- 24.3.4.2. Use of test items other than those specified in Section 24.3.4.1 shall be subject to NYCT approval.
- 24.3.4.3. The items used for testing shall be manufactured according to the latest revision of manufacturing documentation and shall have been subjected to all prescribed quality control procedures.
- 24.3.4.4. Components used for qualification testing shall be clearly identified as test components, and disposed of in accordance with the directions of NYCT at the completion of testing.

24.3.5. Test Failure and Discrepancy Analysis

- 24.3.5.1. Anomalies, discrepancies, and failures occurring during test activities shall be documented and dispositioned as specified in the Contractor's approved Quality Assurance Program Plan (QAPP) (Section 23.3.3).

- 24.3.5.2. A test failure shall have occurred when the test unit(s) does not conform within the specified limits of the QAPP or specification requirements, or it is observed that physical damage or deformation has occurred as a result of testing or other pre-test activities.
- 24.3.5.3. NYCT reserves the right of final determination as to the occurrence of a test failure.
- 24.3.5.4. In the event of a test failure, a Failure Analysis Report (FAR) shall be submitted to NYCT, except for the component routine tests at the manufacturer's facility. The corresponding test shall be suspended until NYCT approves the corrective action in the FAR.
- 24.3.5.5. The FAR shall identify the unit being tested, identify equipment and cause(s) of failure, indicate what corrective action is necessary, and the extent of such action.
- 24.3.5.6. Where the Contractor recommends that no change be made, justification for the recommendation shall be submitted to NYCT for review and approval.
- 24.3.5.7. The Contractor shall continue tests that are not included in the suspension and shall continue such ancillary activities that are not suspended.
- 24.3.5.8. The FAR shall be submitted within 30 days of the reported failure. Additionally, the Failure Reporting and Corrective Action System (FRACAS) described in Section 21.1.7 shall be updated to include the failure.

24.3.6. Test Instrument Calibration

- 24.3.6.1. Except as noted, the Contractor shall be responsible for the maintenance and calibration of all inspection and test equipment necessary to assure that testing conforms to the corresponding test requirements. See also Section 23.8.4.
- 24.3.6.2. Calibration information for all test equipment utilized shall be traceable from each test report. It is understood that some equipment does not require calibration such as power supplies utilized strictly to provide source power for other equipment.
- 24.3.6.3. A copy of the calibration procedure utilized, particularly if the test equipment was calibrated in-house and/or the manufacturer's recommended calibration procedure, shall be available for review upon request by NYCT for each piece of test equipment utilized to obtain test data.
- 24.3.6.4. If the Contractor utilizes its in-house lab to calibrate test equipment, a list of all Calibration Standards, including copies of Calibration Certificates and traceability to the National Institute of Standards and Technology (NIST) standard shall be on file and available for review upon request by NYCT.
- 24.3.6.5. If an outside lab performed any of the calibration on the test equipment used, a copy of the lab's NIST certification shall be provided to NYCT.
- 24.3.6.6. A copy of the Calibration Certificates and traceability to the NIST standard shall be on file at the outside lab and available for review upon request by NYCT for each piece of test equipment utilized to obtain test data
- 24.3.6.7. All test equipment shall have calibration stickers and calibration seals, where required, that are intact and in place.

24.4. Component Qualification Tests

24.4.1. General

- 24.4.1.1. The component qualifications listed in Table 24-1 shall be performed by the Contractor, or under its direction.

Table 24-1: Component Qualification Tests

Note: The equipment used for these tests shall be selected from that produced for the pilot cars of each type.

Test	Frequency	TS Reference
Equipment Noise Tests	One of each equipment type	2.9.4 and 24.4.2
Equipment Shock and Vibration Susceptibility	One of each equipment type	2.9.6 and 24.4.3
Car Body Structural Tests	One carbody of each type	3.6.11 to 3.6.17, 3.6.20, and 24.4.4
Crash Energy Management Test	One set of car ends	2.15.4, 3.6.18 and 3.6.19
Coupler, Draft Gear and Link Bar	One of each equipment type	4.6.2, 4.6.3
Passenger Seat	One seat assembly of each type	15.10.3.8
Lighting Components	One of each equipment type	8.6.1.4
Electric Motors (auxiliary)	Two motors as selected by NYCT	24.4.4
Auxiliary Power Supplies	Two units as selected by NYCT	9.6.4
Low Voltage Power Supply	Two units as selected by NYCT	9.6.4
Battery	One set, as selected by NYCT	9.6.7
Traction Motors	First motor, one at random, and then one of every 100 motors as selected by NYCT	10.6.8
Gear Unit	Two, as selected by NYCT	10.6.9
Truck	One of the first three produced	11.6.10 to 11.6.15
Friction Brakes	One of each equipment type	12.6.8
Door Panel	One door panel of each type	15.4.1.7
Windows	Two windows of each type	15.6.6.5
Flammability, Smoke Emission and Toxicity	All materials	19.1.10
Electrical Components	One of each equipment type	19.29.1

24.4.2. Equipment Noise Tests

- 24.4.2.1. The Contractor shall perform noise design qualification tests on all noise generating car equipment early in the production phase, prior to installation on cars, to demonstrate compliance with Section 2.9.4.
- 24.4.2.2. Test conditions shall be those applicable to pre-installed equipment as stated in Section 2.9.4.

24.4.3. Equipment Shock and Vibration Susceptibility Tests

- 24.4.3.1. The Contractor shall perform shock and vibration design qualification tests on all carbody mounted equipment early in the production phase, prior to installation on cars, to demonstrate compliance with Section 2.9.6.
- 24.4.3.2. Test conditions applied shall be the more stringent of levels determined either from running tests or levels based on IEC 61373-2010 as stated in Section 2.9.6.

24.4.4. Electric Motor Qualification Tests

- 24.4.4.1. The first production AC auxiliary motor of each type, and an additional motor of each type as selected at random by NYCT, shall be given an IEC Publication 349-2 type test, IEEE Std. 11-2000 Type Test or equivalent. The test procedure shall be submitted for NYCT approval.
- 24.4.4.2. Each AC auxiliary motor shall be tested at its respective continuous rating.
- 24.4.4.3. The first low voltage DC motor of each type, and one additional motor of each type as selected at random by NYCT, shall be load tested at maximum application load and maximum ambient temperature conditions.
- 24.4.4.4. The DC motor external temperature shall be within the manufacturer’s recommended limits for a 30 year motor life.
- 24.4.4.5. The above noted tests shall be performed by the respective motor manufacturer.

24.5. System Qualification Tests

24.5.1. General

- 24.5.1.1. The system qualification tests listed in Table 24-2 shall be performed by the Contractor, or under its direction, at its assembly facility, to demonstrate conformance to the requirements of the Specification.

Table 24-2: System Qualification Tests

Test	Frequency	TS Reference
Door System	One Set of Each Type (One System)	6.6.1.3
HVAC System and Controls	One System	7.7
Propulsion System	One Car Set	10.6.10
Friction Brake System	One Car Set	12.6.7, 12.6.9, 12.6.10 to 12.6.12

Test	Frequency	TS Reference
Communications System	One Train Set	13.14
Network System	One Train Set	16.6.2
EMC Lab Tests	One Car Set	24.5.2

24.5.2. Electromagnetic Compatibility Lab Tests

General

24.5.2.1. The Contractor shall perform the following EMI/EMC tests to demonstrate compliance with Section 2.11:

- a) Lab Conducted EMI.
- b) Lab Inductive EMI.

24.5.2.2. The test report shall identify the source of all narrow band emissions from 14 kHz to 6000 MHz and incorporate results of the measurements at 6 ft. (1.83m) distance from the centerline referenced in Section 3.4.1 contained within Appendix C-6 (“NYCT AC Train EMC Standards Document (ES)”).

Electromagnetic Emission Tests and Limits

24.5.2.3. Worst-case emissions testing shall be as defined in Section 3.1 of the ES referenced in 24.5.2.2.

24.5.2.4. Worst-case lab testing shall incorporate variations of the input voltage as stated in Section 2.5.2.

Lab Conducted EMI Test

24.5.2.5. The Contractor shall perform the Lab Conducted EMI Tests defined in the ES Section 3.2.1.

24.5.2.6. In addition to separate power unit tests, a combined test of the Propulsion System and the auxiliary inverter(s) shall be performed to ensure Electromagnetic Compatibility (EMC). The Contractor shall submit a Lab Test Procedure for each power unit and the combined test for approval. The draft test procedure shall be available at the Preliminary Design Review.

24.5.2.7. The Contractor shall submit test reports, for each power unit and the combined test for NYCT approval.

24.5.2.8. The reports shall relate lab test results to anticipated results of the planned field test.

Lab Inductive EMI Tests

24.5.2.9. The Contractor shall perform Lab Inductive EMI Tests defined in the ES Section 3.3.1.

24.5.2.10. In addition to separate power unit tests, a combined test of the propulsion system and the auxiliary inverter(s) shall be performed to ensure EMC.

24.5.2.11. The Contractor shall submit a Lab Test Procedure and Test Report for each power unit and the combined test for approval. The draft procedure shall be available at the Preliminary Design Review.

24.6. Car Qualification Tests

24.6.1. General

24.6.1.1. The car qualification tests listed in Table 24-3 shall be performed by the Contractor on selected cars at the Contractor’s facility. The selection of cars to be tested shall be approved by NYCT.

Table 24-3: Car Qualification Tests

Test	Frequency	TS Reference
Watertightness	One car of each type	24.6.2
Carbody Air Leakage	One car of each type	24.6.3
Door Operation	Two cars of each type	24.6.4
Climate Room	One of first four A Cars	24.6.5, 24.6.6, 24.6.7
Heated Windshield	One of first four A Cars	24.6.8
Lighting	One car of each type	24.6.9
Weight Balance	One car of each type	24.6.10
Coupled Car Clearance	Two cars of each type	24.6.11
Parking Brake	Two cars of each type	24.6.12
Noise and Vibration	One car of each type	24.6.13
Horn	One A Car	24.6.14
Car Networks	One car of each type	24.6.15

24.6.2. Watertightness Test

24.6.2.1. The watertightness test shall be performed on each of the first car types as part of the car qualification test, following the procedure defined in Section 24.9.2.

24.6.2.2. The fresh air and electric equipment ventilation intake ducts in all the car type roofs shall be water tested with the ventilating fans running at full speed, to determine the effectiveness of the water-excluding features of the duct work. At the conclusion of the test, there shall be no evidence of moisture in the ducts downstream of the water excluding features or evidence of water in any equipment.

24.6.2.3. Exterior equipment enclosures or interior equipment enclosures which have access to the outside, are required to be watertight. Enclosures shall receive a water test at the point of manufacture. During test of the enclosures, the required spray is to be directed at the exposed sides and ends of the enclosures simulating car washing operations, water spray from the wheels or wind driven rain on exposed elevated trackage. At the conclusion of the test, there shall be no evidence of moisture in the enclosures.

24.6.3. Carbody Air Leakage Test

24.6.3.1. The first car of each type shall undergo an air leakage smoke bomb test with the interior positively pressurized.

24.6.3.2. All exterior openings related to normal ventilation shall be sealed during the test.

24.6.3.3. Any leaks shall be corrected by the Contractor and the drawings and work instructions revised to prevent similar leaks on production cars.

24.6.4. Side Door Operation Tests

- 24.6.4.1. The Contractor shall perform tests to demonstrate the side door operation with the requirements of the Specification as defined in Section 6.6.
- 24.6.4.2. The first two cars of each type and two other cars of each type, selected at random by NYCT, shall have all doors operated for 1,000 continuous trouble-free cycles. For the cycle test, one of the four cars of each type shall be loaded to AW3 per Appendix C-46 (NYCT Document SD #02-04, rev. A "Loading Weights on Railcars")
- 24.6.4.3. The opening and closing time of all doors on one side of a car shall be measured and recorded electrically under loading to 105% AW3. Failure to operate at the prescribed speed specified in Section 6, or any indication of binding shall require corrective action to be taken by the Contractor.
- 24.6.4.4. Any door or door control failure occurring prior to completion of the test on each car shall nullify the test, and the test shall be completely rerun after the fault has been corrected.

24.6.5. Climate Room Testing Requirements

General

- 24.6.5.1. Climate room test shall be performed on an A Car agreed upon between NYCT and the Contractor. Provided that it conforms to production cars in configurations relevant to the test, the mock-up car may be used for the climate room test. Measurement of air volumes shall be performed on the first B Car, unless it can be adequately demonstrated on the A Car. The climate room test shall demonstrate the HVAC system's ability to comply with the temperature control and operational requirements of Section 7.2.
- 24.6.5.2. Subject to NYCT approval, the results of the A Car testing shall, by extrapolation and analysis, confirm that the B cars will also meet the same temperature control and operational requirements.
- 24.6.5.3. Testing shall include, but not be limited to, a functional check of all HVAC apparatus including temperature sensors and controls, air balance and air distribution verification, a car pressurization test, and a temperature and relative humidity check to show compliance with the specified cooling requirements with all apparatus operating at nominal voltage except when specified otherwise.
- 24.6.5.4. The HVAC system shall be powered by the car auxiliary and low voltage power systems, i.e., only nominal primary power shall be supplied to the car.
- 24.6.5.5. During the air cooling tests, the temperature of the most sensitive temperature critical components of the HVAC unit inverters shall be monitored, recorded, and incorporated into the test report. The following shall be monitored:
 - a) Input power.
 - b) Output voltage each phase.
 - c) Output current each phase.
 - d) Temperature of the most sensitive temperature critical component/components of the inverter, if used.

Climate Room Test Prerequisites

- 24.6.5.6. Prior to being shipped to the climate room test facility, the test car shall successfully pass all production conformance systems testing including the HVAC System Car Level Testing described in Section 24.9.9.
- 24.6.5.7. An air balance and air distribution adjustment and test shall be conducted to demonstrate compliance with the nominal design fresh air and return air volumes and the car pressurization

requirements given in Section 7.2.1.1 and confirmed by the ventilation system prototype testing described in Section 7.7.1.

- 24.6.5.8. The volumes of the variable cab air supply shall be noted.
- 24.6.5.9. The combined return and fresh air volumes of each HVAC unit shall be within ± 10 percent of the design supply air volume.
- 24.6.5.10. The delivered air distribution and diffuser outlet velocities required by Sections 7.2.4.8, 7.2.4.9 and 7.2.4.10 shall be demonstrated.
- 24.6.5.11. On the climate room test car, the linear slot diffusers shall be adjustable and adjusted from inside the passenger compartment without the need to open panels or dismantle the diffusers.
- 24.6.5.12. The HVAC system shall be water tested as specified in Section 24.6.2. Testing shall be conducted with and without the evaporator blowers energized. Fresh air intake water eliminator performance shall conform to the requirements of Section 7.4.3.3. At the conclusion of the test, there shall be no evidence of moisture in the ducts downstream from the water excluding apparatus or evidence of water in any of the HVAC equipment.
- 24.6.5.13. The approved temperature control switch points shall be verified before the car climate room testing begins. If, during testing, those switch points need to be revised to accomplish acceptable system performance, the Contractor shall make all the necessary modifications to the controls so that all cars conform to the final control configuration determined during the climate room test.
- 24.6.5.14. It shall be demonstrated to NYCT's satisfaction that the refrigerant compressor capacity reduction method and associated system and control design permits the HVAC unit to operate continuously at any inside or outside temperature within the specified control range and without damage or detriment to the HVAC unit or its components.

Climate Room Requirements

- 24.6.5.15. The climate room for the car level HVAC system tests shall be capable of providing and maintaining test temperatures from $0^{\circ}\text{F}^{(\text{DB})}$ ($-17.8^{\circ}\text{C}^{(\text{DB})}$) to $126^{\circ}\text{F}^{(\text{DB})}$ ($52^{\circ}\text{C}^{(\text{DB})}$) and relative humidity between 25 percent and 90 percent throughout the temperature range.
- 24.6.5.16. Temperatures in the facility shall be uniform throughout. Fans may be used to circulate the air in the facility. There shall be no more than 5°F (3°C) variation from 24 inches (610 mm) above the running rail to 24 inches (610 mm) above the vehicle roof and from end to end of the car.
- 24.6.5.17. Passenger load shall be simulated by means of heaters and humidity generating equipment. Solar and equipment loads shall be simulated by means of electric heaters inside the cars. Humidity introduced into the car to simulate the latent heat loads shall be carefully metered to assure the accurate proportioning of sensible and latent design loads.
- 24.6.5.18. Load simulating equipment shall be evenly distributed throughout the car as closely as possible to represent the actual operating conditions.

Instrumentation

- 24.6.5.19. The test car and the climate room instruments shall meet the following:
 - a) A proof of the calibration of all instruments, traceable to a master at the national standards organization of the applicable country, shall be submitted to NYCT for approval, prior to testing. See Section 24.3.6 for details on test instrument calibration.
 - b) The relative humidity of the fresh air and the car interior shall be measured at each return air grille and fresh air inlet using an approved sampling device in accordance with ASHRAE Standard 41.1.

- c) A minimum of 28 car and cab interior temperature measurement locations, determined during the air balance and distribution testing, shall be provided in locations in the passenger and cab areas as agreed to between the Contractor and NYCT.
- d) An additional three temperature sensors shall be located on the high ceiling panels. One sensor shall be at the transverse center on the car longitudinal centerline and the other two between 16 and 30 inches (406 and 762 mm) from each low ceiling transition.
- e) All data (temperatures, pressures, voltages, currents, motor speeds, and events) shall be continuously recorded by an NYCT approved data acquisition system using appropriate and approved transducers. The data acquisition system shall be capable of providing graphical representation of selected channels while testing is in progress.
- f) To demonstrate the temperature variations as the HVAC equipment cycles, data shall be recorded every minute for 30 consecutive minutes at each stabilization point.
- g) Refrigerant pressure measurements shall be taken with Bourdon tube gauge and/or Electronic pressure transducers.
- h) The accuracy of the refrigerant pressure measuring instruments shall permit measurements within ± 2.0 percent of value being measured. In no case shall the smallest scale division of pressure measuring instrument exceed 2.5 times the specified accuracy.
- i) Air pressure measurements shall be made with manometers, or approved equal, having an accuracy of ± 0.01 inches of water (2.5 Pa).
- j) Electrical instruments used for measuring the electrical input to heaters shall be accurate to ± 1.0 percent of the quantity measured. Instruments used for measuring the electrical input to fan motors, compressor motors, or other equipment accessories shall be accurate to ± 2.0 percent of the quantity measured.
- k) Rotational speed measurements shall be made with either a revolution counter, tachometer or stroboscope having an accuracy of ± 1.0 percent.
- l) The air flow measurements shall be made with a "Flow Hood 8410", as manufactured by Shortridge Instrument Company or approved equal. Adapter ducts may be used when required.
- m) An Event Recorder shall be used to monitor operation of relays and contactors.

Data Collection

24.6.5.20. The following data shall be available during testing. However, only the data pertinent to the test being performed shall be recorded.

- a) Temperatures:
 - i. Return air (9-point grid).
 - ii. Fresh air (9-point grid).
 - iii. Mixed Air (9-point grid).
 - iv. Air exiting evaporator (9-point grid).
 - v. Supply air to the evaporator/heater.
 - vi. Supply air (9-point grid).
 - vii. Condenser inlet (9-point grid).
 - viii. Condenser outlet (9-point grid).

- ix. Floor heater grille – at two of the hottest spots determined in initial testing. If radiant floor heating is supplied, the Contractor shall propose a measurement methodology.
 - x. Climate Room - 6 places.
 - xi. Car interior - 28 thermocouples, minimum.
- b) Refrigerant System Temperatures:
- i. Refrigerant compressor discharge line 12 inches (305 mm) from the refrigerant compressor.
 - ii. Refrigerant compressor suction line 12 inches (305 mm) from the refrigerant compressor.
 - iii. Liquid line leaving the condenser coil.
 - iv. Liquid line at the thermal expansion valve(s) or capillary header as applicable.
 - v. Suction line at the evaporator header(s).
 - vi. Refrigerant compressor crankcase.
- c) Refrigerant Pressures - psig (kPa):
- i. Discharge at the refrigerant compressor.
 - ii. Suction at the refrigerant compressor.
 - iii. Liquid leaving condenser.
 - iv. Liquid at thermal expansion valve(s) (if applicable).
 - v. Suction at evaporator(s).
- d) Air Pressures - w.g. (Pa):
- i. Evaporator blower (fan) total or static pressure.
 - ii. Evaporator coil pressure drop.
 - iii. Condenser coil pressure drop.
 - iv. Air supply plenum.
 - v. Car pressurization.
 - vi. Cab pressurization.
- e) Electrical Data:
- i. Evaporator blower motor voltage - each phase.
 - ii. Evaporator blower motor current - each phase.
 - iii. Evaporator blower motor watts – each phase.
 - iv. Evaporator blower motor power factor.
 - v. Evaporator blower motor speed.
 - vi. Condenser fan motor voltage - each phase.
 - vii. Condenser fan motor current - each phase.
 - viii. Condenser fan motor watts – each phase.
 - ix. Condenser fan motor power factor.
 - x. Condenser fan motor speed.

- xi. Refrigerant compressor motor voltage - each phase.
 - xii. Refrigerant compressor motor current - each phase.
 - xiii. Refrigerant compressor motor watts – each phase.
 - xiv. Refrigerant compressor motor power factor.
 - xv. Refrigerant compressor speed.
 - xvi. Overhead heater watts.
 - xvii. Floor heater watts, (each stage if applicable).
 - xviii. Radiant floor heater watts (if applicable).
- f) Event Data:
- i. Compressor Operation.
 - ii. Contactor operation (if applicable).
 - iii. Liquid line solenoid valve(s).
 - iv. Overhead heat over temperature thermostats.
 - v. High limit switch.
 - vi. High and low pressure cutout switches.
 - vii. Back-up protection activating devices.

24.6.6. Car Climate Room Heating Tests

- 24.6.6.1. Heating tests shall be performed to measure the carbody insulation value and demonstrate that the heating equipment meets the criteria specified in Section 15.2.2.
- 24.6.6.2. In addition to testing the heating system at normal design conditions, restricted evaporator/heater air flow and overhead heater over temperature conditions shall be simulated to show compliance with the over temperature protection system requirements. Relevant data shall be continuously recorded during all testing.

Pull Up and Steady State without Passengers Test

- 24.6.6.3. The climate room shall be maintained at 11°F (-11.7°C). With the side and end doors opened, the car shall be ‘soaked’ until the interior temperature reaches stabilization at 11°F (-11.7°C). Stabilization is defined as temperature swings of less than 1°F (less than -0.60°C) for a minimum of 30 minutes. Soaking shall continue for an additional 30 minutes.
- 24.6.6.4. At the end of the soak period, all doors shall be closed and the HVAC system shall be placed in the layover mode. Once the layover temperature defined in Section 7.2.2.3 has been reached, the HVAC system shall be placed in the automatic mode.
- 24.6.6.5. The time required for the internal temperature to reach 62°F (16.7°C) shall be noted. The pull up time (defined as the time to reach the required temperature from achieving the layover temperature) shall not be greater than that specified in Section 7.2.2.2 b). The mass capacitance of the car shall be determined during this test.
- 24.6.6.6. The overhead heating shall then be enabled, and the car interior shall be permitted to stabilize under automatic control.
- 24.6.6.7. The temperature in the car shall be maintained within the limits specified in Section 7.2.1.2.

- 24.6.6.8. The temperature throughout the car shall be uniform within the tolerances specified in Section 7.2.1.4.
- 24.6.6.9. If the requirements of Section 7.2.1.4 are not met, air balance and diffuser setting corrections shall be made. At the discretion of NYCT, and based on the severity of the readjustments, the test sequence shall be repeated starting from the air balance and distribution testing and include a full soak.

Side Door Cycling Test

- 24.6.6.10. With the interior temperature at stabilization, a side door cycling test shall be run to show conformance to the requirements of Section 7.2.3.4.
- 24.6.6.11. The test requirements must be met for all but the coldest 2.5 percent (hourly) of the ambient conditions representative of a "Meteorological Year" as defined by the National Renewable Energy Laboratory for New York City (Central Park).

Layover Heat Test

- 24.6.6.12. Car controls shall be placed in the layover mode and interior temperature allowed to stabilize.
- 24.6.6.13. The temperature shall be stabilized and maintained at the temperature specified in Section 7.2.2.3.
- 24.6.6.14. Car controls shall be then returned to the automatic mode and the interior temperature allowed to stabilize.
- 24.6.6.15. The time required for the internal temperature to reach 62°F (16.7°C) shall be noted.
- 24.6.6.16. The climate room temperature shall be slowly raised to 45°F (7.2°C) at a rate not to exceed 2°F per minute (1.1°C per minute).
- 24.6.6.17. The interior temperature shall remain in the range shown in Section 7.2.1.2 for an ambient temperature range of 11°F (-11.7°C) to 40°F (4.4°C).
- 24.6.6.18. As the climate room temperature changes, interior temperature and equipment cycling shall not exhibit instability.

Restricted Air Backup Protection Test

- 24.6.6.19. With the evaporator blower running and the air flow device bypassed, the overhead heater shall be set to operate at full power at the higher limit of the input voltage.
- 24.6.6.20. The test shall be conducted by slowly restricting the air flow to the evaporator/heater such that the temperature of the air from the heater output rises at a rate of approximately 2°F per minute (1.1°C per minute) until the high limit thermostat actuates and causes the power to the heater to be removed.
- 24.6.6.21. The condition shall be maintained until the high limit switch recloses, the heater re-energizes, and the cycle repeats.
- 24.6.6.22. Cycling shall be permitted to continue for 60 minutes with the temperatures recorded every 5 minutes.
- 24.6.6.23. The test shall be considered successful when the following criteria are met:
- At no time during the test does the backup thermostat activate.
 - The elevated temperatures did not cause visible damage to the HVAC unit or the car.
 - There was a total absence of smoke and odors.

- 24.6.6.24. At the end of the 60 minutes cycling period, the high limit thermostat shall be bypassed and the temperature from the heater allowed to rise until the backup thermostat actuates and causes the overhead heat shunt trip circuit breaker to open.
- 24.6.6.25. The temperatures shall be recorded every minute and recording shall continue for 10 minutes after the overhead heat circuit breaker trips.
- 24.6.6.26. The test shall be considered successful when the following criteria are met:
- Elevated temperatures do not cause visible damage to the HVAC unit or the car.
 - Total absence of smoke and odors.

Nuisance Tripping Test

- 24.6.6.27. With the evaporator blower running, the overhead heat shall be operated at full power for 1 hour. At the end of the hour, the evaporator blower and overhead heat shall be simultaneously shut down.
- 24.6.6.28. The temperature overshoot from the overhead heater shall not cause the backup thermostat to actuate and trip the overhead heater circuit breaker.

Carbody Heat Transfer Test

- 24.6.6.29. A carbody heat transfer (U-Factor) test shall be conducted to verify that the carbody insulation system is in conformance with Section 15.2.2.
- 24.6.6.30. The test shall be performed at an ambient temperature between 10°F (-12°C) and 25°F (-4°C) with the evaporator blowers shut down and all external grilles blocked. Internal heating may be provided by the car floor heaters or by auxiliary heaters evenly distributed in the interior.
- 24.6.6.31. For U-Factor calculations, the heat generated by the auxiliary blowers used to minimize temperature stratification shall be considered part of the internal heat load.

24.6.7. Car Climate Room Cooling Tests

- 24.6.7.1. The cooling tests listed below shall be conducted in sequence and without prolonged interruptions and/or temperature changes between tests, except for car interior temperature changes due to the application of heat loads.

Pull Down and Steady State at Design Conditions Without Passengers

- 24.6.7.2. The climate room shall be held at 105°F^(DB) and 75°F^(WB) (40.6°C^(DB) and 23.9°C^(WB)). With the HVAC units shut down, the simulated solar, lighting, internal equipment loads energized, and the side and end doors opened, the car shall be 'soaked' until the interior temperature reaches stabilization.
- 24.6.7.3. At the end of the soak period, all doors shall be closed and the HVAC system shall be placed in the automatic mode.
- 24.6.7.4. The time required for the internal temperature to reach 80°F (26.7°C) shall be noted.
- 24.6.7.5. The car interior shall be permitted to stabilize under automatic control.
- 24.6.7.6. The temperature in the car shall be maintained within the limits specified in Section 7.2.1.2.
- 24.6.7.7. The temperature throughout the car shall be uniform within the tolerances specified in Section 7.2.1.4.
- 24.6.7.8. If the requirements of Section 7.2.1.4 are not met, the air balance and diffuser setting shall be readjusted to correct the deficiencies. At the discretion of NYCT, and based on the severity of the readjustments, the test sequence shall be repeated.

Side Door Cycling Test

- 24.6.7.9. With the interior temperature at stabilization, a side door cycling test shall be run until steady-state temperatures are achieved to show conformance to the requirements of Section 7.2.3.4.
- 24.6.7.10. The requirement must be met for all ambient conditions representative of a "Meteorological Year" as defined by the National Renewable Energy Laboratory for New York City (Central Park).

Steady State at Design Conditions and AW3 Passenger Loading

- 24.6.7.11. With the interior temperature stabilized and the climate room maintained at 105°F^(DB) and 75°F^(WB) (40.6°C^(DB) and 23.9°C^(WB)), the simulated AW3 passenger heat load shall be energized and the interior again allowed to achieve stabilization.
- 24.6.7.12. The system shall maintain full cool operation, the average interior temperature shall not be less than 20°F (-6.7°C) below exterior ambient temperature.
- 24.6.7.13. The temperature in the car shall be maintained within the limits specified in Section 7.2.1.2.
- 24.6.7.14. The system shall operate for 4 hours without malfunction or condensate carryover.
- 24.6.7.15. During the test, no condensate shall drip, run, or blow off the HVAC unit. All condensate from the evaporator coil shall be retained inside the drain pan, no condensate shall spill or overflow from the drain pan, and no condensate shall enter the supply air ducts.

High Temperature Test

- 24.6.7.16. The climate room temperature shall be slowly raised to 125°F (51.7°C) at a rate not to exceed 2°F (1.11°C) per minute.
- 24.6.7.17. During the climate room temperature rise from 105°F (40.6 C) to 115°F (46.1 C), the interior temperature shall remain at least 20°F (11.1°C) below the climate room temperature.
- 24.6.7.18. During the climate room temperature rise from 115°F (46.1°C) to 125°F (51.7°C), the HVAC unit shall not shut down due to high pressure or refrigerant compressor motor overload. The interior temperature shall be whatever the HVAC units can provide.
- 24.6.7.19. The HVAC units shall then be operated for a minimum of 1 hour with no malfunction.
- 24.6.7.20. During the climate room temperature changes, temperature swings, and equipment cycling shall not exhibit performance variations exceeding expected values (instability).

Low Temperature Test

- 24.6.7.21. The climate room temperature shall be slowly lowered to 50°F (10°C) at a rate not to exceed 2°F (1.11°C) per minute and maintained at stabilization for 4 hours.
- 24.6.7.22. During the climate room temperature transition, the refrigeration system shall not be permitted to be locked-out and the internal heat loads shall be energized as needed to maintain continuous refrigerant compressor operation at minimum capacity.
- 24.6.7.23. During the transition from 105°F (40.5°C) to 50°F (10°C), the interior temperatures shall remain in the ranges shown in Section 7.2.1.2.
- 24.6.7.24. During the test period, the HVAC equipment shall operate without damage to itself and without the formation of ice or frost on the evaporator coil or refrigerant piping. Oil return volumes acceptable for compressor operation shall be verified.
- 24.6.7.25. During the climate room temperature changes, temperature swings and equipment cycling shall not exhibit performance variations exceeding expected values or exhibit instability.

24.6.8. Heated Windshield Test

- 24.6.8.1. The heated windshield shall be tested to illustrate compliance with the requirements of Section 15.6.2.13. The overheat protection requirements of Section 5.7.10.6 shall also be verified.
- a) The Cab End Door and Cab Door shall be closed for the duration of the humidification period and the demisting period.
 - b) A simulated "one person heat load" with a minimum of 75W sensible and 59W latent shall be used to allow fog on 100% of the internal surface of the windshield.
 - c) The Windshield Defroster is then activated while the cab heater is turned on (Auto Mode with the air diffuser oriented toward the windshield).
 - d) Heated Windshield controls are detailed in Section 5.7.10.

24.6.9. Lighting Test

- 24.6.9.1. Light intensity readings shall be taken (without light from other sources) on the first car of each type to verify conformance with the requirements in Section 8.6.1.4.

24.6.10. Weight Balance Test

- 24.6.10.1. Weight balancing tests shall be performed on one completed car of each type to verify compliance with the requirements of Section 2.4.2.

24.6.11. Coupled Car Clearance Test

- 24.6.11.1. The first completed car of each type shall be coupled to the appropriate adjacent cars and checked for proper truck, drawbar, coupler, cable, and hose clearance under the worst case geometric requirements for these elements.
- 24.6.11.2. The car ends shall be checked for proper intercar clearance.
- 24.6.11.3. The couplers and drawbar shall be checked for proper vertical and horizontal swing and for clearance from the truck, undercar components, anti-climber and ground (top of rail).
- 24.6.11.4. All truck, trainline, and coupler cables and hoses shall be checked for clearance and the absence of stretching and chafing.
- 24.6.11.5. The trucks shall be checked for proper vertical and horizontal swing and for clearance from undercar components.
- 24.6.11.6. The intercar barriers shall be checked for proper function at entry to, and exit from, curves and in reverse curves.

24.6.12. Parking Brake Test

- 24.6.12.1. The Contractor shall perform a parking brake system test on the first Unit or on each individual car type (A and B) of a Unit, to demonstrate that brake design complies with Section 12 by measuring the force required to move the Unit with the parking brake applied.
- 24.6.12.2. The test shall be performed with bedded shoes with a minimum of 85 percent contact area. The test results shall be compared to the results of the capacity test specified in Section 12.6.12.
- 24.6.12.3. The Contractor shall perform a test to demonstrate the brake response times, and shoe force vs. pressure concurrent with the parking brake testing. Results shall be compared to the results of the combined system test specified in Section 12.6.7.

24.6.13. Noise and Vibration Tests

- 24.6.13.1. After equipment installation, noise and vibration tests shall be performed on the first car of each type to confirm compliance with the static car condition requirements of Section 2.9.
- 24.6.13.2. Compliance with the Specification shall be based on measurements taken in a field environment such as outdoors, away from any reflecting surfaces other than the ground, ties, and ballast, on-track with newly ground, welded rail.
- 24.6.13.3. Reflected sound shall be such as to not influence the directly radiated sound from the equipment measured by more than 2 dB.
- 24.6.13.4. All measurements shall be made with an ambient sound level in the vicinity of the test measurement locations of not less than 10 dB below the noise produced by the equipment being measured, when evaluated using the same scale or octave band.
- 24.6.13.5. For these tests, the following shall be recorded:
 - a) Description of noise or vibration source being measured, including pertinent performance data.
 - b) Description of the environment where the noise or vibration source is measured, including a sketch showing source and measurement positions.
 - c) Operating conditions of noise or vibration source during measurements.
 - d) Pertinent meteorological data.
 - e) Locations and orientations of microphones with respect to noise source.
 - f) Equipment used for making measurements.
 - g) Description and measurements of ambient noises.
 - h) Data obtained, including range of variation.
 - i) Instrument settings, corrections, and calibration records.
- 24.6.13.6. The results shall be evaluated and any corrective action required shall be approved by NYCT. After corrective action is taken, the applicable tests shall be rerun. If the corrective action is successful, it shall be applied to all cars. If not successful, these steps shall be repeated until compliance is successfully attained.

24.6.14. Horn Test

- 24.6.14.1. The horn, as mounted on the first completed A Car, shall be tested for compliance to the requirements of Section 12.2.7.

24.6.15. Car Networks Test

- 24.6.15.1. The Contractor shall test the car network systems on the first car of each type. A simulator may be used to generate trainline signals. Testing shall include wayside data transmission if applicable. See Section 17.3.2.5.
- 24.6.15.2. The test shall include, but not be limited to, the following:
 - a) Test the ability to communicate with all network nodes.
 - b) Measure data rates and error rates.
 - c) Proper transmission and reception of signals by nodes and their connected systems.
 - d) Exercise all network commands.
 - e) Response to faults.

24.7. Unit and Train Qualification Tests

24.7.1. General

- 24.7.1.1. The Unit and Train Qualification Tests listed in Table 24-4 shall be performed on NYCT property by the Contractor to demonstrate that the car design complies with the requirements of the Specification, and is suitable for service on the NYCT system.
- 24.7.1.2. Prior to Qualification testing, the Prototype Trains shall have successfully completed all Car Qualification Tests in Section 24.6.
- 24.7.1.3. All Prototype Trains shall perform the following inspections and testing prior to Qualification testing:
 - a) Unpacking Inspection.
 - b) Incoming Inspection.
 - c) Miscellaneous Body Tests and Adjustments (see Section 24.10.2).
 - d) Pneumatic System Leakage Test (see Section 24.10.3).
 - e) Functional Tests (see Section 24.10.4).
- 24.7.1.4. If at any time during the project, it is determined that the qualification test procedures are not sufficient, or fail to cover any of its intended functions, or significant modification were made to any major subsystem(s), the Contractor shall rewrite the affected procedure and retest as necessary.

Table 24-4: Unit Qualification Tests

Test	Frequency	TS Reference
Train Networks	First two Units (tested for 8 and 10 car trains)	24.7.2
Trainlines	First two Units (tested for 8 and 10 car trains)	24.7.3
Clearance	First or second Unit, any type	24.7.4
Performance	First two Units (tested for 8 and 10 car trains)	24.7.5
Noise and Vibration	First or second Unit, any type	24.7.6
EMC Field Test	First two Units, any type	24.7.7
Battery Capacity	First or second Unit (tested for 4 and 5 car Unit)	24.7.8
Thermal Mapping	First or second Unit, any type	24.7.9
FMECA Validation	First or second Unit, any type	24.7.10
Communication and CCTV	First two Units (tested for 8 and 10 car trains)	24.7.11

Test	Frequency	TS Reference
Parking Brake	First or second Unit (tested for 4 and 5 car Unit)	24.7.12
PEHU	First two Units (tested for 8 and 10 car trains)	24.7.13
30 Day Operations in Service	First two Units, any type	24.7.14

24.7.1.5. At the sole discretion of the NYCT Project Manager, certain Unit and Train qualification tests may be performed following the 30 Day Operations in Service (See Section 24.7.14).

24.7.2. Train Networks

24.7.2.1. The Contractor shall perform the train network test to validate the operation of the complete system on two-Unit configurations, see Section 16.6.3.

24.7.2.2. To validate functionality with possible increased train size configuration, the Contractor shall conduct a train network test with a configuration consisting of 4, and 5-car Units.

24.7.2.3. Tests shall include verification of all coupling configurations before or after the “30-Day Operations Passenger Service Test”.

24.7.2.4. Tests shall contain all elements tested in lower level network qualification tests, including the CBTC network traffic (in case that cars come equipped with CBTC), in compliance with Sections 14 – Train Control System and 16 - Trainline and Car Control Architecture.

24.7.3. Trainlines

24.7.3.1. The first two Units shall be tested, in both static and dynamic modes, to demonstrate that all trainline functions between operating Units perform satisfactorily when coupled together.

24.7.3.2. The two Units shall be coupled in all possible combinations.

24.7.3.3. Trainline validation tests shall include all trainline and network signals that are routed through the coupler electrical heads and intercar cables as necessary.

24.7.3.4. All operating conditions and including faults, and functional operations of all digital data networks shall be verified.

24.7.3.5. Car end configuration shall be tested following the successful completion of the “30-Day Operation Passenger Service Test”.

24.7.3.6. Propagation time of the brake pipe during emergency brake application shall be verified. See Section 12.2.2.4.

24.7.4. Clearance Test

24.7.4.1. One Unit shall be operated at low speeds over the entire B Division to verify clearances both on the Car and on the wayside, the latter as defined in Appendix D-1 (“Memorandum of Understanding Car and Line Equipment Clearances”).

24.7.4.2. The test shall include all track configurations such as crossovers.

- 24.7.4.3. The exterior of the car shall be checked for proper carbody, truck, inter-car, and undercar equipment clearance.
- 24.7.4.4. Clearances shall be confirmed to meet the dynamic clearance envelope. The trucks shall be checked for proper vertical and horizontal swing and for clearance from undercar components.
- 24.7.4.5. All truck, trainline, and coupler cables and hoses shall be checked for clearance and the absence of stretching and chafing.
- 24.7.4.6. The couplers shall be checked for proper vertical and horizontal swing and for clearance from the truck, undercar components, anti-climber and top of rail.
- 24.7.4.7. The vertical and horizontal gaps at each doorway on the train shall be checked against a nominal platform, as defined in Appendix D-1 (“Memorandum of Understanding Car and Line Equipment Clearances”).
- 24.7.4.8. All inter-car barriers shall be checked for operation and clearances.
- 24.7.4.9. The following areas shall be slowly traversed and carefully monitored:
 - a) Tightest crossovers and turnouts.
 - b) Tightest horizontal and vertical curves.
 - c) Greatest unbalanced super elevation.
 - d) Speed restrictions due to track irregularities.
 - e) Worst case combinations of all of the above.

24.7.5. Performance Tests

- 24.7.5.1. The Contractor shall perform a series of Performance Tests to demonstrate the proper functioning of propulsion and braking systems, and to verify compliance with Section 2 - Design and Performance Criteria.
- 24.7.5.2. The tests listed in Table 24-5 shall be performed on the complete first and second Units under noted loading conditions.

Table 24-5: Performance Tests

Test	No of Units	Load level	Type	TS Reference
Propulsion Performance	Two Units (tested for 4 and 5 car Units)	AW0, AW2, AW3	Motoring, Braking	24.7.5.24
Braking Performance	Two Units (tested for 4 and 5 car Units)	AW0, AW2, AW3	Braking	24.7.5.25
Thermal Capacity	One Unit	AW0, AW3	Motoring, Braking	24.7.5.28
Wheel Slip and Slide Control	One Unit	AW0	Braking	24.7.5.29
Auxiliary AC Power Supply	Two Units (tested for 4 and 5 car Units)	N/A	Normal, Shedding	24.7.5.30
	One Unit	AW2	Motoring	24.7.5.31

Power and Energy Consumption	One Unit	AW2	Regenerative Braking	24.7.5.31
	One Unit	AW2	Auxiliary System	24.7.5.33
	One Unit	AW2	Climate System	24.7.5.34
Transient Power	Two Units	AW2	Power Up	24.7.5.37

- 24.7.5.3. As a minimum, two round trips at the NYCT designated test site shall be performed for each test. For the Power Consumption test, a minimum of three round trips shall be performed.
- 24.7.5.4. The Contractor shall schedule tests to not interfere with passenger service operations and/or system maintenance. Test schedules shall be submitted to NYCT for approval at least 30 days prior to the projected test start date.
- 24.7.5.5. The test shall contain steps to determine the optimum settings of the propulsion and braking equipment. The results of those tests shall be used as a reference for the remaining Units and Car Acceptance Program.
- 24.7.5.6. The tests shall contain steps to determine the relationships of motor torque vs. car loading and the brake cylinder pressure vs. car loading, for a continuous range of loads from AW0 to AW3 as measured by air spring pressure. Those relationships shall be used as a reference to validate the performance of all other Units, which may then be tested without load during Unit Pre-shipment Dynamic Tests and Unit Acceptance Tests.
- 24.7.5.7. Test reports shall be submitted to, and become the property of NYCT. Records of all parameter settings for acceleration and deceleration shall be furnished for each car.
- 24.7.5.8. Test reports will be submitted with all recorded data corrected for voltage and grades as part of the Contractor’s test report, if necessary.
- 24.7.5.9. If any Unit, Units or car, under any load condition or train configuration, or any apparatus fails to satisfy the specified performance and design criteria, the Unit, Units or cars, with the necessary adjustments, shall be retested at the Contractor’s expense.
- 24.7.5.10. If modifications are necessary, they shall be verified by appropriate retest, as determined by NYCT, and implemented on a fleet wide basis at the Contractor’s expense.

Instrumentation

- 24.7.5.11. The Contractor shall instrument each test Unit with a multiple-channel digital data acquisition system and produce a permanent test record.
- 24.7.5.12. The data acquisition system shall be capable of real time viewing and processing of raw data signals. Collected data shall be processed immediately following a test, or concurrently during the test, and be presented for preliminary review in an approved format.
- 24.7.5.13. All data acquisition equipment shall be calibrated prior to any test. Calibration records shall be included with each test report.
- 24.7.5.14. Each test run shall be labeled with the date, time, trip number, elapsed time from departure, and identity of the test engineer.
- 24.7.5.15. A high accuracy independent speed sensor shall be provided for speed and distance measurements. The supplied hardware shall be verified against the devices that are already approved or utilized by NYCT.
- 24.7.5.16. The Contractor shall supply all equipment needed to power and operate this instrumentation.

- 24.7.5.17. Instrumentation shall utilize the car battery low voltage power system supply. The equipment shall function over the battery low voltage range described in Section 2.5 and otherwise not be damaged by the conditions specified in Section 9.2.3.
- 24.7.5.18. Internal combustion engines driving a generator or use of the vehicle auxiliary inverter to power the instrumentation will not be permitted.
- 24.7.5.19. Isolation amplifiers shall be provided as part of the instrumentation package to isolate the inside car instrumentation wiring and equipment from high voltages.
- 24.7.5.20. Exposed terminals with potential differences greater than 50 volts shall not be permitted.
- 24.7.5.21. The test wiring termination panels shall include test jacks and switching for each channel to permit calibration signals to be injected into each recorder channel, without requiring wiring or connectors to be disconnected, and shall be arranged so that calibration signals cannot be fed back into the monitored equipment.
- 24.7.5.22. The accuracy and response of the instrumentation shall be sufficient to determine the degree of compliance with the specification and design data.
- 24.7.5.23. For each Performance Test, the following channel assignments shall be permanently recorded simultaneously, as specified:
- a) Acceleration (positive and negative).
 - b) Traction motor torque (each truck).
 - c) Spin-slide control system active (each truck – magnitude of spin or slide as required for validation).
 - d) Brake cylinder pressure (each truck).
 - e) Braked wheel temperature on one axle.
 - f) Contact Rail voltage.
 - g) Line current for all car types.
 - h) Brake signal current for all trucks.
 - i) Speed (Unit and individual axles).
 - j) Auxiliary current.
 - k) Propulsion and braking trainline signals (may be multiplexed to a single analog channel).
 - l) An independent time base with one-second time intervals.
 - m) Distance intervals using digital odometer to record 10, 100, and 1,000-foot (3, 30.5, and 305 m) increments.
 - n) Such channels as the Contractor feels necessary to record the voltage transients of Section 9.6.1.6.
 - o) A voice narration or comment channel.
 - p) Two spare event channels for additional tests which may be requested by NYCT.
 - q) Two spare analog channels for additional tests which may be requested by NYCT.

Propulsion Performance Tests

- 24.7.5.24. The Contractor shall perform, on two Units, a series of propulsion performance tests at simulated AW0, AW2 and AW3 loads, and at normal operating temperature, to demonstrate compliance with the performance requirements in Section 2.7. Braking effort shall be monitored during the tests.

Braking Performance Tests

- 24.7.5.25. The Contractor shall perform a series of All Friction Brake Stop Tests on two Units to demonstrate compliance with the performance requirements of Sections 2.7.4 and 2.7.5. Emergency braking tests shall conform to Appendix D-20 (NYCT Document MISC #95-01, "Emergency Stop Distance Memorandum of Understanding"). These tests shall be performed at AW0, AW2, and AW3 loads. For the tests, brake elements shall be cooled to a maximum of 125°F (52°C) as measured by thermocouples before initiation of any test.
- 24.7.5.26. Brake shoes utilized in stop tests shall be bedded in to a minimum 85 percent contact area.
- 24.7.5.27. The pneumatic emergency brake pipe system shall be tested to verify compliance with the emergency brake reaction time requirements of Section 12.2.2.

Thermal Capacity Tests

- 24.7.5.28. The Contractor shall instrument one complete Unit to perform a Thermal Capacity Test to verify the duty cycle requirements under loss of propulsion and braking capabilities as specified in Section 2.7.11. Results shall be compared to the results of the braking capacity test specified in Section 12.6.12.

Wheel Slip and Slide Control Tests

- 24.7.5.29. The Contractor shall instrument one fully complete Unit to perform a series of Wheel Slip and Slide Control tests to demonstrate operation in all power and braking modes and verify compliance with Section 2.7.7. At least four trucks on the Unit shall be monitored and recorded.

Auxiliary AC Power Supply

- 24.7.5.30. The Contractor shall perform tests to demonstrate performance of Auxiliary AC Power Supply and verify compliance with requirements of Section 9 - Auxiliary Electrical Equipment and Distribution. The Auxiliary AC Power Supply shall be instrumented throughout performance tests to sample and record the Auxiliary AC Power Supply operating characteristics. The test records of Auxiliary AC Power Supply conformance test and Unit Performance test shall be included in Auxiliary AC Power Supply test report.

Power and Energy Consumption

- 24.7.5.31. The Contractor shall perform a Power and Energy Consumption Test on one complete Unit to validate the energy consumption estimates used in the design calculation. The test shall be performed while operating under simulated AW2 load over a typical route and schedule as directed by NYCT.
- 24.7.5.32. The data collected for the Propulsion System, shall be presented in the test report showing motoring, regenerative braking, and net power and energy consumption.
- 24.7.5.33. The data collected for the Auxiliary AC Power Supply shall be presented in the report showing combined power and energy consumption.
- 24.7.5.34. The data collected for the Climate Control System (HVAC and floor heaters, simulating summer and winter conditions), shall be presented in the report showing combined power and energy consumption.
- 24.7.5.35. The test report shall include a histogram of overall Unit power consumption level over the duration of test.

- 24.7.5.36. The test report shall also include data of stationary energy consumption of auxiliary systems during typical extended yard layover conditions.

Transient Power

- 24.7.5.37. Two Units shall be tested separately and together to demonstrate that transient power consumption levels associated with capacitive filter charging operation are compatible with NYCT's power distribution system and meet the requirements of Section 9 - Auxiliary Electrical Equipment and Distribution.
- 24.7.5.38. The Units and the substation in the area shall be instrumented to measure actual currents under all the yard and line filter charging scenarios.

24.7.6. Noise and Vibration Tests

- 24.7.6.1. The Contractor shall perform the noise and vibration tests on one complete Unit to validate compliance with the requirements of Section 2.9.
- 24.7.6.2. The Contractor shall submit reports in support of the noise testing including car interior and exterior level testing.
- 24.7.6.3. All static noise test measurements shall be made in an outdoor free-field type environment, with the test Unit stationary on the track at location where reflected sound will not directly influence the measurements by more than 2 dB.
- 24.7.6.4. The ambient background sound level in the vicinity of the test measurement locations shall be 10 dB or more, below the noise produced by the equipment being measured, when evaluated using the same scale or octave band.
- 24.7.6.5. The noise level measurements shall be taken with a meter complying with the requirements of Type 2 Sound Level meter of ANSI S1.4.
- 24.7.6.6. Where octave band or 1/3-octave band measurements are specified, the Contractor shall use an analyzer that meets the requirements for Class II Filters as given in ANSI S1.11.
- 24.7.6.7. 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 protection board on the measurement side, and in a box section subway without sound absorption on the walls.
- 24.7.6.8. For noise and vibration tests, the following shall be recorded:
- a) Description of noise or vibration source being measured, including pertinent performance data.
 - b) Description of the environment where the noise or vibration source is measured, including a sketch showing source and measurement positions.
 - c) Operating conditions of noise or vibration source during measurements.
 - d) Pertinent meteorological data.
 - e) Locations and orientations of microphones with respect to noise source.
 - f) Equipment used for making measurements.
 - g) Description and measurements of ambient noises.
 - h) Data obtained, including range of variation.
 - i) Instrument settings, corrections, and calibration records.

- 24.7.6.9. The results shall be evaluated and any corrective action required shall be approved by NYCT. After corrective action is taken, the applicable tests shall be rerun. If the corrective action is successful, it shall be applied to all cars. If not successful, these steps shall be repeated until Specification compliance is attained.
- 24.7.6.10. In addition, the Contractor shall conduct on NYCT's behalf, a test in compliance with Appendix C-4 ("New York City-Rapid Transit Noise Code, Chapter 736").
- 24.7.6.11. All noise measurements should be taken with windows closed.
- 24.7.6.12. No noise measurements should be undertaken during periods of mist, fog, snow, or rain as these have a detrimental effect upon the measurement equipment and the measured results.

24.7.7. Electromagnetic Compatibility Field Tests

General

- 24.7.7.1. The Contractor shall perform the following EMI/EMC tests to demonstrate compliance with Section 2.11:
- Field Conducted EMI.
 - Field Inductive EMI.
 - Field Radiated EMI.
- 24.7.7.2. The Contractor shall retain an independent subcontractor experienced with the rail car EMI testing, to perform all EMI/EMC tests.
- 24.7.7.3. The Subcontractor shall be accredited by either the "National Institute of Standards and Technology", or "The American Association for Laboratory Accreditation", and shall be subject to NYCT approval.
- 24.7.7.4. NYCT shall be notified a minimum of 10 business days prior to the start of any test.
- 24.7.7.5. The Subcontractor shall prepare all EMI/EMC test reports and directly deliver them to NYCT. The test reports shall not be edited or changed by the Contractor.
- 24.7.7.6. The test report shall identify the source of all narrow band emissions from 14 kHz to 6000 MHz and incorporate results of the measurements at 72 inches (1.83m) from the centerline referenced in Section 3.4.1 contained within Appendix C-6 ("NYCT AC Train EMC Standards document (ES)").
- 24.7.7.7. The electromagnetic compatibility tests shall be performed on two completely assembled Units, as approved by NYCT.
- 24.7.7.8. The electromagnetic test shall be conducted on NYCT designated tracks by methods referenced in Section 2.11 to ensure compliance with specified requirements and compatibility with the NYCT traction power distribution and communications systems.
- 24.7.7.9. Confirmation of appropriate emissions limits as previously developed shall be conducted by monitoring the traction power distribution, railway signal, and communication systems functions.

Electromagnetic Emission Tests and Limits

- 24.7.7.10. Worst case emissions testing shall be as defined in ES Section 3.1.
- 24.7.7.11. For the field tests, the third rail voltage settings shall be varied as allowed by the substation output adjustment capability at the test site.

Field Conducted EMI Test

- 24.7.7.12. The Contractor shall develop a Contractor Conducted EMI Test Procedure (Contractor CETP) and perform a Field Conducted EMI Test as specified in ES Section 3.2.2 contained within Appendix C-6 (and "NYCT AC Train Conducted EMI Test Procedure (NYCT CETP) contained in Appendix C-43.").
- 24.7.7.13. The "2004 and after" column of the NYCT CETP Table 6-1 shall be used to determine NYCT worst case track circuit length.
- 24.7.7.14. The Conducted Emissions limits shall be as described in the ES Section 3.2.3.

Field Inductive EMI Test

- 24.7.7.15. The Contractor shall perform a Field Inductive EMI test as defined in ES Section 3.3.2.
- 24.7.7.16. The Contractor shall submit a Field Inductive EMI test procedure and test report for approval. The draft procedure shall be available at the Preliminary Design Review.
- 24.7.7.17. The report shall identify the source of all narrow band emissions from 20 Hz to 20 kHz.
- 24.7.7.18. The Inductive Emissions limits shall be as described in the ES Section 3.3.3.

Field Radiated EMI Test

- 24.7.7.19. The Contractor shall perform a Field Radiated EMI Test defined in ES Section 3.4.1.
- 24.7.7.20. The Contractor shall submit a Field Radiated EMI test procedure and test report for approval. The draft procedure shall be available at the Preliminary Design Review (PDR).
- 24.7.7.21. The Radiated Emissions Limits shall be described in Section 2.11.4.
- 24.7.7.22. Measurements for compliance with the emission limits shall be conducted 50 feet (15.24 m) from the centerline of the rails.

24.7.8. Battery Capacity

- 24.7.8.1. All battery packs on one Unit shall be tested for compliance with requirements of Section 9.2.4, to verify that essential loads and duty cycles can be maintained for the required time.
- 24.7.8.2. Unit batteries shall be discharged so that the remaining capacity corresponds to the worst case design conditions.

24.7.9. Thermal Mapping

- 24.7.9.1. The Contractor shall perform a Thermal Mapping test to validate the temperature simulation model(s) and condition assumptions used in design of car equipment.
- 24.7.9.2. The Contractor shall instrument one operating Unit to measure the actual thermal profile of all temperature-sensitive components during the most severe operating conditions permissible within the requirements and design parameters of the Specification.
- 24.7.9.3. The collected data and test results shall be compared against the design assumptions to determine validity of those assumptions, and whether design changes are necessary to ensure Specification compliance, including reliability requirements.
- 24.7.9.4. The testing shall be performed over the same line as specified in the temperature simulation model(s).

24.7.10. Failure Mode, Effects and Criticality Analysis (FMECA) Validation

- 24.7.10.1. One Unit shall be utilized to verify compliant performance with the System Safety Program requirements of Section 21.3. Specifically, Category I and II hazards, identified as required within Section 21.3.3, shall be validated to not create an unsafe condition.

24.7.10.2. Subsystem(s) differing from those installed on the selected Unit must be validated on a subsystem by subsystem basis.

24.7.11. Communications and CCTV System Tests

24.7.11.1. The Contractor shall perform communication system and CCTV system tests to validate conformance with Section 13 - Communications. Requirements are contained in Sections 13.14.9 to 13.14.16.

24.7.12. Parking Brake Test

24.7.12.1. The Contractor shall perform a parking brake system test on one Unit as specified in Section 2.7.6.

24.7.13. Passenger Emergency Handle Unit Test

24.7.13.1. The Contractor shall perform Passenger Emergency Handle Unit (PEHU) qualification test to validate the requirements of Sections 12.2.8 and 12.3.4.

24.7.13.2. The test shall be performed on the first two Units, on randomly selected PEHUs on A and B Cars, totaling four PEHUs per train.

24.7.14. 30 Day Operations Passenger Service Test

24.7.14.1. The first two Units shall be subject to a 30-day Revenue Service Test with passengers on a designated NYCT line(s), according to a procedure similar to Appendix C-44 (NYCT Document ETP #00-02, "R188 30-Day Operations Passenger Service Test Procedure").

24.7.14.2. The test shall begin only after having completed all other Unit Qualification tests and the issuance of NYCT Safety Certification, see Section 21.3.6.

24.7.14.3. NYCT shall provide train crews, test engineering, and inspection support.

24.7.14.4. Prior to being placed in service, the test Units shall be subject to operations, safety, and reliability tests, as approved by NYCT, to verify compliant operation of the doors, brakes and coupler controls as a minimum.

24.8. Routine Tests

24.8.1. General

24.8.1.1. The performance of all car equipment listed in Table 24-6 shall be verified through series of functional and acceptance tests at the corresponding manufacturer’s facilities prior to shipment to the Contractor’s assembly plant.

24.8.1.2. The Contractor shall confirm that all tests performed by its suppliers are in compliance with the Specification and in accordance with the approved QAPP.

24.8.1.3. The Contractor shall ensure that Electrical and Electronic Apparatus Tests and Insulation and Hi-Pot Testing are performed on the car equipment listed in Table 24-6, where applicable.

Table 24-6: Routine Tests

Test Description	Reference
Electrical and Electronic Apparatus	24.8.2
Insulation and Hi-Pot Testing	24.8.3
Traction Power Control Test	24.8.4
Brake Equipment	24.8.5
Communications and Network Equipment	24.8.6

Test Description	Reference
Trucks	24.8.7
Couplers	24.8.8
Electric Motors (auxiliary)	24.8.9
HVAC Unit	7.7.5
Auxiliary AC Power Supply	9.6.6
Low Voltage Power Supply	9.6.6
Battery	9.6.7
Traction Motors	10.6.11
Gear Units	10.6.12

24.8.2. Electrical and Electronic Apparatus Tests

- 24.8.2.1. Each system that is separately assembled, housed, and wired into a packaged unit prior to installation in a car or Unit, shall be tested at its point of manufacture.
- 24.8.2.2. Electronic assemblies shall undergo Environmental Stress Screening in accordance with the requirements of Section 19.29.2.4 and 19.29.2.5.
- 24.8.2.3. Equipment and enclosures that are subject to exterior installation shall be water tested, see Section 24.6.2.3.
- 24.8.2.4. The manufacturer of the equipment shall provide a certified test report, signed by the responsible Quality Assurance representative.

24.8.3. Insulation and High-Potential Testing

- 24.8.3.1. The integrity of the electrical insulation shall be confirmed by performing insulation resistance tests and high potential tests on individual devices, systems, apparatus, and all wiring.
- 24.8.3.2. Semiconductor devices and capacitors may be protected against the test voltage by means of shorting jumpers if they are not inherently protected by the circuit in which they are used.
- 24.8.3.3. On items with double insulation, such as grid resistors mounted by insulators to a frame insulated from car body, each set of insulation shall be individually tested; i.e., resistors to frame and frame to car body.
- 24.8.3.4. Insulation resistance testing shall be conducted on all circuits within a device or system apparatus.
- 24.8.3.5. The high potential ground insulation test shall be conducted in accordance with IEC 61133 Ed 3.0 "Testing of rolling stock on completion of construction and before entry into service". The insulation impedance test shall be carried out both before and after the high potential test, the test conditions shall be the same for both tests and the impedance value measured by the test following the high potential test shall not differ by more than 10 % from that measured in the initial test.
- 24.8.3.6. Insulation resistance tests shall be conducted to verify the state of the insulation to the equipment case, between wiring of different voltage classes, and between the input and output circuit of high voltage line switches and circuit breakers.
- 24.8.3.7. The insulation resistance limits in Table 24-7 shall apply when all circuits on the car of a given voltage class are connected in parallel under all environmental conditions including high humidity.

Table 24-7: Insulation Test Limits

Nominal Circuit Voltage (DC or AC RMS)	Minimum Insulation Resistance
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Below 90 Volts except battery assembly	2 Mega ohms at 500 VDC
90 to 300 Volts	4 Mega ohms at 1,000 VDC
Above 300 Volts	5 Mega ohms at 1,000 VDC

- 24.8.3.8. The test limits for individual devices or apparatus shall be higher than the above listed limits as appropriate for that hardware, so that limits for the completed car can be met.
- 24.8.3.9. A high potential test shall be conducted after the first insulation resistance test is completed and passed.
- 24.8.3.10. All components and systems shall be protected when the high potential tests are being performed. The Contractor shall jumper together the various wires in a system to ensure that all parts of a system are tested, and to prevent capacitive currents or fault currents from passing through and damaging low voltage devices.
- 24.8.3.11. The high potential test shall be conducted on all circuits within a device or system. Tests shall be conducted to verify the state of the insulation to the equipment case, between wiring of different voltage classes, and between the input and output circuit of high voltage line switches and circuit breakers.
- 24.8.3.12. The high potential test limits in IEC 61133 shall apply.
- 24.8.3.13. Alternative high potential test criteria, based on Table 24-8, may be proposed for NYCT approval.

Table 24-8 High-Pot Test Limits

Nominal Circuit Voltage (DC or AC RMS)	Test Voltage (AC RMS, 60Hz)
Below 300 Volts	2 V + 1000 Volts
Equal to or above 300 Volts	2.25 V + 2,000 Volts

V = the nominal system voltage for a circuit

- 24.8.3.14. The test shall be conducted by applying the test voltage, as listed in Table 24-8 for a period of 1 minute, across the insulation being tested. The high potential test is passed if there is no insulation breakdown or excessive leakage current.

24.8.4. Traction Power Control Test

- 24.8.4.1. With control power connected and traction power disconnected, the traction power control system shall be tested for correct recognition and initiation of all external interface signals including, but not limited to, all trainline and network commands, door and brake release interlocks, friction brake interface signals, and monitoring and diagnostics interfaces.
- 24.8.4.2. The external conditions necessary for this verification process may be simulated, as necessary.
- 24.8.4.3. Traction power system shall pass all built-in low voltage self-test routines, including but not limited to Central Processing Unit (CPU) and memory tests, contactor and relay operation tests, speed sensor tests and phase gate driver tests.
- 24.8.4.4. With traction power available, the system shall undergo and pass all built-in high voltage test routines, including but not limited to filter capacitance tests, phase and chopper IGBT switch operation tests.
- 24.8.4.5. A momentary low-level power application (“bump test”) shall be conducted to verify correct phase connections of traction motor cables.

24.8.5. Brake Equipment

- 24.8.5.1. The Contractor shall perform a series of tests to demonstrate the proper operation of the brake equipment.
- 24.8.5.2. The Contractor shall test all production brake equipment. Certificates of conformance shall be provided for small components provided by sub-suppliers and third party sources.
- 24.8.5.3. The Contractor shall perform a high potential and insulation resistance tests on all electrical and electronic assemblies in accordance with Section 24.8.3, or IEC 60571 recommendations.
- 24.8.5.4. The Contractor shall conduct functionality tests, and certify for performance all electrical and electronic assemblies in accordance with manufacturer's specifications and test codes, as approved by NYCT.
- 24.8.5.5. All valves shall be test-rack tested and certified for performance in accordance with the manufacturer's specification and test codes, as approved by NYCT.
- 24.8.5.6. All air reservoirs shall be tested and certified in accordance with ASME Codes for Unified Pressure Vessels per the requirements of Section 19.15.

24.8.6. Communications and Network System Test

- 24.8.6.1. The Contractor shall test the communications and network system to demonstrate the functionality and operation of all components making up the Communications and Network System.
- 24.8.6.2. The Contractor shall perform a high potential and insulation resistance tests on all electrical and electronic assemblies in accordance with Section 24.8.3.
- 24.8.6.3. The Contractor shall conduct functionality tests and certify the performance of entire Communications and Network System in accordance with manufacturer's specifications and test codes, as approved by NYCT.
- 24.8.6.4. This validation shall also include verification of network's error rate during normal traffic conditions.
- 24.8.6.5. The test procedures shall make full use of the capabilities of the network Portable Test Equipment (PTE) as described in Section 22.8.5 to test components making up the Communication System including Radio, PA, CCTV, signs etc.

24.8.7. Trucks

- 24.8.7.1. The Contractor shall test each fully assembled production truck and its components, in accordance with the agreed upon test plan, to confirm compliance with design requirements.
- 24.8.7.2. The Contractor shall validate the welds, bolster, and any other primary structural member of the truck using either magnetic particle, or dye penetration method, in accordance with ASTM E 709 and ASTM E 165 respectively.
- 24.8.7.3. Weld validation shall be performed on 10% of trucks chosen at random by NYCT.
- 24.8.7.4. Inspection of critical welds shall be performed using radiography or by section and etch method, or as otherwise approved by NYCT, on every tenth truck randomly selected by NYCT.
- 24.8.7.5. If defects are found during sampling inspection, the Contractor shall positively locate the beginning of such defect in previous truck frames and apply appropriate corrective action.
- 24.8.7.6. The Contractor shall measure and confirm the lateral clearance requirements on every tenth fully assembled journal bearing.

- 24.8.7.7. The Contractor shall furnish axle inspection records per Section 11.6.17.
- 24.8.7.8. The Contractor shall furnish wheel press records and axle set serial and heat numbers listed together with the serial numbers of the trucks to which they are installed per Section 11.6.16.
- 24.8.7.9. The Contractor shall measure and confirm the gauge dimension requirements on all fully assembled wheel-axle assemblies per Section 11.4.5.4.
- 24.8.7.10. The Contractor shall measure and confirm the axle-run-out (concentricity) on all fully assembled wheel axles against the requirements set forth in Section 11.4.5.5.
- 24.8.7.11. The Contractor shall measure and verify the lateral and radial tread-run-out on all fully assembled wheel axles per Sections 11.4.5.6 and 11.4.5.7.
- 24.8.7.12. The Contractor shall measure and verify the conformance of tram and axle parallelism on all fully assembled trucks per Section 11.2.1.4.

24.8.8. Couplers

- 24.8.8.1. The Contractor shall perform a series of routine tests to demonstrate the proper operation of couplers and link bars.
- 24.8.8.2. The Contractor shall perform tests to demonstrate mechanical coupling and uncoupling.
- 24.8.8.3. The Contractor shall perform tests to demonstrate automatic coupling and uncoupling of electrical heads, including validation of trainline signals and network connection.
- 24.8.8.4. The Contractor shall perform test to demonstrate coupling and uncoupling of pneumatic heads.
- 24.8.8.5. The Contractor shall perform tests to demonstrate centering of the coupler assembly.

24.8.9. Electric Motor Routine Tests

- 24.8.9.1. Each AC auxiliary motor, and DC motor shall be given a "routine" test by the manufacturer in accordance with IEC Publication 349 or IEEE Std. 11-2000, or an alternative test standard used in the industry may be proposed. The test procedure shall be submitted for NYCT approval.
- 24.8.9.2. Motor balance shall be dynamically tested in accordance with NEMA MG 1-12.06.

24.8.10. CBTC Interface Test

- 24.8.10.1. The Contractor shall perform tests to verify the correct installation of Interfaces between the CBTC system and the vehicle.

24.9. Pre-Shipment Tests

24.9.1. General

- 24.9.1.1. Prior to shipment from its manufacturing plant, the Contractor shall perform a series of tests and inspections, as listed in Table 24-9, on each Unit to assure that all installed equipment complies with the requirements of the Specification.
- 24.9.1.2. The Contractor shall take corrective action when non-compliance or any defect occurs during testing. The Contractor shall retest to the satisfaction of NYCT before the system is accepted.
- 24.9.1.3. The Contractor shall submit all test results to NYCT representatives for approval.
- 24.9.1.4. NYCT representatives shall approve the test results before authorizing the release of Unit for packing and shipment.

Table 24-9: Pre-Shipment Tests

Test Type	Test	TS Reference
Static Tests	Watertightness	24.9.2
	Car Weighing	24.9.3
	Car and Unit Wiring	24.9.4
	Pneumatic System Leakage Test	24.9.5
	Trainlines and Network System	24.9.6
	System Functionality Verification	24.9.7
	Doors, Operators, and Controls	24.9.8
	HVAC System	24.9.9
	Lights, Headlight and Taillights	24.9.10
	Friction Brake	24.9.11
	Traction Power Control Test	24.9.12
	Communications System Test	24.9.13
	Monitoring and Diagnostics	24.9.14
	Event Recorder	24.9.15
CBTC Pre-shipment Test	24.9.16	
Dynamic Tests	Propulsion and Brake Test	24.9.17
	CBTC Pre-shipment Test	24.9.18

24.9.2. Watertightness Test

- 24.9.2.1. For each car within a Unit, all areas of the car sides, ends, and roof, including doors and windows, and undercar, shall be subject to a complete watertightness test.
- 24.9.2.2. The Contractor shall complete the watertightness test before the installation of sound deadening material, thermal insulation, and interior finish.
- 24.9.2.3. Water shall be sprayed from nozzles that are at distance of 46 inches (1163 mm) to 84 inches (2123 mm) from the car body, and aimed directly at, the surface being tested.
- 24.9.2.4. No less than 0.182 gallons per minute shall be delivered to each square foot of surface being tested (7.43 L/min for each square meter). The velocity of water at the nozzle shall be 77 to 90.2 feet per second (23.5 m/sec to 27.5 m/sec).
- 24.9.2.5. All spray applications shall run for 10 minutes before the inspection for leaks begins, and shall run continuously during the inspection. Exterior equipment enclosures and interior equipment enclosures exposed to the outside shall be tested as indicated in this Section.
- 24.9.2.6. The traction motor clamshell and external lead connections shall also be subject to a water test. The water flow rate and velocity shall be as specified above.
- 24.9.2.7. The Contractor may propose alternate methods for watertightness test of the carbody, subject to NYCT’s approval.

24.9.3. Car Weighing

- 24.9.3.1. The Contractor shall weigh each car prior to shipment.

- 24.9.3.2. The weight of individual trucks on each car shall be recorded separately.
- 24.9.3.3. The Contractor shall make use of a weighing device that provides a permanent record of the weight measurements, and those weight tickets shall be submitted to NYCT. Copies shall be included in the Car History Book, or in the form of an equivalent database.
- 24.9.3.4. The accuracy of weighing device shall be maintained within 0.2 percent.
- 24.9.3.5. The Contractor shall submit written verification that the weighing device has been calibrated at least once every 12 months.

24.9.4. Car and Unit Wiring Test

- 24.9.4.1. The Contractor shall perform wiring acceptance tests on all completely assembled cars and Units. The wiring tests shall include continuity and insulation checks on all fully assembled circuits. During this test, metallic backshells shall be isolated from carbody wiring.
- 24.9.4.2. Continuity tests shall be performed on all circuits in the both active and inactive states, to ensure continuity and correct polarity of equipment and devices. All frame grounds and terminal connections shall be checked for proper termination and tightness.
- 24.9.4.3. The insulation of all car circuits shall be subject to insulation resistance and high potential testing to demonstrate the compliance with requirements of Section 24.8.3. The test voltage on a completed car shall be 0.85 times the value defined in Section 24.8.3. Detachable car jumper cables shall receive independent insulation resistance and high potential tests.
- 24.9.4.4. Not used.
- 24.9.4.5. For the insulation resistance testing, the battery assembly shall be subject to a separate test for insulation from car body. Each terminal of the battery shall be measured to the metallic portion of the battery tray with a micrometer.
- 24.9.4.6. The high potential ground insulation test shall be conducted in accordance with IEC 61133. The insulation impedance test shall be carried out both before and after the high potential test, the test conditions shall be the same for both tests, and the impedance value measured by the test following the high potential test shall not differ by more than 10 % from that measured in the initial test.
- 24.9.4.7. The Contractor may request permission to disconnect certain components likely to be damaged or which, if not disconnected, would render the result invalid, under any of the above tests. The test report shall detail all mis-wiring, component failures, or other anomalies.
- 24.9.4.8. The Contractor shall immediately notify NYCT of any failures during this test.

24.9.5. Pneumatic System Leakage Test

- 24.9.5.1. The Contractor shall perform a pneumatic system leakage test on each Unit.
- 24.9.5.2. The test shall include measurement of change in system pressure over time to demonstrate the compliance with the specified requirements.
- 24.9.5.3. All cutout-cocks shall be set in normal operating position.
- 24.9.5.4. The air system, including the suspension system, shall be fully charged, leveling valves in the lap position, and the compressor controls adjusted to normal operating pressures.
- 24.9.5.5. After the system is fully charged, slowly bleed air from the main reservoir until the air compressor starts. Close the main reservoir bleed, and allow the compressor to recharge the system. The startup of compressor shall be inhibited during the test period.

- 24.9.5.6. After the compressor cuts-out and after any drain valve action has terminated, record the main reservoir test gauge reading and start the clock.
- 24.9.5.7. After the compressor cuts out wait for three minutes (for temperature effect), and record the main reservoir test gauge reading.
- 24.9.5.8. Wait for five minutes and record the main reservoir test gauge reading.
- 24.9.5.9. Main reservoir pressure drop shall not exceed a total of 10 psig (70 kPa) over the full 8 minute interval, and a total of 5 psig (34.5 kPa) in the last five minutes of the test. The air compressor shall not be allowed to start during the timed test period.
- 24.9.5.10. Failure to meet the specified performance shall require correction of the leakage and any related faults, and rerunning of the test.
- 24.9.5.11. The test report shall detail all component failures, or other anomalies.

24.9.6. Trainlines and Network System

- 24.9.6.1. The Contractor shall perform tests to validate the operation of trainlines and network functions on each Unit.
- 24.9.6.2. The Contractor shall verify the trainline signals on each intercar trainline connection and coupler electric heads.
- 24.9.6.3. The Contractor shall use a network protocol analyzer to confirm that statuses of trainline and network signals correspond to the commands set by Unit's controls.
- 24.9.6.4. The Contractor shall develop a set of standard worst case conditions to allow uniform network tests. Simulation routines within the various connected systems may be used to provide the necessary traffic levels.
- 24.9.6.5. The methodology and conditions for network tests shall be developed as part of the Unit Networks Qualification Test. The test shall validate 100 percent functionality of the networks.
- 24.9.6.6. The trainline and network tests shall also include validation of coupler functionality.
- 24.9.6.7. The Contractor shall immediately notify NYCT of any failures during this test. The test report shall detail all component failures, or other anomalies.

24.9.7. System Functionality Verification

- 24.9.7.1. The Contractor shall perform a complete series of static functionality tests on each car making up the Unit, to validate the operation of car's subsystems and to certify that the train can be properly controlled from the Train Operator's console.
- 24.9.7.2. The tests shall be conducted with the Unit powered under nominal contact line voltage.
- 24.9.7.3. After completion of each test, the Contractor shall demonstrate that all discrepancies logged against the Unit during its construction and test period, by either the Contractor's inspection staff or NYCT inspectors, have been suitably resolved to the satisfaction of NYCT.

24.9.8. Door Operators and Controls

- 24.9.8.1. The Contractor shall perform tests to demonstrate the correct operation of the passenger door system and validate all of the operating modes, including manual, emergency and Crew Switch operation.
- 24.9.8.2. The doors shall be subject to a minimum of 100 consecutive, successful cycles, operated from each Master Door Controller. Initiation of the cycling shall be through the normal control circuitry.

- 24.9.8.3. The door test shall verify proper functions of doors system including panel alignment, smooth operation, opening and closing speeds, door announcements, and proper functioning of controls, signals and interlocks.
- 24.9.8.4. The test shall measure and confirm the door obstruction feature, validation of proper opening and closing forces on every door before and after the above cycling. These features shall operate properly, without the need for readjustment at the end of the cycling tests.
- 24.9.8.5. The Contractor shall make use of the door PTE to monitor the door performance.
- 24.9.8.6. The door test shall be performed on the completely assembled Unit, resting on level tangent track.
- 24.9.8.7. This door tests must be completed with no fault found in operation of the door system, either visually or as recorded by the door system diagnostic system and/or the car's MDS.
- 24.9.8.8. Following this test, the door adjustment shall be rechecked. The test will fail if any adjustment parameter is found to be out of specification.

24.9.9. HVAC System

- 24.9.9.1. The Contractor shall perform a test to demonstrate the operation and function of the HVAC system.
- 24.9.9.2. All functions, including the sequence of refrigerant compressor unloading, the pressure transducers and switches operation, expansion and solenoid valve operation, system modulation and system pump-down, shall be verified on a completed car.
- 24.9.9.3. The system refrigerant charge and the refrigerant condition (wet or dry) in liquid sight glasses shall be recorded.
- 24.9.9.4. Car air balance and pressurization shall be verified on the first 20 cars and then on one of each car type in each sequential 40-car lot.
- 24.9.9.5. Noise and vibration levels shall also be measured and recorded on each unit.

24.9.10. Lighting, Headlights and Taillights

- 24.9.10.1. The Contractor shall perform tests to validate the operation of the Unit's lighting system and controls.
- 24.9.10.2. The Contractor shall confirm the proper operation and functions of all interior and exterior lighting assemblies and respective control circuits.
- 24.9.10.3. The headlights and taillights on each car shall be adjusted to the requirements specified in Section 8 - Lighting Systems.

24.9.11. Friction Brake Test

- 24.9.11.1. The Contractor shall perform a test to validate all of the functions and operation of the Friction Brake System.
- 24.9.11.2. Tests shall include verification of feedback command and load-weight signals and the appropriate response.
- 24.9.11.3. The test shall include verification of brake cylinder pressure settings, valves, control and indicator checks, and leakage tests.
- 24.9.11.4. The test shall include verification of the brake fault detection system.
- 24.9.11.5. The test shall include validation of emergency brake functions and proper operation of the air compressor.
- 24.9.11.6. The performance of all electrical and electronic assemblies shall be checked for proper operation.

24.9.12. Traction Power Control Test

- 24.9.12.1. The Contractor shall test the traction power control to validate the operation of traction control system.
- 24.9.12.2. The test shall be conducted with Low Voltage control power connected, and traction power disconnected.
- 24.9.12.3. The test shall validate the self-test propulsion test including recognition and initiation of all trainline and network commands, door and brake cylinder pressure interlocks, interface signals to friction brake, monitoring and diagnostics interfaces.
- 24.9.12.4. The external conditions necessary for this verification process may be simulated, as necessary. Any component that fails to function properly shall be repaired and the test repeated until successful before proceeding to the next sequence of the propulsion test series.

24.9.13. Communication System Test

- 24.9.13.1. The Contractor shall test the Communication System to demonstrate the performance of the system, including signs, on each Unit.
- 24.9.13.2. The test shall validate the operation of train radio, Passenger Information System (PIS), and the Automatic Announcement System (AAS).
- 24.9.13.3. The train radio shall be tested for power output, Voltage Standing Wave Ratio (VSWR), and for clarity of voice transmission and reception on all channels and modes.
- 24.9.13.4. Output power from the train radio shall be measured at the antenna. Measured reflected power and calculated VSWR shall be less than 2.0.
- 24.9.13.5. Sound pressure level measurements of minimum and maximum gains at each doorway location shall be made using a test tone generator, see Section 13 - Communications, and adjusted to meet predetermined criteria.
- 24.9.13.6. All Passenger Emergency Intercom (PEI) locations shall be tested.
- 24.9.13.7. The PEI shall be tested using predetermined test script software.
- 24.9.13.8. The CCTV System, including the Digital Video Recorders (DVR's), shall be functionally tested.

24.9.14. Monitoring and Diagnostics System Test

- 24.9.14.1. The Contractor shall test the Monitoring and Diagnostics System (MDS) to validate its operation and functions.
- 24.9.14.2. The test shall validate the correct reporting of data to MDS over the car and Unit network, including all required car system events and variables.
- 24.9.14.3. The test shall validate the communication link to a wayside wireless access point.
- 24.9.14.4. The Contractor shall validate that MDS logs and messages are properly configured, including the time synchronization with the master clock, and in accordance with the specification requirements.

24.9.15. Event Recorder Test

- 24.9.15.1. The Contractor shall test the Event Recorder system to validate its operation and functions.
- 24.9.15.2. The test shall validate the correct reporting of all faults and event data to the Event Recorder.

24.9.15.3. The Contractor shall validate that Event Recorder logs and messages are properly configured, including time synchronization with the master clock, and in accordance with Specification requirements.

24.9.16. CBTC System Static Pre-shipment Test

24.9.16.1. The CBTC supplier shall perform static Post Installation Check-Out (PICO) testing of the CBTC system (including transponder and radio (Data Communication System)) on each Unit to validate the function of the CBTC system.

24.9.17. Propulsion and Brake System Dynamic Test

24.9.17.1. The Contractor shall perform dynamic propulsion and braking tests at its facility to validate the Unit performance and compliance with requirements of Section 2 - Design and Performance Criteria.

24.9.17.2. The Contractor shall perform dynamic tests on each Unit under AW0 condition, up to the traction motor's base speed or test track speed limit, whichever is higher.

24.9.17.3. The Contractor shall supply test equipment and instrumentation, including recorders, sensors, pickups, wiring, and inverters. The equipment shall be compatible with the onboard Low Voltage Power Supply (LVPS) system described in Section 2.5 and otherwise not be damaged by the conditions specified in Section 9.2.3.

24.9.17.4. Internal combustion engines driving a generator or use of the vehicle auxiliary inverter power the instrumentation will not be permitted.

24.9.17.5. Isolation amplifiers shall be provided as part of the instrumentation package to isolate the instrumentation wiring and equipment from high voltages; no exposed terminals with potential differences greater than 50 volts will be permitted.

24.9.17.6. The Contractor shall gather test data using a multiple-channel digital data acquisition system.

24.9.17.7. All data shall be submitted in tabular and graphical format to allow comparison against the Specification requirements and datasets gathered during the onsite design qualification.

24.9.17.8. The accuracy and response of the instrumentation shall be sufficient to determine the degree of compliance with the Specification and design data.

24.9.17.9. All test results, including charts obtained from the recordings, shall become the property of NYCT. The following parameters data shall be recorded:

- a) Acceleration.
- b) Car Speed.
- c) Line Voltage.
- d) Line Current for each car.
- e) Traction Motor current on each truck.
- f) Traction Motor torque on each truck (for verification of dynamic and friction brake efforts).
- g) Propulsion and braking trainline control signals.
- h) Brake cylinder pressure for each truck.
- i) Distance.
- j) Time.

- 24.9.17.10. Immediately following the dynamic tests, the Contractor shall download and analyze all MDS faults. The fault log shall be included as part of the test report.
- 24.9.17.11. Operational or safety faults, or an excessive number of maintenance level faults, arising as a result of testing will render the dataset invalid.
- 24.9.17.12. Any adjustments required as a result of the tests, to obtain values corresponding to the specified performance, shall be made by the Contractor prior to shipment to NYCT for acceptance testing and, shall be noted in the Car History Book.

24.9.18. CBTC System Dynamic Pre-shipment Test

- 24.9.18.1. The Contractor shall perform any dynamic testing of the CBTC system (including transponder and radio (Data Communication System)) on each Unit that is defined in Section 14, Train Control System.

24.10. Acceptance Tests

24.10.1. General

- 24.10.1.1. Upon delivery to NYCT, the Contractor shall perform a set of comprehensive acceptance tests, as listed in Table 24-10, on each Unit to validate the operation, performance, and readiness of Unit for revenue service.
- 24.10.1.2. The Contractor shall provide all test equipment, materials, qualified personnel and any other necessary means and resources to safely perform all of the required acceptance tests.
- 24.10.1.3. The Contractor shall perform all necessary adjustments and/or repairs on the test Unit before the initiation of acceptance testing.
- 24.10.1.4. Upon delivery of a completed Unit to NYCT property, the Contractor and NYCT shall perform an Unpacking Inspection and Incoming Inspection.

Table 24-10: Acceptance Tests

Test	Number of Units	Reference
Miscellaneous Body Tests and Adjustments	All Units	24.10.2
Pneumatic System Leakage Test	All Units	24.10.3
Functional Test	All Systems on all Units	24.10.4
Dynamic Tests	All Units	24.10.5
Burn-In Test	All Units	24.10.6

24.10.2. Miscellaneous Body Tests and Adjustments

- 24.10.2.1. The Contractor shall complete all of the required car body tests and adjustments prior to starting of Dynamic Tests.
- 24.10.2.2. The Contractor shall verify the car’s height, overall dimensions, and truck clearances.
- 24.10.2.3. The Contractor shall verify the proper operation, level, and alignment of the couplers.
- 24.10.2.4. The Contractor shall adjust the air spring suspension system within the specified air pressure design tolerance.

24.10.3. Pneumatic System Leakage Test

- 24.10.3.1. The Contractor shall perform a Pneumatic System Leakage test to demonstrate compliance with Section 24.9.5.
- 24.10.3.2. In the event that the Pneumatic System Leakage checks do not pass the test requirements, the fault must be corrected and the Unit retested until the requirements are met.

24.10.4. Functional Tests

- 24.10.4.1. The Contractor shall perform a comprehensive functional test of each and every Unit's system to verify proper operation of all systems, both under normal and faulty operating conditions.
- 24.10.4.2. Functional tests shall be performed at a NYCT facility on each unit prior to track operation on NYCT property.
- 24.10.4.3. The Contractor shall use the PTEs to complete functional tests.
- 24.10.4.4. Unit's systems that cannot be validated by use of PTE, shall be tested by other approved means.

24.10.5. Dynamic Tests

- 24.10.5.1. The Contractor shall perform traction power, dynamic and friction braking, and auxiliary power test on each Unit to validate performance and compliance with the requirements of Section 2 - Design and Performance Criteria.
- 24.10.5.2. The dynamic test shall be conducted over an NYCT test track, under AW0 loading.
- 24.10.5.3. The Contractor shall supply three complete sets of test equipment including sensors, isolation amplifiers, pickups, inverters, wiring and cable assemblies, cabinets, power supplies and data acquisition equipment, including storage media, to allow recording and playback of parameters as specified below.
- 24.10.5.4. The accuracy and response of the instrumentation shall be sufficient to determine the degree of compliance with the Acceptance Test requirements.
- 24.10.5.5. A high accuracy speed sensor shall be provided for speed and distance measurements. The supplied hardware shall be verified against the devices that are already approved or utilized by NYCT.
- 24.10.5.6. The test equipment shall be compatible with the onboard LVPS system described in Section 2.5 and otherwise not be damaged by the conditions specified in Section 9.2.3.
- 24.10.5.7. Internal combustion engines driving a generator or use of the vehicle auxiliary inverter power the instrumentation will not be permitted.
- 24.10.5.8. No exposed terminals with potential differences greater than 50 volts shall be permitted.
- 24.10.5.9. The Contractor shall gather test data using a multiple-channel digital data acquisition system.
- 24.10.5.10. The Contractor shall provide sufficient recording media to store all records from the dynamic testing.
- 24.10.5.11. All data shall be submitted in tabular and graphical format to allow comparison against the Specification requirements and datasets gathered during the onsite design qualification.
- 24.10.5.12. No engineering and assembly work shall be required, other than to set the equipment into a car and to plug or connect the test cables into the car equipment and test equipment.
- 24.10.5.13. The Contractor shall provide the necessary wiring diagrams, schematics, and procedures to permit the test equipment to be installed, calibrated, operated, maintained and repaired.
- 24.10.5.14. All tables and graphs shall be clearly annotated to allow easy identification of all test parameters.

- 24.10.5.15. All charts obtained from the recordings shall become the property of NYCT.
- 24.10.5.16. All test instrumentation and the test equipment manufacturer furnished manuals shall become the property of NYCT upon completion of Dynamic Tests. The instrumentation equipment shall be operational at the time of turn over.
- 24.10.5.17. The Contractor shall perform dynamic functional tests on the track test to observe, validate, monitor and record the operation of the following signals:
- a) Acceleration.
 - b) Car Speed.
 - c) Line Voltage.
 - d) Line Current for each car.
 - e) Traction Motor current on each truck.
 - f) Traction Motor torque on each truck (for verification of dynamic and friction brake efforts).
 - g) Propulsion and braking trainline control signals.
 - h) Brake cylinder pressure for each truck.
 - i) Distance.
 - j) Time.
- 24.10.5.18. Any adjustments that might be required due to failed test, and/or to obtain values corresponding to the specified performance, shall be made by the Contractor and retested prior to Acceptance.
- 24.10.5.19. The Contractor shall perform a test to demonstrate the performance of auxiliary power supplies while negotiating non-bridgeable third rail power gaps. Gap testing could be combined with tractive power test.
- 24.10.5.20. The power gap test shall include a series of tests at selected gap locations to measure the performance of the system under a variety of load and speed conditions. Load conditions shall include train in regen when entering gap, all auxiliary loads running when entering the gap, and full auxiliary load call when exiting the rail gap.
- 24.10.5.21. Car speeds shall be varied to test the system when the time between third rail power removal and reapplication is at a maximum, a minimum, and a point in between.

24.10.6. Burn-In Test

- 24.10.6.1. The Contractor shall perform a monitored Burn-In test on each delivered Unit, to demonstrate the availability and reliability of Unit's systems, subsystems, and carborne equipment.
- 24.10.6.2. The Burn-In test shall commence after successful completion of all other tests on the corresponding Unit.
- 24.10.6.3. The Burn-In test shall consist of two coupled Units running 24 hours in simulated revenue service.
- 24.10.6.4. The Contractor shall collect MDS records covering the 24-hour test period, and make them available for review by NYCT.
- 24.10.6.5. During the last eight hours of Burn-In test, the following system functions shall be monitored and recorded by the onboard Event Recorder System:
- a) Brake Cylinder Pressure.
 - b) Tractive Effort Level.

- c) Brake Pipe Pressure.
- d) Cab Status (T/O, C/R, Non-Active).
- e) Deadman Control.
- f) Direction Forward/Reverse.
- g) Distance.
- h) Door Close Status.
- i) Emergency Brake Application.
- j) Speed.
- k) T/O Indication.
- l) Time.
- m) Trip Cock Activation.

- 24.10.6.6. The train crew shall monitor the proper operation of the lighting, announcements, information signs, doors and the HVAC system.
- 24.10.6.7. The Burn-In test will be considered successful only if there are no reports of relevant equipment failures (as defined in Section 21.1.2.7) during the last eight hours of testing.
- 24.10.6.8. In the event of equipment malfunction, failure, or defective condition, the contractor shall repair and document all reported defects using the appropriate NYCT form. The report shall be signed off by both NYCT and the Contractor.
- 24.10.6.9. Following the correction, the Contractor shall repeat the eight-hour portion of the test.

Section 25

Staten Island Railway Cars (R211S)

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25. Staten Island Railway Cars (R211S)

25.1. General Requirements and Scope

25.1.1. General Requirements

- 25.1.1.1. This section defines the requirements for the supply of R211S cars for the Staten Island Railway (SIR), to be developed in coordination with the New York City Transit (NYCT) R211A as defined in Section 1.1.3 b). SIR requirements in this section augment or supersede requirements found in sections 1 through 24 of the R211 specification.
- 25.1.1.2. All requirements of the R211A Specification Sections 1 through 24 shall apply to the R211S cars, except as specifically noted in this Section as changed or as new requirements.
- 25.1.1.3. Requirements for the R211S cars shall include, but are not limited to, those related to performance, function, design, maintainability, and validation of the trains.
- 25.1.1.4. The R211S cars shall accommodate the operational differences between SIR and NYCT, with a minimum of changes from the base R211A cars. Key differences include:
- a) SIR uses an Automatic Train Control (ATC) system which is different from the Automatic Block Signaling (ABS) and Communications-Based Train Control (CBTC) systems currently in use or planned for use on other NYCT lines. R211S cars shall be equipped with carborne ATC equipment compatible with the existing wayside SIR ATC system, while NYCT R211A cars shall be equipped with a carborne CBTC system per Section 14.
 - b) The R211S cars shall be electromagnetically compatible with the SIR 100 Hz pulse code modulated track circuits for train detection and cab signaling. Other NYCT rail lines use 25 Hz and 60 Hz track circuits and CBTC.
 - c) For St. George bound trains at Clifton station and Richmond Valley station in both directions, doors on the rear car shall not open, because safe passenger boarding/alighting cannot be guaranteed due to curvature at the end of the platform. Procedures call for the SIR crew to manually cut out affected door panels at Clifton station.
- 25.1.1.5. This Section is written to include a subsection which matches each main section of the R211A Specification. Each subsection identifies changes to be made to the R211A Specification for the R211S, additional requirements for the R211S, or notes that the R211A Specification remains unchanged for the R211S.
- 25.1.1.6. Submittal, test, and mockup requirements have not been revised from the R211A specification. Where the same document, test, or mockup has been approved, performed satisfactorily or created on identical equipment for other R211 trains under this Contract, a repeat will not be required, subject to NYCT approval.
- 25.1.1.7. Supplements to existing documents, such as Operating and Maintenance Manuals, providing appropriate content applicable to the SIR cars shall be created and delivered to NYCT.
- 25.1.1.8. Note that in the other sections of this Specification the individual who normally occupies the head end cab of a train and is responsible for performing functions necessary for train movement and monitoring is referred to as the Train Operator. SIR refers to this individual as the Locomotive Engineer. For the purposes of this Specification, it may be assumed the two are equivalent.

- 25.1.1.9. The specific type of ATC system used by SIR is a Cab Signaling system. In this specification where the general term “ATC system” is used, it shall be understood to mean the specific SIR Cab Signaling system
- 25.1.1.10. Where items are noted as requiring “NYCT approval”, the process shall encompass approval by both NYCT and SIR.

25.1.2. The Staten Island Railway (SIR) system

- 25.1.2.1. SIR spans approximately 14 miles and 22 stations, with 24-hour service seven days a week between the St. George and Tottenville stations.
- 25.1.2.2. SIR currently uses a fleet of R44 cars configured specifically for SIR’s operational needs. The cars are maintained in the SIR Clifton Maintenance Shop.
- 25.1.2.3. SIR maintains and operates a fleet of four diesel-electric locomotives for maintenance-of-way and emergency operations. These locomotives shall be able to mechanically couple to R211S cars, using a coupler adapter supplied by the Contractor, applied to and carried on the SIR locomotives (see Section 25.4).

25.1.3. Changes to R211A Section 1 Requirements

- 25.1.3.1. No changes from R211A specification.

25.2. R211 TS Section 2: Design and Performance Criteria

25.2.1. Changes to R211A Section 2 Requirements

- 25.2.1.1. Replace Section 2.1.3 with the following: “The R211S cars shall be designed and manufactured to operate within the Staten Island Railway environment (see Appendix A – Fixed Facilities Description).”
- 25.2.1.2. Replace Section 2.2.1.1 with the following: “Each operating Unit shall be comprised of five cars.”
- 25.2.1.3. Replace Section 2.2.1.2 b) with the following: “A Cars shall be equipped with ATC equipment, as described in Section 25.14.”
- 25.2.1.4. Replace Section 2.2.1.3 with the following: “Not used”.
- 25.2.1.5. Replace Section 2.2.1.4 with the following: “The R211S cars shall be operable as trains comprised of one or two operating Units. Note that SIR only operates single Unit trains in revenue service.”
- 25.2.1.6. Replace Section 2.5.1.1 with the following: “The car shall be capable of operational functionality and performance under the infrastructure and climate conditions specified in Appendix A - A – Fixed Facilities Description, which provides a system description of the fixed facilities, including dimensions and track alignment and construction, and environmental conditions of the Staten Island Railway.”
- 25.2.1.7. Add new Section 2.5.1.5: “R211S cars shall be compatible with existing SIR operations, procedures, signaling system, and Maintenance Facility.”
- 25.2.1.8. Add new Section 2.5.1.6: “The R211S cars shall not require any change to the existing SIR operations, procedures, signaling system, or Maintenance Facility, without prior approval of NYCT.”

- 25.2.1.9. Add new Section 2.5.1.7: “R211S cars shall be fully suited to, and provide revenue service operation on the SIR between the St. George and Tottenville stations, as well as being able to operate on all siding and yard tracks at St. George (including track to Ballpark), Clifton (including Bay Street), and Tottenville.”
- 25.2.1.10. Add new Section 2.5.1.8: “R211S cars shall be fully suited for train movement and maintenance in SIR maintenance and storage areas, including the yard at Tottenville Station, the SIR Clifton Maintenance Shop and NYCT’s Coney Island Yard.”
- 25.2.1.11. Add new Section 2.5.1.9: “R211S five-car Units shall be operable on NYCT’s B-Division for car performance testing purposes with the SIR carborne ATC system disabled.”
- 25.2.1.12. Add new Section 2.5.1.10: “The Contractor shall perform all necessary surveys, investigations, and analyses of the SIR operating environment and procedures, to identify differences relative to the B Division environment, and operating and maintenance procedures which affect the design, manufacture, operation, or maintenance requirements of the R211S car. The Contractor shall provide an SIR Operating Environment Report detailing all identified differences. [CDRL]”
- 25.2.1.13. Add new Section 2.5.1.11: “The Contractor shall develop and submit an SIR Design Report, describing in overview, and supported by details, how the R211S cars will fulfill the requirements of the SIR Operating Environment Report. [CDRL]”
- 25.2.1.14. Add new Section 2.5.1.12: “The Contractor shall design, manufacture, and deliver R211S cars which fulfill the requirements of the SIR Design Report.”
- 25.2.1.15. Replace Section 2.5.3.1 with the following: “Contact line voltages are as follows: Maximum Voltage 780 Vdc
- Substation Light Load Voltage 675 Vdc
 - Nominal Voltage 600 Vdc
 - Minimum Voltage 450 Vdc.”
- 25.2.1.16. Replace Section 2.7.2.6 with the following: “The R211S propulsion system shall be designed with two performance modes, designated as High Performance and Low Performance, in the same manner as the R211A system. However, R211S cars shall be configured so that they normally operate in the High Performance mode.”
- 25.2.1.17. Replace Section 2.11.1.6 with the following: “Except where explicitly required otherwise, the Unit shall comply with all requirements of NYCT AC Train EMC Standards document (ES) that is included in Appendix C-6. The Contractor is not required to perform the Radio Emissions Susceptibility Qualification Test with the 1000W Microwave Oven that is detailed in Section 6.1, Table 6-1b of the NYCT AC Train EMC Standards. SIR does not have the same signaling system as the NYCT system. The Contractor shall be responsible for determining the rolling stock interference limits which apply for all SIR track circuits and shall test the R211S to those limits. For the R211S cars only, the Contractor shall assume the NYCT test track will not have SIR specific equipment installed, and shall submit an alternative test procedure to the NYCT AC Train Conducted EMI Test Procedure. Such a test procedure shall be developed in accordance with UMTA-“MA-06-0153-85-6, Volume II “Conducted Interference – Suggested Test Procedures”.

- 25.2.1.18. Add new Section 2.11.1.10: "In addition to the requirements of TS 2.11, the R211S shall be electromagnetically compatible:
- a) Within itself.
 - b) With all other trains and equipment in operation at SIR.
 - c) With the SIR signal system.
 - d) With SIR wayside communications systems.
 - e) With other SIR electronic equipment as specified elsewhere within Section 25 of this Specification.
 - f) With equipment owned by neighbors of SIR along its right-of-way."

- 25.2.1.19. Add new Section 2.11.1.11: "Track circuits used on SIR include, but are not limited to, the following:
- a) 100 Hz coded track circuits used by the ATC system.
 - b) 60 Hz single rail track circuits at St George.
 - c) 60 Hz double rail track circuits at Tottenville Yard.
 - d) Audio Frequency overlay track circuits in interlockings.
 - e) Audio Frequency track circuits for sidings and route request locations.
- A listing of all track circuits used on SIR will be provided to the Contractor by NYCT after NTP."
- 25.2.1.20. Add new Section 2.11.1.12: "The Contractor shall perform all necessary field and laboratory analysis to characterise the signal and coupling susceptibility levels for each of the SIR Track Circuits. The Contractor shall survey all track circuits used on SIR. The analysis shall determine the following:
- a) Conducted Emission Impulse limit.
 - b) Conducted Emission Repeating Broadband limit.
 - c) Conducted Emission Harmonic limit.
 - d) Inductive Emission relay pickup levels.
 - e) Inductive Emission limits.
- The Contractor shall submit a susceptibility characterization test procedure for approval. **[CDRL]**"
- 25.2.1.21. Add new Section 2.11.1.13: "A complete SIR Track Circuit EMC Characterization Report shall be submitted for approval. The R211S rolling stock interference levels and frequency ranges shall be clearly stated in this report based on the measurements and calculations made by the Contractor. **[CDRL]**"
- 25.2.1.22. Add new Section 2.11.1.14: "R211S cars shall be compatible with all SIR track circuits. The Contractor shall provide complete analysis, reports, and test results consistent with the requirements of NYCT AC Train EMC Standard for 25 Hz and 60 Hz track circuits, Appendix C-6 extended to cover all SIR track circuits, demonstrating EMC, to the satisfaction of NYCT."
- 25.2.1.23. Add new Section 2.11.1.15: "The Contractor shall demonstrate that the R211S cars have a margin of at least 6 dB between the worst case level of Cab Signal Interference (CSI) caused by operation of an R211S Unit and the lowest level of CSI at which the CSI can disturb the normal operation of the ATC cab signal receiver, when operating in the SIR track circuit with the lowest valid level of cab signal."
- 25.2.1.24. Replace Section 2.11.2.1 with the following: "The conducted emission limits shall be as determined by the Contractor in the SIR Track Circuit EMC Characterization Report."
- 25.2.1.25. Replace Section 2.11.3.1 with the following: "The inductive emission limits shall be as determined by the Contractor in the SIR Track Circuit EMC Characterization Report."
- 25.2.1.26. Replace Section 2.15.2.4 with the following: "Final approval of EMC compliance shall be based on testing of full trains (one Unit), under worst case conditions on the actual SIR right of way, as defined in Section 24 – Testing Program."
- 25.2.1.27. Add new Section 2.15.2.12: "The Contractor shall develop a SIR Track Circuit EMC Characterization Test Procedure. **[CDRL]**"
- 25.2.1.28. Add new Section 2.15.2.13: "The Contractor shall develop a SIR Track Circuit EMC Characterization Test Report. **[CDRL]**"

25.2.1.29. Replace the table in Section 2.16 with the following. The individual CDRLs on this have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

The following Contract Deliverables are defined in this section:

CDRL	Ref	Deliverable	Timing
2-1	2.2.4.1	Identification system for equipment and components on Units and cars	IPDR
2-2	2.5.1.4	List of recommended cleaning agents	IPDR
25-3	25.2.1.12	SIR Operating Environment Report	IPDR
25-4	25.2.1.13	SIR Design Report	IPDR
2-3	2.11.1.9	EMI detector FMECA, FTA, and HSA	CDR
25-5	25.2.1.20, 25.2.1.27	Track circuit susceptibility characterization test procedure	IPDR
25-6	25.2.1.21, 25.2.1.28	SIR Track Circuit EMC Characterization Report	IPDR
2-4	2.14.7.6	Obsolescence Management Plan	CDR
2-5	2.15.1.3	Description of the dynamic simulator	Prior to analysis
2-6	2.15.1.4	Final report of the results of the dynamic simulation	Prior to approval of the truck drawings
2-7	2.15.1.6	Fully configured dynamic simulation model	Delivery of the first car
2-8	2.15.2.2	Draft EMC plan	PDR
2-9	2.15.2.3	EMC Design Report	CDR
2-10	2.15.2.5	EMI safety analysis	CDR
2-11	2.15.2.8	Preliminary description of the EMI Detector, if used	PDR
2-12	2.15.2.9	Detailed EMI Detector design	CDR
2-13	2.15.3.1	Summary drawing defining the relationship between subsystems	PDR
2-14	2.15.4.1	Preliminary Crashworthiness plan	PDR
2-15	2.15.4.1	Crashworthiness analysis	IPDR

** PDR = Preliminary Design Review, IPDR = In-process Design Review, CDR = Critical Design Review*

25.3. R211 TS Section 3: Carbody Structure

25.3.1. No changes from R211A specification.

25.4. R211 TS Section 4: Coupler Systems

25.4.1. Changes to R211A Section 4 Requirements

- 25.4.1.1. Replace Section 4.1.3.4 with the following: "R211S cars shall mechanically and pneumatically couple with existing SIR work locomotives using a coupler adapter to be provided by the Contractor to be carried on each locomotive (4 total), as described in Section 4.4.4."
- 25.4.1.2. Not used.
- 25.4.1.3. Not used.
- 25.4.1.4. Add new subheading after Section 4.4.4.5: "Coupler Adapter for work locomotives"
- 25.4.1.5. Add new Section 4.4.4.6: "Four lightweight (portable) coupler adapters shall be furnished to permit mechanical and pneumatic coupling of the R211S coupler to SIR work locomotives."
- 25.4.1.6. Add new Section 4.4.4.7: "The coupler adapter shall have sufficient strength to pull or push (in the event of an emergency) a failed train under the conditions defined in Section 4.2.1.2."
- 25.4.1.7. Add new Section 4.4.4.8: "The coupler adapter shall be provided with an NYCT approved carrier, to be mounted on or inside the work locomotives at an NYCT approved location. The preferred location for the coupler adapter is the existing location on the work cars. If the existing location is not feasible the location of the coupler adapter shall be approved by NYCT."

25.5. R211 TS Section 5: Cab and Cab Controls

25.5.1. Changes to R211A Section 5 Requirements

- 25.5.1.1. Replace Section 5.1.2.3 with the following: "The initial cab design shall be similar to the R160 or the R179 Car, and guided by the conceptual renderings in Figures 5-1 through 5-5. Please note that these illustrations depict the R211A requirements. The written requirements of this Section, where they conflict, override the renderings of the R211A."
- 25.5.1.2. Replace Section 5.1.2.6 d) with the following: "Any of a) through c) above with the train under the supervision of the ATC system specified in Section 25.14."
- 25.5.1.3. Add new heading 5.1.3: "SIR Cab Arrangement".
- 25.5.1.4. Add new Section 5.1.3.1: "The general arrangement of the R211S cab shall be identical to the R211A cab. The key differences between the R211S and R211A cabs are that the R211S cab controls will accommodate the SIR ATC system, instead of the CBTC system installed on the R211A."
- 25.5.1.5. Add new Section 5.1.3.2: "The Contractor shall submit detailed layouts of the R211S cab for approval by NYCT. Upon approval, the design shall be incorporated in the R211A cab mock-up for final approval. A separate cab mock-up is not required for the R211S. The R211A mock-up cab shall be arranged in such a way that the details of the R211S cab layout can be presented to NYCT for review. Items like the cab console shall be arranged in a modular fashion such that the R211A cab console can be easily removed and replaced with a R211S cab console for the cab mock-up. [CDRL]"
- 25.5.1.6. Add new Section 5.2.8.4: "The CBTC locker detailed in Section 5 for the R211A cars shall be used to house the R211S carborne ATC system components."

- 25.5.1.7. Replace Section 5.3.1.1 with the following: “The design of controls, indicators, and displays shall be coordinated to support operation under Train Operator and Conductor control, OPTO control, or ATC control, and shall provide platform edge (provision for) and onboard CCTV viewing.”
- 25.5.1.8. Replace Section 5.3.1.16 with the following: “The allocation of controls and indicators to the three Train Operator Displays (TODs) (i.e. CCTV TOD, ATC TOD, and MDS TOD) shall be arranged for normal operation with all three TODs functioning.”
- 25.5.1.9. Replace Section 5.3.1.21 with the following: “In the event that the ATC TOD fails, a selector switch on the console shall allow the Train Operator to switch the ATC TOD screen onto the MDS TOD.”
- 25.5.1.10. In Section 5.3.3.1, replace Table 5-1 with the following:

Table 5-1: List of R211S Cab Console Controls and Indicators

<u>Item</u>	<u>Name</u>	<u>Type</u>	<u>Specification Reference</u>
1	Not used for R211S		
2	Not used for R211S		
3	Not used for R211S		
4	Carbody Lights On/Off	3-Position Momentary Selector Switch	Section 8.3.1.2
5	Cab Light (Off/On)	2-Position Selector Switch	Section 8.3.1.5
6	HVAC (On/Off)	3-Position Momentary Selector Switch	Section 7.3.4.1
7	Windshield Defroster	Alternate-action Pushbutton w/ Integral Indicator	Section 5.7.10
8	Windshield Wiper (Off/Int./Low/High)	4-Position Selector Switch	Section 5.7.12
9	Windshield Washer	Pushbutton	Section 5.7.13
10	Horn	Yellow Mushroom Pushbutton	Section 12.4.7.1
11	Buzzer	Pushbutton	Section 13.7.3
12	Uncouple Key Switch	Key Switch	Section 4.1.5
13	Uncouple	Pushbutton	Section 4.1.5
14	Advance	Pushbutton	Section 4.1.5
15	Isolate	Pushbutton	Section 4.1.5
16	Left Door Key Switch	Key Switch	Section 6.4
17	Left Door Open	Pushbutton	Section 6.4
18	Left Door Close	Pushbutton	Section 6.4

Item	Name	Type	Specification Reference
19	Left Door Enable	Pushbutton w/ Integral Indicator	Section 6.4
20	Right Door Enable	Pushbutton w/ Integral Indicator	Section 6.4
21	Door Closed Interlock Bypass	Pushbutton w/ Integral Indicator	Section 6.4
22	Lamp Test	Pushbutton	Section 5.5.12.1
23	Door Closed & Locked	Indicator	Section 6.4.19.6
24	Push To Talk	Pushbutton	Section 13.3.2
25	Reading Light Dimmer	Control Dimmer	Section 8.3.1.6
26	ATC TOD Select (Normal/Back Up)	2-Position Selector Switch	Section 14.4.5.2
27	CCTV Control Key Switch	Key Switch	Section 5.3.1.20
<i>The following are required for R211S in addition to the above</i>			
28	ATC Acknowledge	Green Mushroom Momentary Pushbutton	Section 25.14
29	Departure Test	Pushbutton, Yellow in Color	Section 25.14
30	Door Cutout	2-Position Selector Switch	Section 25.6.1.2
31	Door Cutout Indicator	Indicator	Section 25.6.1.2
32	Headlight Dimming On/Off	2-Position Selector Switch	Section 25.8.1.1

- 25.5.1.11. Replace Section 5.3.3.2 with the following: “Not used.”
- 25.5.1.12. Replace Section 5.4.1.1 a) with the following: “One ATC TOD.”
- 25.5.1.13. Replace Section 5.4.1.15 with the following: “The TODs shall be self-contained, requiring no external controls other than clearly indicated touch screen interface buttons and/or menus to allow the crew and maintenance personnel to communicate with the ATC system, the MDS, the CCTV system, and other car systems.”
- 25.5.1.14. Replace Section 5.4.1.18 c) with the following: “The “sleep” mode shall initiate a screen saver with a subway or train oriented motif when the train is keyed up but stopped for a specific interval with no user interaction or updated ATC data;”
- 25.5.1.15. Replace Section 5.4.1.18 e) with the following: “The screen shall “wake-up” from screen saver mode if there is Train Operator interaction or a change in ATC data.”

- 25.5.1.16. Replace Section 5.4.2.10 with the following: “As part of the design process, the Contractor shall provide preliminary screen layouts for the MDS TOD, the ATC TOD, and the CCTV Display for NYCT approval. [CDRL]”
- 25.5.1.17. In Section 5.4.3.3, replace Table 5-3 with the following:

Table 5-3: MDS TOD Indications

<u>Item</u>	<u>Indication</u>	<u>Active Screen</u>	<u>Specification Reference</u>
1	Snow Brake On/Off Indication	Operating Screen	Section 12.3.6
2	Energy Conservation Mode On/Off Indication	Operating Screen	Section 10.2.4.2
3	Next Stop (as displayed on interior message displays)	Operating Screen	Section 13
4	Distance from previous station	Operating Screen	Section 13
5	Fault Indication (flashing)	Operating Screen	Section 17
6	Passenger Emergency Handle Unit (PEHU) (with exact location)	Trouble Screen	Section 12.3.4
7	Consist Indication (cars in train, with car numbers shown in order and lead car indicated)	Operating Screen Trouble Screen Maintenance Screen	Section 17
8	Odometer Display	Maintenance Screen	Section 10.3.12
9	Location of applied friction brake/parking brake	Trouble Screen	Section 12
10	Route and Destination	Control Screen	Section 13
11	Regenerative Brake Cutout	Control Screen	Section 10
12	Time and Date	Control Screen	Section 17
13	C/R Indication	Operating Screen	Section 17
14	Trainline and Network Controller Mode	Operating Screen	Section 14
15 to 18	Not used for R211S		
19	Air/Parking Brake Release Indicator	Operating Screen	Section 12
20	CCTV System Failed	Operating Screen	Section 13
21	HVAC State (Hot car/Cold Car and location)	Trouble Screen	Section 7
22	ATC System Fault	Operating Screen	Section 25.14
23	Rear Car Door Cutout	Operating Screen	Section 25.6.1.2
24	ATC System Cutout	Operating Screen	Section 25.14

- 25.5.1.18. Replace Section 5.4.3.11 with the following: "When the carborne ATC equipment is off, failed, or cutout, the train speed shall be displayed on the Doppler Speedometer Display. When the ATC system is on, functional, and not cutout, the carborne ATC system shall display the train speed on the ATC TOD as described in Attachment 1. When the train speed is displayed on the ATC TOD, the Doppler Speedometer Display shall not display the train speed."
- 25.5.1.19. Replace Section 5.4.4 heading with the following: "ATC TOD Screens".
- 25.5.1.20. Replace Section 5.4.4.1 with the following: "The CBTC TOD specified for the R211A cab shall be used as the ATC TOD on the R211S. The ATC TOD shall display the information required by the Aspect Display Unit (ADU) and the ATC Fault Display as described in Attachment 1. The R211S ATC TOD shall be in the same location as the R211A CBTC TOD and shall be identical in construction."
- 25.5.1.21. Replace Section 5.4.4.2 with the following: "The ATC TOD screens are described in more detail in Attachment 1."
- 25.5.1.22. Add new Section 5.5.5.8: "The Bypass and Cutout Switches located in the Bypass and Cutout Panel specified in Section 5.5.5 shall be the same for the R211A and R211S."
- 25.5.1.23. Replace Section 5.5.6.3 with the following: "The Event Recorder circuit breaker and ATC circuit breakers shall incorporate clear covers that are sealable in the closed (ON) position."
- 25.5.1.24. Replace Section 5.5.9 heading with the following: "ATC Bypass Panel".
- 25.5.1.25. Replace Section 5.5.9.1 with the following: "An ATC Bypass Panel shall be provided on the left side of the cab."
- 25.5.1.26. Replace Section 5.5.9.2 with the following: "The ATC Bypass Panel shall have a clear hinged cover door, locked using the Master Door Controller key."
- 25.5.1.27. Replace Section 5.5.9.3 with the following: "The R211S ATC devices listed below shall be housed in the space allocated to the CBTC Bypass panel specified in Section 5.5.9 for the R211A cars:
- a) Terminal Mode key switch;
 - b) Positive Stop Cutout switch;
 - c) Speed Control Cutout switch;
 - d) ATC System Cutout switch."
- 25.5.1.28. Add new Section 5.5.9.4: "The key design for the Terminal Mode key shall be spring loaded. Details of the existing Terminal Mode Key will be made available to the Contractor after NTP.
- 25.5.1.29. Replace Section 5.5.10 with the following: "Not used."
- 25.5.1.30. Replace Section 5.5.13.1 with the following: "Audible indications shall be provided in the cab for at least the following events:
- a) Passenger Emergency Intercom (see Section 13).
 - b) Buzzer; (see Section 13).
 - c) Parking Brake Applied with Train in Motion (see Section 12).
 - d) Direction set to Reverse (see Section 13).
 - e) Passenger Emergency Signal (PEHU) (see Section 12).
 - f) Radio Transmit Timeout (see Section 13).
 - g) As needed for the ATC system (see Section 25.14)."

25.5.1.31. Add new Section 5.5.14.7: “New devices unique to the R211S that have been specified in this Section shall be appropriately identified with their R211S function identified. Where any device from the R211A is not included in the R211S, no identification or label shall be present for the R211S.”

25.5.1.32. Replace the table in Section 5.9 with the following:

The following Contract Deliverables are defined in this section:

CDRL	Ref	Deliverable	Timing
5-01	5.1.2.10, 25.5.1.5	Layouts of the R211S cab and cab equipment	PDR
5-02	5.4.1.4	The location of the all TODs	PDR
5-03	5.4.2.10, 5.8.1.3	Preliminary screen layouts for the MDS TOD, the ATC TOD, and the CCTV TOD	PDR
5-04	5.5.2.4	Arrangement of the MDCs	PDR
5-05	5.5.6.5	Circuit Breaker Panel arrangement	PDR
5-06	5.5.13.3	Audible Alarm Scheme including an audible demonstration of all of the proposed tones and combinations therein	PDR
5-07	5.7.11.2	Windshield glare control method	PDR
5-08	5.8.1.1	Specific data on the Master Controller	PDR
5-09	5.8.1.4	Ergonomic studies for cab layout	PDR

25.6. R211 TS Section 6: Side Door System

25.6.1. Changes to R211S Section 6 Requirements

25.6.1.1. Add new subheading after Section 6.4.12.41: “Rear Doors Cutout”.

25.6.1.2. Add new Section 6.4.12.42: “A two position switch shall be provided in the cab to initiate the Rear Doors Cutout function, to prevent the doors on the rear car and the rear door panels on the fourth car of the Unit from opening in both directions at the Richmond Valley station and for St. George bound trains at Clifton station.”

25.6.1.3. Add new Section 6.4.12.43: “The switch shall be able to be activated from any active cab, but shall cutout the rear car (the non-active end car) and the rear door panel on the fourth car of the Unit in the scenario described above regardless of which cab it is commanded from.”

25.6.1.4. Add new Section 6.4.12.44: “Rear Doors Cutout status shall be recorded by the MDS and displayed on the TOD.”

25.7. R211 TS Section 7: Heating, Ventilation and Air Conditioning (HVAC)

25.7.1. No changes from R211A specification.

25.8. R211 TS Section 8: Lighting Systems

25.8.1. Changes to R211A Section 8 Requirements

- 25.8.1.1. Add new Section 8.3.2.10 with the following: "A headlight dimming function shall be incorporated into the headlight design. When the dimming function is active the headlight beams shall illuminate the running rail approximately 75 feet (22.9m) from the front of the car. The dimming function shall be activated using the cab console Headlight Dimming On/Off selector switch described in Section 25.5.1.10."

25.9. R211 TS Section 9: Auxiliary Electric Equipment and Distribution

- 25.9.1. No changes from R211A specification.

25.10. R211 TS Section 10: Propulsion System

25.10.1. Changes to R211S Section 10 Requirements

- 25.10.1.1. Add new Section 10.2.1.7: "If significant differences between the NYCT and the SIR system are found during the investigations required by Section 25.2.1.12, then the impact to the propulsion system shall be minimized to the greatest extent possible. The Contractor shall accommodate those differences wherever possible by using adjustable software parameters such that propulsion hardware and software do not have to be changed for the R211S."
- 25.10.1.2. Add new Section 10.2.1.8: "Software parameters shall be adjustable by PTE by authorized NYCT personnel to switch to a preset "SIR Mode" to allow for testing when the cars are transferred to an NYCT Maintenance or Overhaul Facility (i.e. – during SMS)."

25.11. R211 TS Section 11: Trucks and Suspension System

25.11.1. Changes to R211A Section 11 Requirements

- 25.11.1.1. Replace Section 11.3.1.3 with the following: "All motorized trucks shall be interchangeable between ends of cars without modifications to the truck except for configuring the leveling valve connections, drawbar stops, and either CBTC or ATC equipment. Non-motorized trucks shall be manufactured so as to accept all equipment necessary for conversion to a motorized truck. No structural changes shall be necessary."
- 25.11.1.2. Replace Section 11.4.1.5 with the following: "The trucks shall have provisions for mounting, without interference, brake equipment, leveling valve(s), trip cocks, current collectors, traction motors, gear units, CBTC equipment, ATC equipment, and all associated wiring and piping."
- 25.11.1.3. Add new item 11.4.1.16 as follows: "The R211S ATC cab signal pickup coil assembly is mounted to the front end of the No. 1 truck. The R211A CBTC Transponder Interrogator Antenna (TIA) is mounted to the rear end of the No. 1 truck. All R211A and R211s trucks shall have provisions for mounting both pieces of equipment such that the trucks are interchangeable."
- 25.11.1.4. Replace Section 11.4.4.13 with the following: "Emergency supports shall be provided for traction motors, gear units, trip cocks, current collectors, and SIR ATC antennas to ensure they remain clear of the track in the event of primary mount failure. Emergency support shall be an integral part of the truck frame and shall not support any weight until a failure has occurred."

25.12. R211 TS Section 12: Friction Brake and Air Supply Systems

25.12.1. Changes to R211A Section 12 Requirements

- 25.12.1.1. In Section 12.3.1.6, add new item m) to the list as follows: "The Friction Brake Electronic Control Unit (FBECU) shall respond to the ATC controlled Full Service Brake trainline with a load corrected full service brake."
- 25.12.1.2. Replace Section 12.3.4.1 with the following: "With PEHU activation, the emergency brake shall be applied if, and only if, the train has proceeded 300 feet (91.4 m) or less from its most recent station stop."
- 25.12.1.3. Replace Section 12.3.4.2 with the following: "If the train has proceeded more than 300 feet (91.4 m) from its most recent station stop, the emergency brake shall be applied when the train has reached its next station stop. See Section 12.4.8."

25.13. R211 TS Section 13: Communications

25.13.1. Changes to R211A Section 13 Requirements

- 25.13.1.1. Replace Section 13.4.9.1.b) with the following: "'CH UP" and "CH DN" keys shall scroll through the frequency channels programmed into the radio from the present setting. The associated Channel Aliases that shall be displayed on the LCD display when the frequency channels are scrolled will be provided after Notice to Proceed."
- 25.13.1.2. Replace Section 13.8.1.12 with the following: "SIR is in the process of procuring a new Train Radio system. The new system will operate in the 800MHz range. The R211S Train Radio assembly shall be designed to function with this new train to wayside radio system. Specific details of the new radio design will be provided after Notice to Proceed."
- 25.13.1.3. Replace Section 13.8.1.13 with the following: "Not used."
- 25.13.1.4. Replace Section 13.8.1.15 with the following: "Not used."

25.14. R211 TS Section 14: Train Control System

25.14.1. Changes to R211A Section 14 Requirements

- 25.14.1.1. Delete Section 14 in its entirety and replace with the contents of Attachment 1 to Section 25.

25.15. R211 TS Section 15: Carbody Equipment and Interiors

25.15.1. Changes to R211A Section 15 Requirements

- 25.15.1.1. Replace Section 15.7.1.1 with the following: "An inter-car barrier system shall be provided on each side of the bi-parting end doors to protect individuals while passing from car to car, independent of car speed and relative alignment."
- 25.15.1.2. Replace Section 15.7.1.2 with the following: "An inter-car barrier system shall also be provided at each non-cab end corner of the carbody to warn, deter, and protect individuals from inadvertently walking off the station platform between cars. This system shall also discourage passengers from attempting to enter the car ends directly from the platform"

- 25.15.1.3. Replace Section 15.7.1.7 with the following: "Inter-car barriers are not required on the No. 1 End of R211S A-Cars."
- 25.15.1.4. Replace Section 15.7.1.8 with the following: "Inter-car barriers adjacent to bi-parting end doors, shall be easily separated (locks shall be provided to prevent un-authorized detachment) while the cars are standing on any track configuration from tangent to the minimum radius curve (see Appendix A - Fixed Facilities Description)."
- 25.15.1.5. Replace Section 15.7.1.9 with the following: "Not used."

25.16. R211 TS Section 16: Trainline and Car Control Architecture

25.16.1. Changes to R211A Section 16 Requirements

- 25.16.1.1. Replace Section 16.2.1.1 with the following: "The response time for all controls from the Operator's (T/O or C/R) cab or the ATC commands to each controlled system shall be:"
- 25.16.1.2. Replace Section 16.3.1.1.c) with the following: "The ATC equipment shall be able to perform its train control functions from any A Car in the train, working in conjunction with an Operator in the lead car and a Conductor, if present, in another A Car. (See Section 25.14)"
- 25.16.1.3. Replace Section 16.3.2.1.d) with the following: "4 x RS-485 Spare".
- 25.16.1.4. Replace Section 16.3.3.1 with the following: "A Cars shall contain a redundant Trainline and Network Controller (TLNC) to receive train crew and ATC commands (as required by the ATC system design), and provide the appropriate resultant command to the trainlines and networks."
- 25.16.1.5. Replace Section 16.3.3.2 with the following: "Where interpretation is necessary, the TLNC shall also receive the necessary information from the trainlines and networks, and provide that information to the cab equipment and to the ATC system (as required by the ATC system design)."
- 25.16.1.6. Replace Section 16.3.3.3 with the following: "The TLNC shall include diagnostic functions that compare the signals from the various cab devices and from the ATC (as required by the ATC system design), check for discrepancies in the signals, and respond in an approved manner to the MDS."
- 25.16.1.7. Add Section 16.3.3.4 as follows: "The TLNC shall arbitrate between console commands and ATC commands (as required by the ATC system design), and provide the appropriate commands to the trainlines. The design of the train subsystems and their arbitration functions shall be presented to NYCT for approval. [CDRL]"
- 25.16.1.8. Replace Section 16.3.4.1.a) with the following: "The Protected Control of the Propulsion and Brake systems for both manual and ATC operation (as required by the ATC system design) and may also include Door system controls, HVAC system controls and other system controls;"
- 25.16.1.9. Replace Section 16.3.5.1 with the following: "Train control shall be a fully integrated system of crew controls and ATC signal controls, using dedicated parts of the TLNC. Please refer to Section 5, Cab and Cab Controls and Attachment 1."
- 25.16.1.10. Replace Section 16.4.3.1.f) with the following: "On each A Car, the local Emergency Magnet Valve (EMV) control circuit shall be coordinated with the ATC system supplier. Refer to Section 25."
- 25.16.1.11. Replace Section 16.4.3.2 with the following: "not used."
- 25.16.1.12. Replace Section 16.4.3.3 with the following: "The entire emergency braking system is subject to review and approval, and may be affected by the ATC design coordination process."

25.16.1.13. Replace the table in Section 16.7 with the following:

The following Contract Deliverables are defined in this section:

CDRL	Ref	Deliverable	Timing
16-1	16.2.3.1	Average and Peak data traffic levels and operating margins for each network	IPDR
16-2	16.3.2.2	Table of trainlines, unitlines, and coupler pin requirements, including spares and redundancy	PDR
16-3	25.16.1.7	Design of subsystems and arbitration functions	IPDR
16-4	16.6.1.1	Control System Response Time Budget Analysis	IPDR
16-5	16.6.2.5	Combined network demonstration plan, detailed test procedures, and failure modes and effects report	CDR
16-6	16.6.3.1	Network Verification Procedures	CDR
16-7	16.6.5.1	Control Signal Identification Plan	PDR
16-8	16.6.6.1	Open architecture information	CDR
16-9	16.6.7.1	Cyber Security and network vulnerability	CDR
16-10	16.6.7.3	Train control architecture SFD	PDR

25.17. R211 TS Section 17: Monitoring and Diagnostics

25.17.1. Changes to R211A Section 17 Requirements

25.17.1.1. Replace Section 17.3.3.9 with the following: “The Trouble Screen shall present, as a minimum, the following train information and function, with the proposed arrangement submitted for approval [CDRL]:

- a) Passenger Emergency Handle Unit activation and location.
- b) Door Not Closed, location and door leaf.
- c) Door Open Enroute.
- d) Both door leafs in one doorway fail to open when commanded.
- e) All doors on one side of a car fail to open simultaneously when commanded.
- f) Stuck Brake, location - car, truck.
- g) Brake In Emergency, location.
- h) Trip Cock activation, location.
- i) Insufficient Propulsion, location.
- j) Axle lockout, location – car, truck.
- k) Circuit Breaker Tripped, location - breaker ID.
- l) Auxiliary Power fault.
- m) Air Supply fault – insufficient air supply.
- n) Hot car (see Section 7.2.1.2).
- o) Network Fault, location and ID.
- p) Passenger Emergency Intercom activation, location.
- q) CCTV fault, location.

r) ATC System Cutout.

s) ATC System Failure.”

25.17.1.2. Replace Section 17.3.6.2 with the following: “The MDS master clock shall be changed through the use of a PTE and by trainline command.”

25.17.1.3. Replace Section 17.3.6.3 with the following: “Not used.”

25.17.1.4. Replace Section 17.5.2.2 with the following: “The following signals are additions to, and clarifications of, the required event recorder signals from IEEE Std. 1482.1-2013, and shall be recorded:

- a) Cab Status (T/O, C/R, Non-Active).
- b) Trip Cock Activation;
- c) Contact Rail voltage.
- d) Door Open Trainline (Left/Right).
- e) Door Enable Trainline (Left/Right).
- f) Zero speed detection (Section 10.3.7).
- g) Door interlock bypass switch status (Section 6.4.17)
- h) ATC Code Rate.
- i) ATC Overspeed Detected.
- j) ATC Overspeed Acknowledged.
- k) ATC Penalty Brake.
- l) ATC Emergency Brake.
- m) ATC Motor Inhibit.
- n) ATC Positive Stop Cutout.
- o) ATC Control Cutout.
- p) ATC System Cutout.
- q) ATC Terminal Mode.
- r) Rear Car Door Cutout.
- s) Three Spares.

25.17.1.5. Replace Section 17.5.2.3 with the following: “Not used.” and delete Table 17-1.

25.18. R211 TS Section 18: Software Systems

25.18.1. No changes from R211A specification.

25.19. R211 TS Section 19: Materials, Processes, and Workmanship

25.19.1. No changes from R211A specification.

25.20. R211 TS Section 20: Program Management

25.20.1. Changes to R211S Section 20 Requirements

25.20.1.1. Add the following to Attachment 20-1:

Spec Ref	Content	When required
25	STATEN ISLAND CARS	
	<ul style="list-style-type: none"> Arrangement and details of designs that are different from the R211A cars 	PDR

25.21. R211 TS Section 21: Reliability, Maintainability and Safety Requirements

25.21.1. Changes to R211A Section 21 Requirements

25.21.1.1. Replace Table 21-1 in Section 21.1.2.2 with the following:

Table 21-1 – MDBSCF Requirements for Critical Subsystems

System	MDBSCF (miles)	MDBSCF (km)
Propulsion System	50,000	80,468
Auxiliary Electrical System	120,000	193,122
Air Comfort System	100,000	160,935
Door System and Controls	100,000	160,935
Air Supply and Friction Brake System	60,000	96,561
Communication Systems (including Signs, CCTV, OPTO related system)	100,000	160,935
Trainlines and Networks	300,000	482,804
ATC System (Cab Signaling) – SIR Cars	300,000	482,803

25.21.1.2. Replace Section 21.1.2.8 c) with the following: “Failure caused by wayside equipment such as ATC or Platform Edge CCTV.”

25.21.1.3. Replace Section 21.3.3.2.t) with the following: “SIR ATC equipment related hazards.”

25.22. R211 TS Section 22: System Support

25.22.1. Changes to R211A Section 22 Requirements

25.22.1.1. Replace Section 22.3.3.4 with the following: “The TOM shall contain procedures and information related to preparation of a train for operation in manual and ATC operating modes, including One Person Train Operation (OPTO) and two-person train operation, and procedures for laying-up trains from service. All operating conditions shall be accounted for, including coupling and uncoupling.”

25.22.1.2. Replace Section 22.5.1.16 with the following: “The Contractor shall attend a one day mandatory NYCT Track Safety class (TS3) and a one day SIR Safety Training class at NYCT’s and SIR’s training facilities, respectively, to learn about NYCT’s and SIR’s safety regulations and facilities.”

25.22.1.3. Replace Section 22.5.5.9 a) with the following: “ATC carborne equipment.”

- 25.22.1.4. Replace Section 22.5.5.12 with the following: "Interactive technology based training modules shall be provided for all major subsystems such as ATC carborne equipment, One Person Train Operation (OPTO), Propulsion, Side Doors and Controls, car CCTV (including protocol for access and chain of custody) and Platform Edge CCTV, Brakes System, Air Compressor, Auxiliary Power, HVAC, and Communications."
- 25.22.1.5. Replace Section 22.5.7.3 with the following: "The training course structure shall include operating sessions, under ATC control, to enable trainees to obtain a proper knowledge about the actual train operations and driving cab experience in maintenance yards and mainline."

25.23. R211 TS Section 23: Quality Assurance Requirements

25.23.1. No changes from R211A specification.

25.24. R211 TS Section 24: Compliance Program

25.24.1. Changes to R211A Section 24 Requirements

25.24.1.1. Add new item to Table 24-2, In Section 24.5.1.1:

Test	Frequency	Reference
ATC System	One Unit Set	Section 25, Attachment 1

25.24.1.2. Add new subheading after Section 24.5.2.11: "Laboratory Cab Signal Interference Test".

25.24.1.3. Add new Section 24.5.2.12 as follows: "The Contractor shall demonstrate that the R211S cars have a margin of at least 6 dB between the worst case level of Cab Signal Interference (CSI) caused by operation of a R211S unit and the lowest level of CSI at which the CSI can disturb the normal operation of the ATC cab signal receiver, when operating in the SIR track circuit with the lowest valid level of cab signal."

25.24.1.4. Add new subsection 24.5.3: "ATC System Test"

25.24.1.5. Add new Section 24.5.3.1 as follows: "The ATC system shall be tested as described in Section 25, Attachment 1, Section 14.7.5."

25.24.1.6. In Section 24.7.1.4, replace Table 24-4 with the following:

Table 24-4: Unit Qualification Tests

Test	Frequency	TS Reference
Train Networks	First Unit	24.7.2
Trainlines	First Unit	24.7.3
Clearance	First or second Unit	24.7.4
Performance	First Unit	24.7.5

Test	Frequency	TS Reference
Noise and Vibration	First or second Unit	24.7.6
EMC Field Test	First Unit	24.7.7
Battery Capacity	First or second Unit	24.7.8
Thermal Mapping	First or second Unit	24.7.9
FMECA Validation	First or second Unit	24.7.10
Communication and CCTV	First Unit	24.7.11
Parking Brake	First or second Unit	24.7.12
PEHU	First Unit	24.7.13
30 Day Operations in Service	First Unit	24.7.14
ATC Qualification Test	First Unit	25, Attachment 1

25.24.1.7. Replace Section 24.7.2.3 with the following: “Tests shall contain all elements tested in lower level network qualification tests, and include the ATC network traffic, in compliance with Section 25 – SIR Cars and 16 - Trainline and Car Control Architecture.”

25.24.1.8. In Section 24.7.5.2, replace Table 24-5 with the following:

Table 24-5: Performance Tests

Test	No of Units	Load level	Type	TS Reference
Propulsion Performance	One Unit	AW0, AW2, AW3	Motoring, Braking	24.7.5.24
Braking Performance	One Unit	AW0, AW2, AW3	Braking	24.7.5.25
Thermal Capacity	One Unit	AW0, AW3	Motoring, Braking	24.7.5.28
Wheel Slip and Slide Control	One Unit	AW0	Braking	24.7.5.29
Auxiliary AC Power Supply	One Unit	N/A	Normal, Shedding	24.7.5.30
	One Unit	AW2	Motoring	24.7.5.31

Power and Energy Consumption	One Unit	AW2	Regenerative Braking	24.7.5.31
	One Unit	AW2	Auxiliary System	24.7.5.33
	One Unit	AW2	Climate System	24.7.5.34
Transient Power	One Unit	AW2	Power Up	24.7.5.37

- 25.24.1.9. In Section 24.7.7.1, add new item d) to the list as follows: “d) Field CSI.”
- 25.24.1.10. Replace Section 24.7.4.1 with the following: “One R211S Unit shall be operated at low speeds over the entire SIR system to verify clearances both on the Car and on the wayside.”
- 25.24.1.11. Replace Section 24.7.7.7 with the following: “The electromagnetic compatibility tests shall be performed on one completely assembled R211S Unit, as approved by NYCT.”
- 25.24.1.12. Replace Section 24.7.7.8 with the following: “The electromagnetic test shall be conducted on SIR designated tracks by methods referenced in Section 25.2 to ensure compliance with specified requirements and compatibility with the SIR traction power distribution and communications systems.”
- 25.24.1.13. Replace Section 24.7.7.10 with the following: “Worst case emissions testing shall be as defined in Section 25.2.”
- 25.24.1.14. Replace Section 24.7.7.12 with the following: “The Contractor shall develop a Contractor Conducted EMI Test Procedure (Contractor CETP) and perform a Field Conducted EMI Test as specified Section 25.2.”
- 25.24.1.15. Replace Section 24.7.7.13 with the following: “The Contractor shall be responsible for determining the SIR worst case track circuit length.”
- 25.24.1.16. Replace Section 24.7.7.14 with the following: “The Conducted Emissions limits shall be determined by the Contractor as described in Section 25.2. The Conducted Emissions limits shall be approved by NYCT.”
- 25.24.1.17. Replace Section 24.7.7.18 with the following: “The Inductive Emissions limits shall be determined by the Contractor as described in Section 25.2. The Conducted Emissions limits shall be approved by NYCT.”
- 25.24.1.18. Replace Section 24.7.14.1 with the following: “The first R211S Unit shall be subject to a 30-day Revenue Service Test with passengers on the SIR system, according to a procedure similar to Appendix C-44 (R188 30-Day Operations Passenger Service Test Procedure ETP #00-02).”
- 25.24.1.19. Add new Subsection 24.7.15: “ATC Qualification Tests”.
- 25.24.1.20. Add new Section 24.7.15.1: “The Contractor shall perform dynamic unit level qualification testing of the ATC system as defined in Section 25, Attachment 1, Section 14.7.8”.
- 25.24.1.21. Replace Section 24.8.10 with the following: “Not Used”.
- 25.24.1.22. In Section 24.9.1.4, Table 24-9: delete “CBTC Pre-shipment Tests” from the Static Tests.
- 25.24.1.23. In Section 24.9.1.4, Table 24-9: delete “CBTC Pre-shipment Tests” from the Dynamic Tests.
- 25.24.1.24. In Section 24.9.1.4, Table 24-9: add “ATC System Pre-shipment Tests” to the Static Tests.
- 25.24.1.25. In Section 24.9.16 replace heading with the following: “ATC System Routine Tests”
- 25.24.1.26. Replace section 24.9.16.1 with the following: “The Contractor shall perform routine testing of the ATC system on each Unit as defined in Section 25.14, Attachment 1, Section 14.7.6”.
- 25.24.1.27. Replace Section 24.9.18 with the following: “Not Used”.

25.24.1.28. In Section 24.10.1.4, Table 24-10, add new item to the end of the table as follows:

Test	Number of Units	Reference
ATC Dynamic Test	All Units	25, Attachment 1

25.24.1.29. Replace section 24.10.6.3 with the following: “The Burn-In test shall consist of a single R211S Unit running 24 hours in simulated revenue service on the SIR system.”

25.24.1.30. In Section 24.10.6.5 add new items to the list as follows:

- n) ATC Code Rate.
- o) ATC Overspeed Detected.
- p) ATC Overspeed Acknowledged.
- q) ATC Penalty Brake.
- r) ATC Emergency Brake.
- s) ATC Motor Inhibit.
- t) ATC Positive Stop Cutout.
- u) ATC Control Cutout.
- v) ATC System Cutout.
- w) ATC Terminal Mode.
- x) Rear Car Door Cutout.

25.24.1.31. Add new subsection 24.10.7: “ATC Dynamic Tests”.

25.24.1.32. Add new Section 24.10.7.1: “The Contractor shall perform dynamic testing of the ATC system on each Unit as defined in Section 25.14 Attachment 1, Section 14.7.9”.

SECTION 25, ATTACHMENT 1

(This attachment replaces Section 14 of the R211A Specification for the R211S cars, and contains the replacement for Section 14, together with Attachments 14A and 14B.)

14. Automatic Train Control System

14.1. Introduction and General Requirements

- 14.1.1. This section defines the requirements for the carborne Automatic Train Control (ATC) system for the SIR R211S cars.
- 14.1.2. ATC Cab Signaling equipment shall be installed on all SIR R211S A Cars.
- 14.1.3. The Contractor shall provide all ATC equipment including but not limited to the following:
 - a) Central processing and control unit.
 - b) Input/output modules.
 - c) Speed sensors.
 - d) Cab signal pick-up coils.
 - e) Relays.
 - f) ATC TOD.
 - g) Cab controls.
- 14.1.4. The carborne ATC system shall interface with the existing SIR wayside ATC system. Details of the existing SIR wayside ATC system are outlined in Attachment 14-A.
- 14.1.5. The Contractor shall provide a new ATC function such that as the train approaches the bumping post a reduced speed limit of 5 mi/h (8 km/h) shall be enforced. This function shall be provided at both the St. George and Tottenville Terminals, and all yard tracks shown highlighted in Attachment 14-C. This function does not currently exist on the SIR system. The Contractor shall provide all required wayside modifications and onboard equipment that is required to implement this new function. This function only applies to the R211S and does not have to be implemented on the existing SIR rolling stock. The design shall be submitted for approval. **[CDRL]**
- 14.1.6. The Contractor shall provide all mounting hardware and interconnecting cabling and conduit for the carborne ATC system.
- 14.1.7. The Contractor's EMC Program shall ensure and document that the Wayside ATC speed commands are not disrupted by CSI, and shall document that the required margin exists between the worst case CSI level produced by the R211S Unit and the most sensitive threshold of the carborne ATC to CSI.

14.2. Functional Requirements

14.2.1. Wayside Interface

- 14.2.1.1. Information on the existing SIR wayside ATC system is for reference purposes only.
- 14.2.1.2. The existing SIR Wayside ATC is an Alstom microprocessor-based audio frequency system, which generates a power frequency signal that is transmitted/superimposed into the running rails.

- 14.2.1.3. When a track circuit is not occupied by a train, the presence of the wayside ATC power frequency signal is received by the track circuit logic system receiver at the opposite end of the track circuit from the transmitter, energizing a track relay and providing indication that the track circuit is unoccupied.
- 14.2.1.4. When the track circuit is occupied by a train, the occupying train wheels and axles shunt the circuit such that the track circuit logic system receiver no longer receives the power frequency signal, de-energizing the track relay and providing indication that the track circuit is occupied.
- 14.2.1.5. Track circuits report status to Wayside ATC so that Wayside ATC is aware of the positions of trains on the line. Wayside ATC generates code rates representing speed commands based on the known position of trains combined with other constraints such as maximum speed limit.
- 14.2.1.6. The carborne ATC system shall receive wayside ATC speed commands through carborne ATC Receiver Coil Assemblies which shall inductively couple the 100 Hz carrier frequency signal from the rails.
- 14.2.1.7. The carborne ATC system shall include a receiver channel which detects 100 Hz signals with minimum signal level of 1.0 Amps in rail current.
- 14.2.1.8. The carborne ATC system shall include a second receiver channel which detects a high-energy signal with minimum signal level of 20 Amps in rail current.
- 14.2.1.9. The carborne ATC system shall decode the wayside ATC speed command signals and translate signals at seven modulation rates (code rates) into speed limits for use by the carborne ATC and Train Operator in accordance with Table 14-1.
- 14.2.1.10. When a 420 code is present in the rails the ATC system shall provide a speed limit of 10 mi/h (16 km/h). The Contractor shall design a new feature so that as the train approaches the bumping post a reduced speed limit of 5 mi/h (8 km/h) shall be enforced. This function shall be provided at both the St George and Tottenville Terminals, and all yard tracks. The Contractor shall provide all wayside and onboard equipment necessary to implement this new feature.
- 14.2.1.11. The carborne ATC system shall calculate overspeed detection points and enforce overspeed protection in accordance with Table 14-1:

Table 14-1: SIR ATC Code Rates and Train Speeds

Code	Code Rate Pulses per minute (ppm)	Speed Limit (mi/h)	Overspeed Detection Point (mi/h)
1	0	Stop and Stay	3 (4.8 km/h)
2	50	15 (Restricting)	17 (27 km/h)
3	75	20	22 (35 km/h)
4	120	35	37 (60 km/h)
5	180	45	47 (76 km/h)
6	270	60	62 (100 km/h)
7	420	10 (Latch-In to Terminal Mode)	10 (16 km/h_
8	420* (Terminal)	5 (Terminal Approach Mode)	5 (8 km/h)
9	420**(High Energy)	Spare	Spare

* New function

** A High Energy 420 PPM Code Rate was used for cab signal Cutout during the original commissioning of the ATC system. It is no longer used.

- 14.2.1.12. A High Energy 420 PPM Code Rate was used for cab signal Cutout by SIR during the commissioning of the ATC system. It was transmitted to the car via loops installed in the gauge between the rails. The high energy 420 PPM Code rate shall be a spare Cab Signal Aspect for the R211S.
- 14.2.1.13. A special 50 PPM Code Rate shall be used at certain locations on the SIR to facilitate train operations and will be employed only under the authority of the Train Dispatcher.
- 14.2.1.14. No-code (zero code rate) shall enforce a stop and stay for all trains.

14.2.2. Carborne ATC Functionality Overview

- 14.2.2.1. The carborne ATC system shall process speed command information from the ATP Receiver Coil Assemblies on only the leading A Car of a Unit.
- 14.2.2.2. The carborne ATC system shall calculate actual train speed and travel direction based on the output signals received from the ATC speed sensors.
- 14.2.2.3. The cab signal received by the carborne ATC system shall be interpreted as a speed limit, the aspect of which shall be displayed to the Train Operator, in addition to actual train speed, on the ATC TOD.
- 14.2.2.4. When a more restrictive speed is received, an overspeed condition shall be detected and the new speed limit shall be displayed on the ATC TOD. The on-board ATC system shall monitor the Train Operator's response to the reduced speed indication and shall intervene if the train does not achieve the required deceleration, or brake pipe pressure within specified time intervals.
- 14.2.2.5. The Contractor shall submit for approval a description of the Cab Signaling system operation and functionality. The Contractor shall also submit for approval a report verifying compatibility of on-board cab signaling operation with the wayside system and with the signal block design safe braking model. For reference, the safe braking model used for the current fleet is included in Attachment 14-D. **[CDRL]**

14.2.3. Normal Operation

- 14.2.3.1. During normal operation, the Cab Signaling system shall receive a speed code from the wayside. This shall be interpreted as a maximum train speed and shall be displayed in the cab on the ATC TOD.
- 14.2.3.2. While the Train Operator maintains a speed of no more than the cab signal speed, the Cab Signaling system shall allow the Train Operator to motor and shall not impose penalty braking.
- 14.2.3.3. The Contractor shall, during the detailed design phase, verify that the worst-case combination of actual wheel diameter, cab signal assumed wheel diameter, and ATC speed signal calibration shall not allow a train to have an actual speed of more than 2 mi/h (3.2 km/h) above cab signal speed without incurring an overspeed alarm. That is, the safe braking model shall not be invalidated by differences between actual train speed and the train speed calculated by the carborne ATC system. **[CDRL]**

14.2.4. Change Of Speed Code

- 14.2.4.1. If the speed code changes to a less restrictive code, the carborne ATC system shall display the new speed limit and accompany this with a single chime of a bell. No acknowledgment or action shall be required by the Train Operator.
- 14.2.4.2. The Train Operator shall be able to accelerate to the new cab signal speed without incurring penalty braking.

- 14.2.4.3. If the speed code changes to a more restrictive speed code (or to no-code), the carborne ATC system shall display the new code and accompany it with a continuous alarm.
- 14.2.4.4. The speed code change shall be acknowledged by pressing the 'Acknowledge' button. Alternatively, the Train Operator shall acknowledge the code change by moving the Master Controller to the Full Service Brake position. If the Train Operator fails to acknowledge within 3 seconds, the carborne ATC system shall apply penalty braking.
- 14.2.4.5. If the train speed is greater than the new cab signal speed, then the carborne ATC system shall register an overspeed condition.

14.2.5. Overspeed

- 14.2.5.1. The carborne ATC detects when actual train speed exceeds the overspeed detection point.
- 14.2.5.2. If actual train speed exceeds the overspeed detection point for a pre-determined time, the carborne ATC system displays an overspeed indication on the ATC TOD, sounds a sustained audible alarm, commands removal of traction power, and commands penalty braking.
- 14.2.5.3. If the carborne ATC system does not detect train deceleration of at least 1.4 mi/h/s (0/63 m/s/s) within 5 seconds of the carborne ATC commanding removal of traction power and application of penalty braking, the carborne ATC commands irrevocable emergency braking.
- 14.2.5.4. The carborne ATC system does not remove an emergency braking command until a train has reached No Motion and the Master Controller is in the Brake position.
- 14.2.5.5. Moving the Master Controller to the Full Service Brake position or pressing the Acknowledge pushbutton within 3 seconds of an overspeed condition immediately silences the overspeed audible alarm, and upon the train reaching underspeed, permits application of traction power and removes the penalty braking command.
- 14.2.5.6. If the Train Operator does not move the Master Controller to the Full Service Brake position or press the Acknowledge pushbutton within 3 seconds of an overspeed condition, the carborne ATC system continues to display an overspeed indication on the ATC TOD, sounds a sustained audible alarm, commands removal of traction power, and commands penalty braking until the train reaches No Motion.
- 14.2.5.7. If the Train Operator achieves the assured retardation or brake pipe pressure reduction within the required time, but subsequently reduces braking effort below that required at any time, then the Cab Signaling system shall immediately initiate penalty braking.
- 14.2.5.8. If the Train Operator achieves retardation to the new cab signal speed without penalty, the Cab Signaling system shall release motoring inhibit and silence visual and audible alarms. The overspeed condition shall only be released if the decelerating train reaches a speed equal to or below the cab signal speed.

14.2.6. Penalty Braking

- 14.2.6.1. If the carborne ATC system initiates penalty braking, then an alarm indication shall be illuminated on the ATC TOD.
- 14.2.6.2. If the need for penalty braking is detected, the carborne ATC system shall provide fail-safe irretrievable penalty braking to a full stop of the train. This shall be done via a vital interface circuit. The retardation rate shall be that of full service braking. The design of the brake system interface and cab signaling operation shall comply with CFR49 Parts 232 and 236.
- 14.2.6.3. Penalty braking shall be realized by de-energizing the Full Service Brake trainline.

- 14.2.6.4. If feedback of the penalty brake application is required it may be done via pressure transducers monitoring the air pipe, brake pipe and brake cylinder pressure or by other means as approved by NYCT and SIR.
- 14.2.6.5. Once the train has stopped, release of the brakes shall be achieved if the Master Controller is placed in the 'Full Service Brake' position.
- 14.2.6.6. The carborne ATC system shall determine that the train is at Zero Speed when the actual train speed values calculated from the two independent speed sensor inputs are both below a defined low speed threshold.
- 14.2.6.7. The carborne ATC system shall command penalty braking if the carborne ATC determines that the train is in the No Motion state for 5 seconds and the Acknowledge Switch is not activated within that 5 seconds.
- 14.2.6.8. The carborne ATC system shall delay penalty braking for 5 seconds if the Acknowledge Switch is activated within 5 seconds of the carborne ATC determining a transition to the No Motion state or within 5 seconds of a prior Acknowledge Switch activation in the No Motion state.
- 14.2.6.9. The carborne ATC system shall command penalty braking upon failing to receive an accurate signal from one or both speed sensors.
- 14.2.6.10. The carborne ATC system shall command penalty braking upon detecting a 5 mi/h (8 km/h) or more difference between the speed values calculated from the two speed sensors.
- 14.2.6.11. The carborne ATC system shall command penalty braking if the carborne ATC is unable to determine travel direction.

14.2.7. Loss Of Code

- 14.2.7.1. Upon loss of cab signal code for any reason the carborne ATC system shall enforce a speed reduction to a stop.

14.2.8. Bi-Directional Operation

- 14.2.8.1. R211S trains shall operate under restricted speed, enforced by the carborne ATC system, when 'Reverse' direction is selected from the Master Controller.
- 14.2.8.2. In the event that there is a loss of direction detection, the carborne ATC system shall enforce a speed reduction to a stop.

14.2.9. ATC Cutout Functions

- 14.2.9.1. One key switch and three cutout switches shall be provided in the cab as follows:
 - a) Terminal Mode Key switch.
 - b) Positive Stop Cutout switch.
 - c) Speed Control Cutout switch
 - d) ATC System Cutout switch
- 14.2.9.2. In the event that the wayside system, or on-board speed detection has failed, the speed enforcement shall be cutout via the Speed Control Cutout switch. This shall allow the Train Operator to motor up to the full line speed. Train speed shall then be maintained according to the SIR Rule Book.
- 14.2.9.3. Indication of speed control cutout (Non-cab territory) shall be provided on the ATC TOD.

- 14.2.9.4. When the Speed Control Cutout switch is in the ON position, the carborne ATC system shall continue to indicate any received speed code on the ATC TOD and accompany it with alarms upon change of speed code in the normal way. The carborne ATC shall command penalty braking if the Train Operator fails to press the Acknowledge Switch or move the Master Controller to Brake within 3. seconds of the carborne ATC receiving a wayside ATC speed command that indicates a more restrictive speed limit than the current speed limit.
- 14.2.9.5. While operating with the Speed Control Cutout switch in the ON position, the carborne ATC system shall command emergency braking upon detecting that the Acknowledge Switch has been continuously activated for at least 3 seconds.
- 14.2.9.6. In case of cab signaling failure, the cab signaling functions and alarms shall be cutout via the Cab Signaling Cutout switch. However, the speed limit received through cab signaling and the actual train speed shall continue to be displayed on the ATC TOD.
- 14.2.9.7. If both Cab Signaling and Speed Control are cut out, all ATC functions shall be disabled. However, received cab signal speed and actual train speed shall continue to be displayed on the ATC TOD.
- 14.2.9.8. The carborne ATC system shall enforce a speed limit of 10 mi/h (16 km/h) when the carborne ATC does not detect a Wayside ATC speed command signal while the Positive Stop Cutout switch is placed in the ON position.
- 14.2.9.9. The carborne ATC system shall enforce a speed limit of 10 mi/h (16 km/h) when the carborne ATC does not detect a Wayside ATC speed command signal while the Terminal Mode Key Switch is placed in the ON position.
- 14.2.9.10. All cutout switches shall be sealed by a lead seal or approved equal.

14.2.10. Active Cab

- 14.2.10.1. R211S trains have two A Cars. Only Train Operator's actions from an active cab shall be provided to the ATC system by the train subsystems.
- 14.2.10.2. Not Used.
- 14.2.10.3. In non-leading cabs, all ATC TOD indications except actual train speed shall be extinguished and all ATC cab controls shall be disabled.

14.2.11. Departure Test

- 14.2.11.1. The carborne ATC system shall perform a self-test when the "Departure Test" button on the cab console is pressed, the ATC system detects No Motion, and the train is located in non-signaled territory.

- 14.2.11.2. The carborne ATC system shall include the following Departure Test functions which verify carborne ATC operation prior to placing a Unit into revenue service:
 - a) Test of vital interface circuits.
 - b) Decoding and ATC TOD display of each speed limit using simulated Wayside ATC speed limit commands sent from the ATC system to test coils.
 - c) Decoding, overspeed detection, and overspeed visual and audible indications using simulated car speed values and simulated Wayside ATC speed limit commands sent from the ATP Module to test coils located in the ATP Receiver Assemblies.
- 14.2.11.3. Cab Signal Pickup Coils shall each contain a test coil that carborne ATC system shall use to verify cab signal operation during the Departure Test.
- 14.2.11.4. Simulated cab signals shall be sent by the carborne ATC system through the test coils, and shall be received by the Cab Signal Pickup Coils test coils during Departure Testing to verify functionality of the carborne ATC system.
- 14.2.11.5. One or more Departure Test failures results in halting the Departure Test, displaying the fault condition(s) on the ATC TOD, and logging of the fault condition by the ATC Data Logger.
- 14.2.11.6. The Contractor shall submit for approval a functional description of the calibration and self-testing systems.

14.2.12. Speed Detection And Processing

- 14.2.12.1. The carborne ATC system shall calculate actual train speed and travel direction based on the output signals received the ATC speed sensors. This information shall be used for speed enforcement by the Cab Signaling system, for recording actual train speed by Data Recorder, and for train speed indication on the ATC TOD.
- 14.2.12.2. Speed sensing accuracy shall be better than ± 0.5 mi/h (± 0.8 km/h).
- 14.2.12.3. Speed sensors shall be functional up to at least 10% above the maximum line speed.
- 14.2.12.4. The carborne ATC system shall determine that the train is in a No Motion state when the actual train speed values calculated from the speed sensor inputs are below a defined low speed threshold.
- 14.2.12.5. The carborne ATC system shall protect against inaccurate calculation of actual train speed:
 - a) The carborne ATC system shall detect and account for wheel slip and slide in its calculation of actual train speed.
 - b) The carborne ATC system shall command penalty braking upon failing to receive an accurate signal from one or both speed sensors.
 - c) The carborne ATC system shall commands penalty braking upon detecting a 5 mi/h (8 km/h) or more difference between the speed values calculated from the two speed sensors.
 - d) The carborne ATC system shall provide for and use a configurable wheel diameter parameter in calculating the actual train speed, to compensate for wheel diameter decrease due to wear.
 - e) The carborne ATC system shall detect any corruption of the wheel diameter value and uses the largest possible wheel diameter value when calculating actual train speed.
 - f) The carborne ATC system shall store the wheel diameter value in non-volatile RAM.
- 14.2.12.6. The Contractor shall submit for approval functional descriptions and drawings, describing how the speed sensing system operates and interfaces with the ATC Cab Signaling system.

14.2.13. ATC TOD Screens

14.2.13.1. The ATC TOD shall display speed command information, cutout status, braking status, and ATC system fault status. The information displayed and screen layout for the ATC TOD shall mimic the information currently displayed on the SIR R44 Aspect Display Unit (ADU) and Fault Display Unit (FDU) to the extent possible. Data sheets and functional details of the existing SIR R44 ADU and FDU are available upon request.

14.2.13.2. The following information shall be displayed by the ATC TOD:

Table 14.2: ATC TOD Information

Function	Details
Actual train Speed	Curved bar graph (speedometer), red in color
Actual Train Speed	Digital speed indication (two numbers), red in color
Speed Code Indication	Illuminated markers around the speedometer curve.
Status Indication	Indication
Fault Indication	Descriptive ATC Fault Information

14.2.13.3. The ATC TOD shall display the status indications as follows:

Table 14.3: ATC TOD Status Indications

Status	Color	Description
CAB SIG CUTOUT	Yellow	Provides indication that cab signaling is disabled by illuminating upon entering non-coded territory or when the Cab Signal Cutout switch is in the Cutout position in the cab.
SPEED CONT CUTOUT	Yellow	Provides indication when the Speed Control Cutout switch is in the cutout position in the cab.
TERMINAL MODE	Yellow	Provides indication when the Positive Stop Cutout switch is in the cutout position, the Terminal Mode key switch is activated, or when the carborne ATC receives a code rate of 420 ppm.
SUPPRESS	Green	Provides indication when a suppression rate of 1.4 mi/h/s (0.63 m/s/s) is achieved.
PENALTY	Red	Provides indication when the ATC Full Service Brake trainline is de-energized.
OVERSPEED	Red	Provides indication when an overspeed condition occurs.
DEPT. TEST	Green	Provides indication while the carborne ATC equipment is undergoing a Departure self-test.
ATC FAULT	Yellow	Provides indication when the carborne ATC detects a fault.

14.2.13.4. The ATC TOD shall display all active carborne ATC fault or failure information associated with the electronic cards, circuits, and inputs from trainlines and controls in a descriptive text format information.

14.2.13.5. The ATC TOD Fault Indication shall provide, at a minimum, the information that is currently provided on the existing SIR R44 FDU. ATC faults shall include, but not be limited to the following:

- a) ATC Communications fault.
- b) ATC software revision fault.
- c) ATC central processing and control unit fault.
- d) ATC input/output board(s) fault.

- e) ATC power up fault.
- f) ATC Speed sensor faults.
- g) TLNC fault.
- h) ATC brake assurance fault.
- i) ATC system timing fault. .
- j) ATC buffer fault.
- k) Departure Test fault.
- l) Departure Test Cab Signal fault.
- m) ATC Data Logger fault.

14.2.13.6. There shall be no subsidiary screens on the ATC TOD.

14.2.13.7. During normal operation, the ATC TOD shall be the primary screen to display ATC information including Brakes In Emergency (BIE) events initiated by the ATC system and other faults described in the Section.

14.2.13.8. The Contractor shall submit the ATC TOD screen layout, fault detection function, and the fault display wording to NYCT for approval [CDRL].

14.2.14. ATC Data Recorder

14.2.14.1. The ATC Data Recorder shall store, as a minimum, the following data for 96 hours:

- a) ATC Time.
- b) Travel Distance.
- c) Train Speed.
- d) Train Travel Direction.
- e) Master Controller position.
- f) Brake applications and operations, including brake pipe and brake cylinder pressures.
- g) Cab signal aspects.
- h) Motoring inhibit.
- i) Penalty brake application.
- j) ATC Emergency brake application.
- k) Cab Signal cutout.
- l) Speed Control cutout.
- m) Full System Cutout
- n) Cab signal acknowledged.
- o) ATC equipment failure/fault.

14.2.14.2. ATC Data Recorder data shall be downloaded via the ATC PTE.

14.2.15. ATC Audible Alarms

- 14.2.15.1. The following ATC audible alarms shall be provided:
- a) An audible alarm sounds when an overspeed condition occurs or when penalty or emergency braking is commanded.
 - b) When in speed control cutout mode, an audible alarm sounds upon the change to a more restrictive speed code.
 - c) A single short “bong” sounds whenever a code rate change is detected, except in the speed control cutout mode.

14.3. Design Requirements

14.3.1. General

- 14.3.1.1. The carborne ATC system shall be installed in the cab of each R211S A1 and A2 Car in the lockers that are used to house the CBTC equipment on the R211A.
- 14.3.1.2. When a 420 code is present in the rails the ATC system shall provide a speed limit of 10 mi/h (16 km/h). The Contractor shall design a new feature so that as the train approaches the bumping post a reduced speed limit of 5 mi/h (8 km/h) shall be enforced. This function shall be provided at both the St George and Tottenville Terminals, and all yard tracks. The Contractor shall provide all wayside and onboard equipment, including but not limited to any transponder readers and mounting brackets, necessary to implement this new feature.
- 14.3.1.3. The Contractor shall perform a design study that ensures that there is adequate space to house all of the required carborne ATC equipment in the A Car cab:
- a) The study shall include 3D renderings of the relevant carborne ATC equipment locker showing the location of all of the carborne ATC equipment and relevant tolerances.
 - b) The study shall include a temperature and heat dissipation analysis that shall demonstrate that the heat from the carborne ATC equipment in the proposed equipment lockers can be dissipated, such that the equipment will not be exposed to temperatures that exceed the equipment’s rated limits.
 - c) For the purpose of the study, the maximum temperature outside the cars shall be considered to be 125°F (52°C), with the HVAC system OFF, car under full solar load, and the ATC equipment in full power.
 - d) Simulated images from thermal imaging analysis modeling software shall be submitted to show that the temperature limits are not exceeded.
 - e) The study shall be submitted to NYCT for approval. [CDRL]
- 14.3.1.4. The ATC locker on the R211S shall be accessed using the same key as the CBTC locker on the R211A.
- 14.3.1.5. The carborne ATC equipment shall be powered from the Low Voltage Distribution Network (LVDN). The Contractor shall provide appropriate circuit breakers for each piece of ATC equipment, as approved by NYCT.
- 14.3.1.6. The carborne ATC equipment shall be provided with a simple, menu-driven facility accessed by means of a laptop computer to provide adjustment of the cab signal functions. This shall include adjustment of assumed wheel diameter and of cab signal pick-up threshold. Security shall be

provided via password protection software to restrict the ability to change cab signal functions to authorized technicians.

- 14.3.1.7. The carborne ATC system shall be insensitive to the Electromagnetic Interference (EMI) on board the trains and along the right-of-way, including power rail collector shoe arcing.

14.3.2. Central Processing and Control Unit

- 14.3.2.1. In the event of a general system failure affecting the microprocessor system, or any of its communications links, the outputs from the system shall be set to a safe state.
- 14.3.2.2. All systems which perform real-time control functions necessary for the safe and/or reliable operation of the railway shall provide integrity checks for all data and programs stored in the memory devices. The check shall consist of a Cyclic Redundancy Check (CRC) of the memory contents.
- 14.3.2.3. In the event that an integrity check is failed, the unit shall immediately provide an indication to the ATC TOD that it has failed, and switch all outputs to their most restrictive condition.
- 14.3.2.4. Inputs and outputs shall incorporate optically isolated circuits or other approved methods to isolate external circuits from the internal components of the circuit boards.
- 14.3.2.5. The system shall have solid state outputs of suitable power to drive relays, serial and parallel inputs to other microprocessor systems, or other devices as required.

14.3.3. Vital Equipment

- 14.3.3.1. Functions that are required to be implemented in a fail-safe manner (i.e., vital functions) shall be designed and implemented following explicitly defined safety assurance concepts as summarized in IEEE 1483.
- 14.3.3.2. Each vital system shall monitor on a continuous basis 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 the databases are valid and not corrupted. Systems which revert to a more restrictive state in the event of corruption are acceptable.
- 14.3.3.3. 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.
- 14.3.3.4. The system shall ensure that inputs and internal variables are current, and not 'stale' data from previous operations.
- 14.3.3.5. The system shall ensure that outputs are driven correctly and are responsive to changes in input status. No de-energized output shall be spuriously energized.
- 14.3.3.6. Data exchanged between microprocessors shall be current and valid.
- 14.3.3.7. Input and output ports shall be isolated. The method of isolation shall be approved by NYCT.
- 14.3.3.8. Failure of the system to meet any or all of the above requirements shall result in a shutdown of the microprocessor and the reversion to a restrictive state of all outputs.

14.3.4. ATC Train Operator Display

- 14.3.4.1. The ATC TOD shall be located on the cab console to the left of the Train Operator. The ATC TOD on the R211S shall be the TOD that is used as the CBTC TOD on the R211A as described in Section 5.4.
- 14.3.4.2. The ATC TOD shall be connected to the train network as described Section 16.3.4.
- 14.3.4.3. The R211S ATC TOD shall be the same hardware, design, and location as the CBTC TOD on the R211A cars, only the content displayed on the ATC TOD shall be different.

14.3.5. Speed Sensors

- 14.3.5.1. The Contractor shall provide speed-sensing equipment for all R211S Units.
- 14.3.5.2. The A1 Car of the R211S shall be equipped with one unpowered truck, with one unbraked, or free, axle on that truck. Speed sensors shall be installed on the axle ends of the free axle. Additional speed sensors may be installed in the gear boxes of powered axles as required.
- 14.3.5.3. Speed sensors shall be readily accessible for routine maintenance.
- 14.3.5.4. Speed sensors shall be fitted so as to not conflict with the limits of the existing car and Unit clearances and wayside clearances of the SIR.
- 14.3.5.5. Speed sensors shall be electrically connected via shielded flexible cable terminating in a waterproof multi-pin connector in accordance with MIL-C-5015 to facilitate truck removal. In designing, installing and wiring sensors, the Contractor shall take into account the severity of the moisture conditions and contaminants encountered in railway operation.
- 14.3.5.6. The ATC speed sensors on all trucks shall be identical. Where possible all speed sensors on the R211S and R211A cars shall be of the same design.
- 14.3.5.7. The Contractor shall provide a basic test tool to test the speed sensors.
- 14.3.5.8. The Contractor shall submit speed sensing equipment and mounting details to NYCT for approval.

14.3.6. ATC Cab Signal Pickup Coils

- 14.3.6.1. The Contractor shall provide two ATC Cab Signal Pickup Coils mounted on the leading end of the #1 truck on all R211S A Cars for the detection of cab signals.
- 14.3.6.2. Cab Signal Pickup Coils shall be electrically connected to the carborne ATC system with twisted shielded pair cable.
- 14.3.6.3. Cab Signal Pickup Coils shall inductively couple the Wayside ATC power frequency signals from the rails and route the signals to the carborne ATC system for processing.
- 14.3.6.4. The Contractor shall submit functional descriptions and drawings, describing how the detection system operates and interfaces with the Cab Signaling system for NYCT approval.
- 14.3.6.5. Cab Signal Pickup Coils shall be encapsulated and shall include laminated bars or approved equal. The pickup coils shall consist of the pick-up coils themselves and separate winding with which to induce cab signal energy into the pickup coils as part of the self-test function.
- 14.3.6.6. The Contractor shall furnish all brackets, fixings and other supports necessary for the fitting of pickup coils.
- 14.3.6.7. The Contractor shall furnish protective covers (cowcatchers) to provide protection for all Cab Signal Pickup Coils.
- 14.3.6.8. Cab Signal Pickup Coils shall be located over the running rails so as to effectively and reliably detect cab signals in the running rails. The Contractor shall locate the coils so as to be protected by the Contractor-furnished protective covers from debris, snow, etc., on the track.

- 14.3.6.9. Cab Signal Pickup Coils shall be readily accessible for maintenance and inspection.
- 14.3.6.10. Cab Signal Pickup Coils and pilots shall be located so as to not conflict with the limits of the R211S clearance gauge and wayside clearances of SIR.
- 14.3.6.11. Cab Signal Pickup Coils shall be placed so as to optimize the reliability of the received signal. In particular, the Contractor shall ensure that the cab signal detection system is insensitive to the existing interference levels, including 3rd rail collector shoe arcing. Also, the Contractor shall provide evidence, to the satisfaction of NYCT, that interference susceptibility levels will not preclude the operation of trains using AC propulsion and auxiliary systems.
- 14.3.6.12. Cab Signal Pickup Coils shall be electrically connected by shielded flexible cable terminated to a waterproof multi-pin connector in accordance with MIL-C-5015 to facilitate truck removal. In designing, and manufacturing the pick-up coils and connecting cables and leads, the Contractor shall take into account the severity of the moisture conditions and contaminants encountered in railway operation.
- 14.3.6.13. Cab Signal Pickup Coils on all trucks shall be identical.
- 14.3.6.14. The Contractor shall submit for approval functional descriptions and drawings, describing how the detection system operates and interfaces with the ATC system. **[CDRL]**

14.3.7. ATC Data Recorder

- 14.3.7.1. The Contractor shall provide an ATC Data Recorder for all R211S A Cars.
- 14.3.7.2. The Contractor shall locate the ATC Data Recorder within the ATC equipment box. The ATC Data Recorder may be embedded within the ATC Cab Signaling system.
- 14.3.7.3. The ATC Data Recorder shall be fitted with a power supply unit for conversion of the train battery voltage to appropriate voltages for the equipment. The power supply unit will be self-regulating and will incorporate surge protection and filtering.

14.4. Car Interfaces

14.4.1. General

- 14.4.1.1. The Contractor shall supply, install, and test all required interfaces between the carborne ATC system and the car subsystems.
- 14.4.1.2. The Contractor shall supply, install, and test all cables, wires, junction boxes, conduit, raceways, etc. that are necessary to interconnect carborne ATC equipment and to connect carborne ATC equipment to car equipment, as approved by NYCT.
- 14.4.1.3. For vital circuits, the car interface with the carborne ATC system shall incorporate fail-safe design principles where required, per Section 2.12.

14.4.2. Trainline and Network Controller

- 14.4.2.1. The Contractor shall supply, install, and test all signal connections between the carborne ATC system and the Trainline and Network Controller (TLNC) in each A Car to allow the carborne ATC system to send and receive commands and status information to the car subsystems.
- 14.4.2.2. The carborne ATC system may interface the train networks via the TLNC to receive information from car subsystems such as the Master Controller position, Propulsion system variables, and feedback from the Brake system.

- 14.4.2.3. The carborne ATC system may send power and brake commands over the Propulsion and Brake Control Network via the TLNC.
- 14.4.2.4. The carborne ATC system shall send and receive information over the MDS Network via the TLNC.
- 14.4.2.5. The carborne ATC system shall send information to and receive information from the ATC TOD and MDS TOD via the TLNC.

14.4.3. Emergency Brake

- 14.4.3.1. The ATC controller shall vitally control application of the Emergency Brake in accordance with the safety design principles of Section 2.12.
- 14.4.3.2. The carborne ATC system shall de-energize the Emergency Magnet Valve to vent brake pipe whenever the carborne ATC system determines that an emergency brake application is required.
- 14.4.3.3. ATC interconnecting wiring to the Emergency Brake system shall be installed per the design documentation required in Section 12.
- 14.4.3.4. All Emergency Brake circuits, including ATC interfaces, shall be reviewed and approved by NYCT. [CDRL]

14.4.4. Full Service Brake Trainline

- 14.4.4.1. The ATC controller shall vitally control application and removal of power to the Full Service Brake Trainline.
- 14.4.4.2. The carborne ATC system shall de-energize the Full Service Brake trainline whenever it determines that a Full Service Brake application is required.
- 14.4.4.3. All Full Service Brake circuits, including ATC interfaces, shall be reviewed and approved by NYCT. [CDRL]
- 14.4.4.4. Alternative designs may be presented to NYCT and SIR during the design review process.

14.4.5. Motoring Inhibit Trainline

- 14.4.5.1. The ATC controller shall vitally control application and removal of power to the Motoring Inhibit Trainline.
- 14.4.5.2. The carborne ATC system shall de-energize the Motoring Inhibit trainline immediately upon detection of an overspeed condition.
- 14.4.5.3. De-energizing the Motoring Inhibit trainline will result in removal of positive tractive effort from the propulsion systems on the train.
- 14.4.5.4. All ATC interface circuits shall be reviewed and approved by NYCT.
- 14.4.5.5. Alternative designs may be presented to NYCT and SIR during the design review process.

14.4.6. Discrete Signals

- 14.4.6.1. The carborne ATC system shall interface with carborne discrete signals (Unitline and local) as required to provide the functionality described in this Section.

14.4.7. Train Operator Displays

14.4.7.1. The carborne ATC system shall output messages to the MDS TOD as described in Section 5.3.3.1. The full list of faults and status messages to be displayed shall be presented to NYCT for approval during design review. **[CDRL]**

14.4.7.2. The carborne ATC system shall output messages to the ATC TOD as described in this Attachment, Section 14.2.13

14.4.8. Monitoring and Diagnostics System (MDS)

14.4.8.1. The carborne ATC system will interface with the MDS via the MDS network.

14.4.8.2. The MDS shall accept carborne ATC system operating status and fault information from the carborne ATC system, as defined in Section 17, Monitoring and Diagnostics System.

14.4.8.3. Section 17 details the signals to be transmitted to the MDS by the carborne ATC system.

14.4.9. Event Recorder

14.4.9.1. The carborne ATC system will interface with the Event Recorder via the MDS network.

14.4.9.2. The Event Recorder shall receive the information defined in Section 17 – MDS system from the carborne ATC system.

14.4.9.3. Section 17 – MDS system details the signals to be transmitted to the Event Recorder by the carborne ATC system.

14.5. Safety Analysis

14.5.1. A safety analysis of operation of the system(s) shall be submitted, consistent with the requirements of Attachment 14-B, System Safety. **[CDRL]**

14.6. Maintainability Requirements

14.6.1. All carborne ATC system equipment installations shall meet the maintainability design requirements of Section 2.14.4.

14.7. Validation Requirements

14.7.1. The Contractor shall submit technical details and documentation related to the installation and integration of carborne ATC equipment for approval. **[CDRL]**

14.7.2. The Contractor shall conduct a validation program for the carborne ATC system that shall demonstrate that the ATC system operates correctly, safely and in compliance with all specification requirements.

14.7.3. The Contractor shall conduct component laboratory qualification tests that shall demonstrate the ability of the ATC components to meet the EMC requirements in Section 2.11, and operate successfully within the operating environment described in Section 25.2.1.

14.7.4. The Contractor shall provide a stress analysis of the bracket and mountings for the truck mounted ATC system receiver coils. **[CDRL]**

14.7.5. The Contractor shall perform carborne ATC system laboratory qualification testing including but not limited to the following:

- a) The functionality of all ATC subsystems including but not limited to the Central Processing and Control Unit, speed sensors, cab signal pick-up coils, and ATC TOD.
- b) The functionality of all interfaces to the car including but not limited to discrete trainlines, communication networks, propulsion system, brake system, MDS system, Event Recorder, ATC TOD, and MDS TOD.
- c) Verification that the receiver tuning is properly centered at 100 Hz, and exhibits proper bandwidth.
- d) Verification that receiver sensitivity is adjustable over the range required.
- e) Verification that each code rate is correctly detected and displayed.
- f) Verification, for each code rate, of the center frequency and the operational frequency tolerance.
- g) Verification of proper operation of all power input voltages throughout the specified range.
- h) Detection of proper response to overspeed, and verification of the related time limits.
- i) Verification of all ATC relay operation.
- j) Verification of all visual and audible alarms.
- k) Verification of departure test functionality.
- l) ATC system response to possible failure modes.

14.7.6. The Contractor shall perform Post Installation Check Out (PICO) testing on each R211S Unit before shipment to NYCT. PICO testing shall fully demonstrate the functionality of all interfaces between the ATC system and other train subsystems. The PICO testing will include, at a minimum, the following functionality:

- a) Verification that the receiver tuning is properly centered at 100 Hz, and exhibits proper bandwidth.
- b) Verification that each code rate is correctly detected and displayed.
- c) Verification, for each code rate, of the center frequency and the operational frequency tolerance.
- d) Detection of proper response to overspeed, and verification of the related time limits.
- e) Verification of all ATC relay operation.
- f) Verification of all visual and audible alarms.
- g) Verification of departure test functionality.
- h) Verification of speed sensor functionality.

14.7.7. The PICO test reports shall be submitted to NYCT, however the unit may be shipped to NYCT once all PICO test have been successfully completed.

14.7.8. The Contractor shall perform full ATC qualification testing of the first R211S Unit on the SIR system. The testing shall demonstrate proper operation of all carborne ATC equipment functions. All required ATC functions shall be tested including possible failure modes.

14.7.9. The Contractor shall perform ATC acceptance testing of all R211S Units on the SIR system. The testing shall demonstrate proper operation of all carborne ATC equipment functions.

14.7.10. Electromagnetic compatibility testing between the R211S and the SIR Wayside ATC system shall be performed on the first R211S Unit.

14.8. Deliverables

The following Contract Deliverables are defined in this section. The individual CDRLs on this list have been defined separately for clarity. CDRLs may be grouped together into a single submittal document that covers all of the individual items. In the case where the proposed design can be demonstrated to be equivalent to a prior design which has been accepted by NYCT, the Contractor may propose a waiver of the associated CDRL requirement.

Table 14-3. Deliverables

CDRL	Ref	Deliverable	Timing
14-01	14.1.5	Design of line end stop enforcement system	IPDR
14-02	14.2.2.5	Description of Cab Signal Functionality	PDR
14-03	14.2.3.3	Safe Brake Model Verification	PDR
14-04	14.2.13.8	ATC TOD screen layout	IPDR
14-05	14.3.1.3	Study of available space and temperature/heat dissipation	IPDR
14-06	14.3.6.14	Cab signal pick-up coil details	CDR
14-07	14.4.3.4	EMV circuit design	CDR
14-08	14.4.4.3	Full Service Brake and Motor Inhibit trainline design	CDR
14-09	14.4.7.1	List of ATC MDS faults to be displayed	IPDR
14-09	14.5.1	ATC Safety Analysis	IPDR
14-10	14.7.1	Technical details and documentation related to the final installation and integration of carborne ATC equipment	IPDR
14-11	14.7.4	Stress analysis of the bracket and mountings for the truck mounted ATC system receiver coils	CDR

ATTACHMENTS:

14-A – SIR Existing Wayside Cab Signal System (For Information Only)

14-B - Carborne ATC System – System Safety Requirements

14-C - St. George Interlocking & Cable Plan, drawing number SOXC005-C, Holly Interlocking Track Arrangement & Cable Plan , drawing number HLXC006-C, and Tottenville Interlocking Track Arrangement & Cable Plan, drawing number TNXC011-C

14-D - R44 Cab Signal Braking Model S-80220

Attachment 14-A: SIR EXISTING WAYSIDE CAB SIGNAL STSTEM (FOR INFORMATION ONLY)

14A.1 Wayside Cab Signal System Requirements

- 14A.1.1 The Contractor’s scope does not include supply of wayside Automatic Train Control (ATC) system or wayside track circuits. This overview information is for reference purposes only.
- 14.2.1.2. The existing SIR Wayside ATC system is an Alstom microprocessor-based audio frequency system, which generates a power frequency signal that is transmitted/superimposed into the running rails.
- 14.2.1.3. The existing SIR wayside ATC system monitors route conditions and transmit appropriate speed commands to the on-board ATC equipment. The on-board ATC equipment utilizes the speed commands for display to the Train Operator and interface to the train braking and propulsion systems.
- 14A.1.4 The wayside speed command current is fed into the track rails as automatically determined by track conditions in advance of trains, except as detailed in Section 14A.3.
- 14A.1.5 Cab signal energy is not injected in the rails until a train occupies the track circuit. Within interlockings, cab signals less restrictive than “Restricting” (“no-code”) are not transmitted unless a permissive wayside signal aspect governing entrance to a route is first displayed and that aspect is more permissive than “Restricting.”
- 14A.1.6 Cab signal codes are fed to the switch and crossover routes of interlocking track circuits utilizing intermediate code feed track connections,
- 14A.1.7 SIR Cab signal wayside installation Contract Drawings are available upon request.

14A.2 Cab Signal Overrun Protection at Interlockings

- 14A.2.1 The interlocking logic provides that cab signal codes only be transmitted to interlocking track circuits for valid routes over which signals had been displayed. Cab signal codes are not transmitted to a train that overruns a stop signal, on any route.
- 14A.2.2 Logic is provided to check occupancy sequences such that only legitimate cab signal codes are fed to a train operating over the proper route. The AC track circuits, and where shown on the Contract Documents, short range overlay track circuits will provide for the determination of over-run conditions.

14A.3 Cab Signal Code Rates and Speeds

- 14A.3.1 Cab-signal carrier frequency is be 100 Hz. The following eight code rates expressed in pulses-per-minute (PPM) are implemented by the on-board cab signal equipment to control movement of trains:

Table F1 - SIR Cab Signal Code Rates and Speeds

Code	Code Rate (ppm)	Cab Signal Aspect for R211S (mi/h)
1	0	0 (Stop and Stay)
2	50	15 (Restricting)
3	75	20

Code	Code Rate (ppm)	Cab Signal Aspect for R211S (mi/h)
4	120	35
5	180	45
6	270	60
7	420	10 (Latch-In to Terminal Mode)
8	420*(High Energy)	Cutout

*A High Energy 420 PPM Code Rate was used for cab signal CutOut during the originally commissioning of the ATC system. It is no longer used.

- 14A.3.2 A manually applied 50 PPM code rate is used at certain locations. The 50 code provides the means for a train to move up to certain signals displaying a stop aspect, for a loop move within an Interlocking or to close into a station and berth when a signal in advance of the train is displaying a stop aspect and no code is available on the approach tracks. Under both circumstances, this code will only be provided remotely from the Control Center under the explicit authority and control of the Train Dispatcher.
- (a) The 50 PPM code is never applied to track circuit if a track circuit is occupied between the first track circuit and the target being approached.
- 14A.3.3 A 420 PPM code rate is provided, in loops within the gauge of the rails, for the purpose of cutting the cab signal system into Terminal Mode (Latch-In) at certain locations. Terminal Mode allows a fully equipped train to seamlessly transition from cab signal territory to non-cab signal territory without stopping, such as entering terminals or certain sidings; to latch into Terminal Mode after powering up (the cab signal system is automatically cut-in upon powering up) at St George and Tottenville platforms as well as storage tracks, and certain other locations. The 420 Loops are located relative to the appropriate signal as described in the Table and are only activated when a permissive signal is displayed.
- 14A.3.4 An automatic 50 PPM code rate is provided in the rails at certain locations for the purpose of providing the means for a train to move up to a signal at stop or restricting when being latched into terminal mode by the 420 code, as described herein. This code is applied automatically upon the route being properly aligned and locked and the appropriate signal displayed. The 50 PPM code is never applied if a track circuit is occupied between the first track circuit and the target being approached.
- 14A.3.5 During interim stages of the SIR ATC system installation high energy 420 PPM code rate was used to provide automatic cutout of the cab signal system when leaving cab signal territory. These high energy code rates are no longer used at SIR.
- 14A.3.6 Table F2 lists allowable combinations of cab signal speed commands and wayside signal aspects.

TABLE F2
Color Position Light Signals
COMBINATIONS OF
CAB SIGNAL SPEED COMMANDS
DISPLAYED IN CONJUNCTION WITH
AND IN THE TRACK CIRCUIT AFTER PASSING
WAYSIDE SIGNAL ASPECTS

WAYSIDE SIGNAL ASPECT	Restricting (R)	20	35	45	60
Clear				X	X
Approach Permissive		X	X	X	X
Approach Medium		X	X	X	
Approach	X	X	X		
Permissive	X	X	X	X	X
Medium Clear		X			
Medium Approach	X	X			
Diverging Permissive	X	X			
Slow Clear	X				
Slow Approach	X				
Restricting	X				
Stop and Proceed	X				
Stop	X				

Attachment 14-B: CARBORNE ATC SYSTEM – SYSTEM SAFETY REQUIREMENTS

1.0 General Requirements

1.1 Applicability.

- a. This section applies to the supplier providing the carborne portion of the R211S Cab Signaling System for the Staten Island Railway (SIR). Hereafter, the carborne portion of the R211S Carborne ATC System shall be referred to as the R211S Cab Signaling System. Note: the terms supplier and contractor are used interchangeably in this specification section, and refer to the R211S Cab Signaling System supplier.

1.2 Scope of the Safety Program for the R211S and carborne Cab Signaling Supplier.

- a. The scope of the safety program includes:
 1. Safety program tasks for the R211S Cab Signaling system.
 2. Safety Certification of the R211S Cab Signaling system.
 3. Safety Certification of the R211S Cab Signaling system interface to the R211S train subsystems.
 4. Safety Certification of the R211S Cab Signaling system and interfaces to other external subsystems, e.g., SIR signaling system, and SIR ATS, etc.
 5. Safety Certification of the overall R211S Cab Signaling system for SIR.
 6. Safety Certification of the R211S Cab Signaling system during all phases of testing, and revenue service deployment.
 7. Establishment of Post Deployment Safety process and requirements for the subsystems and systems implemented through the SIR R211S Cab Signaling project.

1.3 Safety Assurance Requirements.

- a. NYCT has developed a safety certification process that will achieve certification for the overall R211S Cab Signaling system, safety certification for the major R211S Cab Signaling subsystems and safety certification of the interfacing subsystems from other Contractors. This safety certification process shall be tailored as necessary for relevance to the specific scope, configuration and phasing of the R211S Cab Signaling Project. The safety certification process follows the guidance provided by the Federal Railroad Administration (FRA) 49 CFR 236 subpart H.
- b. The table presented in Appendix C of Attachment 14-B maps the requirements of the Product Safety Plan as defined by the FRA 49 CFR 236 subpart H, against the requirements of the R211S Technical Specification.
- c. The R211S Cab Signaling system and Subsystems shall be certified against the applicable sections of the R211S Technical Specification including the applicable interface requirements.
- d. The safety program for the Project, as detailed in this Section, is designed to ensure that safety is integrated into the design, implementation, and ongoing operation of the R211S Cab Signaling system.

- e. The safety program has the following main elements:
1. The analysis of safety-relevant functions of the R211S Cab Signaling system, including interfaces to R211S train subsystems, other SIR subsystems, and their integration.
 2. The identification and management of hazards of the R211S Cab Signaling system, at system and subsystem levels. Interface hazards shall be considered.
 3. The compilation of safety certification evidence to demonstrate compliance of the R211S Cab Signaling system against the relevant sections of these Specifications. The Contractor shall be required to show compliance to each safety related, safety critical, and vital safety requirement.
 4. The safety program and safety certification evidence to show compliance with the Specifications for the overall R211S Cab Signaling system.
 5. The configuration and revision control methods required to ensure that the functional safety requirements and safety-critical hazard mitigation measures and processes are not compromised as a result of changes during the development, commissioning and post implementation phases. This shall include the processes to ensure the appropriate level of analysis and testing at factory and site. The process shall detail the documentation generated for each system change together with the submission, including sufficient time for NYCT to review and approve the modification, verification and testing details prior to the modification being deployed for on-site testing at NYCT.
 6. The maintenance procedures and processes to be implemented to ensure that the safety of the system is maintained throughout the lifetime of the system and subsystems. This shall include details of the tests, including their periodicity and the required record keeping of the processes. The procedures for defining the tests shall be defined in the Project Safety Plans for the R211S Cab Signaling System. The details of the tests and procedures shall be included in the maintenance manuals for each product.
- f. The Contractor shall be responsible for ensuring that the R211S Cab Signaling system safely interfaces with the SIR Signaling System.
- g. The Contractor shall be responsible for ensuring that the R211S Cab Signaling system safely interfaces to the other SIR subsystems, for example ATS, SIR wayside subsystems, and operates safely with other SIR trains and cab signaling systems.

1.4 Safety Certification Requirements

- a. NYCT safety process requires that the Contractor(s) provide a system safety analysis of their scope of supply.
- b. Safety justification for the R211S Cab Signaling system will be compiled within a System FSR. Safety justification for R211S Cab Signaling subsystems (as applicable) will be compiled within standalone Subsystem FSR for each subsystem.
- c. Final Safety Reports must capture the safety justification and positive statements of safety for their scope (system or subsystem). Each Final Safety Report shall include justification of the internal and external interfaces (internal to R211S Cab Signaling and external to R211S Cab Signaling) in accordance with this Specification.
- d. The subsystem Final Safety Reports (if applicable) shall be used as elements in the safety justification for the complete system.
- e. Certification of the system shall require all applicable subsystem certifications in addition to system-level certification of the specific, deployed configuration.

- f. The safety certification requirements are applicable to the R211S Cab Signaling system, and car subsystems as follows:
1. The Contractor shall certify the R211S Cab Signaling equipment as provided within their scope of supply.
 2. Subsystem safety certification evidence shall be provided to NYCT and to the Independent Safety Assessor (ISA). Note the ISA is separately contracted by NYCT.
 3. The Contractor shall provide system engineering support to achieve system level certification (i.e., among R211S train subsystems, the R211S Cab Signaling system, SIR signaling system, etc.).
 4. The Contractor shall allocate sufficient time and adequate scheduling to achieve subsystem and system safety certification activities.
 5. The Contractor shall be responsible for the delivery of the safety certification of the system.
 6. The Contractor shall be responsible for completion of NYCT Safety Certification 10-Steps, as described in NYCT Rail Safety Program Plan (RSPP) (to be supplied at NTP), and as outlined below:
 1. Contractor Final Safety Report
 2. Independent Safety Assessor (ISA) Recommendation
 3. Mean Time Between Hazardous Events (MTBHE) determination
 4. Hazard Closure
 5. Test Completion
 6. Operating Rules and Procedures
 7. Maintenance Procedures
 8. Training
 9. NYCT Working Group assessment of CDRL items and safety
 10. System Safety Certification Board (SSCB) approval (signed certificate)

1.5 Software Verification and Validation Responsibilities.

The Software requirements for this project shall include requirements, design, and test evidence to assure safety and correct functionality.

1.6 Safety Program Responsibilities.

- a. For NYCT
1. NYCT has established the overall safety program and the required safety performance levels, as defined in these Specifications.
 2. NYCT will review all aspects of the Contractor's safety program to monitor that the R211S Cab Signaling system requirements, design parameters, operational factors, system integration, and system support environment are consistent with the required safety performance levels.
- b. Independent Safety Assessor (ISA)
1. The Independent Safety Assessor (ISA) will audit compliance with the safety program and audit the system development, test processes and safety analysis methods used by the Contractor. In performing this role, the Independent Safety Assessor will retain independence from the execution of the program and provide independent safety program guidance to NYCT. The ISA will use 49 CFR 236 Subpart H Appendix D as guidance in the activities undertaken for the R211S Cab Signaling Project.
 2. In particular, the Independent Safety Assessor will review and audit the following:

- (a) Acceptability of the design criteria to be applied by the R211S Cab Signaling Contractor to achieve the specified safety performance.
- (b) The safety analysis methods and safety verification techniques employed by the Contractor during system design including, interoperable subsystem design, and system integration.
- (c) The Contractor test plans and data collection program. This will be audited to verify safe performance of the R211S Cab Signaling system.
- (d) Compliance with the safety assurance process as defined in the Contractor System Safety Program Plan, which cover the activities for requirements, design, implementation, test, and system integration safety activities.
- (e) Hazard documentation for accuracy and completeness.
- (f) Compliance with the Contractor Project Safety Plans for the safety assessment and certification of subsystems and system integration.
- (g) Acceptability and suitability of the post implementation testing and configuration management processes.
- (h) The re-use of safety analyses and data if applicable.
- (i) Software algorithms used in the design of safety-critical functions for correctness, and vital system implementation. (The review of Software Algorithms is dependent on the Contractor's development lifecycle process, and will be scheduled accordingly.)
- (j) Subsystem Safety review for fail safe hardware design, and safe interface design. (The review of Subsystem analysis is dependent on the Contractor's development lifecycle process, and will be scheduled accordingly.)
- (k) Platform safety case analysis for correctness, and robust fail-safe functionality
- (l) EMI/EMC design and test for correctness and fail safe design.

1.7 Codes, Standards and Specifications.

- a. Codes, standards and specifications referenced in this Section are to be the latest edition in effect at the time of contract award unless otherwise noted, and are considered to be a part of this Section as applicable.
 - 1. NYCT Railroad Safety Program Plan (to be supplied at NTP) for Safety Critical Systems, Capital Program Management/Vital Systems Integrity NYCT.
 - 2. "Communications and Signals Manual of Recommended Practices". American Railway Engineering and Maintenance of Way Association (AREMA) – Latest revision.
 - 3. IEEE 1228-1994, "IEEE Standard for Software Safety Plans".
 - 4. 49 CFR 236 Subpart H – "Standards for Processor Based Signal and Train Control Systems".
 - 5. MIL-STD-882E: "System Safety Program Requirements".
 - 6. IEEE 1483-2000, "IEEE Standard for Verification of Vital Functions in Processor-Based Systems".
 - 7. CENELEC Standard Publication EN 50126:1999: "Railway Applications. The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)".
 - 8. CENELEC Standard Publication EN 50128:2011: "Railway Applications - Communication, Signaling and Processing Systems - Software for Railway Control and Protection Systems". March 2001.

9. CENELEC Standard Publication EN 50129:2003: "Railway Applications. Communication, Signaling and Processing Systems. Safety Related Electronic Systems for Signaling".
10. Federal Transit Administration Handbook for Safety and Security Certification. FTA-MA-90-5006-02-01. November 2002.
11. Federal Transit Administration Hazard Analysis Guidelines for Transit Projects. DOT-FTA-MA- 26-5005-00-01. January 2000.
12. Nuclear Regulatory Commission Fault Tree Handbook NUREG-0492. January 1981.
13. IEC 60812:2006, "Analysis Techniques for System Reliability – Procedure for Failure Mode and Effects Analysis (FMEA)".

1.8 Safety Program Milestones.

- a. The R211S Cab Signaling system safety program and its deliverables are scheduled around the project design reviews (Preliminary, In-Process, and Critical), testing phases, cutover milestones, and revenue service milestones. The safety program is required to support all project design review activities, including readiness assessments, and software and hardware releases.
- b. The Project Safety Plan submitted shall demonstrate how the safety program will support the system integration process and design reviews.
- c. Submittals and delivery schedule are defined in detail in Section 2.0.

1.9 Preliminary Design Review (PDR).

- a. The system safety approach and description of the safety analyses for the R211S Cab Signaling system and subsystems shall be developed during the Preliminary Design Review (PDR) of the Project.
- b. The PDR shall be used to demonstrate the safety programs, certifiable items and planned analyses required to confirm the safety of the design of each subsystem and the integrated system.
- c. The Contractor shall present the following for consideration at the PDR:
 1. A documented Project Safety Plan in accordance with the requirements of Section 2.1.a of this attachment.
 2. The Certifiable Items List (CIL).
 3. Contractor evidence to demonstrate compliance with the safety requirements to include but not limited to:
 - i. Platform hardware and software safety certifications
 - ii. Identification of Vital, System level functional requirements. (This should be included in System-level technical documentation.)
 4. The Project Hazard Log. The Hazard Log shall include hazards identified as being relevant to the R211S Cab Signaling system.
 5. Preliminary versions of all R211S Cab Signaling system and subsystem hazard analyses (e.g. Preliminary Hazard Analysis, Subsystem Hazard Analyses, Operating and Support Hazard Analyses, Fault Tree Analyses, etc.).
 6. Validation and Verification methods as defined in the Validation and Verification Plans; this shall include software, subsystems and systems.
 7. The post implementation testing and configuration control methods proposed by the Contractor shall be presented.
 8. The Contractor shall support NYCT ISA in scheduling the ISA analyses, e.g., the algorithm reviews, and the subsystem analyses.

1.10 In-Process Design Review (IPDR).

- a. The Contractor shall present the following for consideration at the In-Process Design Review (IPDR):
 1. An updated Project Hazard Log. The Hazard Log shall include hazards identified as being relevant to the R211S Cab Signaling system and R211S Cab Signaling subsystems, including hazards related to the interfaces of the R211S Cab Signaling system/subsystems.
 2. Updated versions of all R211S Cab Signaling system and Subsystem hazard analyses (e.g. Preliminary Hazard Analysis, Subsystem Hazard Analyses, Operating and Support Hazard Analyses, Fault Tree Analyses, etc.).
 3. Identification of Vital, System level functional requirements as mapped to the system design. (This should be included in System-level technical documentation.)
 4. Identification of Vital, System level functional requirements as mapped to the software requirements. (This should be included in System and software-level technical documentation, e.g., Requirements Traceability Matrix and Software Requirements Specification(s) (SRSs).)

NOTE:

This activity depends on the availability of the software requirements. The Contractor shall schedule this activity in the appropriate phase, consistent with their development lifecycle approach.

1.11 Critical Design Review (CDR).

- a. The Critical Design Review (CDR) phase requires the completion of the safety program analyses required for eventual safety certification.
- b. The CDR shall be used to demonstrate the implementation of the safety program within the design of the R211S Cab Signaling system and Subsystems.
- c. The following shall be presented for consideration at the CDR:
 1. The Project Hazard Log shall present the hazards identified for subsystems and systems and how these have been mitigated or resolved. The Project Hazard Log shall be populated with emphasis placed on the early mitigation of identified hazards. The Project Hazard Log shall be populated with hazards as soon as they are identified allowing early implementation of the hazard management processes detailed in Section 2.1. of this attachment The Project Hazard Log activities shall include:
 - (a) Design actions to eliminate or mitigate risks to an acceptable level shall be assigned to the identified hazards.
 - (b) Review of hazards against the Operating Rules and Procedures in place for SIR R211S Cab Signaling operation.
 - (c) Inclusion of any additional requirements or requirement modifications.
 - (d) Development and incorporation of any test and verification planning information.
 2. The hazard analyses commenced in the earlier phase of the project shall be finalized and submitted. This shall include System Hazard Analysis, Subsystem Hazard Analysis, Interface Hazard Analysis and Operating and Support Hazard Analysis (O&SHA), as well as the design and equipment based analyses, including those required for design, and certification. The Project Hazard Log shall be amended to include the outputs of the analyses.

3. Demonstration of key elements of the safety program during the Critical Design Review phase shall include:
 - (a) Verification of performance of safety critical/vital system and subsystem operation.
 - (b) Verification of recommendations and corrective actions.
 - (c) Verification of operational safety devices, warning devices, procedures and training to protect personnel and equipment.
 - (d) Identification of residual risk.
 - (e) Gathering and inclusion of all verification assurance documentation and supporting data.
 - (f) Acceptance of residual risk.
- d. The evidence submitted for the Critical Design Review for the R211S Cab Signaling subsystems shall be such as to enable the Contractor to achieve safety certification for their R211S Cab Signaling system.
- e. Identification of Vital, System level functional requirements as mapped to the software requirements and software detailed design elements. (This should be included in System and software-level technical documentation, e.g., Requirements Traceability Matrix Software Requirements Specification(s) (SRSs), and Software Design Documents (SDDs).)

NOTE:

This activity depends on the availability of the software requirements and software detailed design. The Contractor shall schedule this activity in the appropriate phase, consistent with their development lifecycle approach.

1.12 Definitions.

NOTE: Where definitions shown in reference documents differ from those identified within this Specification, the definitions listed in this Specification shall be used.

- a. **Safety** - Freedom from those conditions that can cause death, injury, occupational illness, or damage to, or loss of, equipment or property, or damage to the environment.
- b. **Safety critical** - A term applied to a system or function, the correct performance of which is critical to safety of personnel and/or equipment. (B) A term applied to a system or function, the incorrect performance of which may result in a Category I or II hazard.
- c. **Unsafe Condition** - Those conditions that can cause death, injury, occupational illness, or damage to, or loss of, equipment or property, or damage to the environment.
- d. **System** - A composite, at any level of complexity, of personnel, procedures, materials, tools, equipment, facilities and software. The elements of this composite entity are used together in the intended operational or support environment to perform a given task or achieve a specific purpose, support, or mission requirement.
- e. **System Safety** - The application of engineering and management principles, criteria and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time and cost throughout all phases of the system life-cycle.
- f. **System Safety Management** - A management discipline that defines system safety program requirements and ensures the planning, implementation and accomplishment of system safety tasks and activities consistent with the overall program requirements.
- g. **System Safety Program** - The combined tasks and activities of system safety management and system safety engineering implemented by acquisition project managers.
- h. **Project Safety Plan** - A description of the planned tasks and activities to be used to implement the required system safety program for the project. This description includes organizational responsibilities, resources, methods of accomplishment, milestones, depth of

effort, and integration with other program engineering and management activities and related systems.

- i. **R211S Cab Signaling System-Level Certification** – The safety certification required for the R211S Cab Signaling system as an integrated (with SIR systems) operating system. R211S Cab Signaling System-Level Certification requires the certification of subsystems that comprise it, as applicable.
- j. **R211S Cab Signaling subsystem Level Certification** – The safety certification required for each of the R211S Cab Signaling subsystems, as applicable.
- k. **Vital Function** - A function in a safety-critical system that is required to be implemented in a fail-safe manner. NOTE-Vital functions are a subset of safety-critical functions.
- l. **Residual Risk** - The risk that remains after the application of mitigation measures.

2.0 Submittals.

2.1 R211S Cab Signaling Safety Submittals.

The following documents are the required submittals for the R211S Cab Signaling Project. Reference Section 4.0 for submittal delivery requirements.

a. Project Safety Plan (PSP)

1. The PSP is the core of the Safety Program. The PSP provides a formal basis of understanding between the Contractor, the ATC system supplier, NYCT, and its Consultants (Including Independent Safety Assessor, Engineering Specialists, etc.), and other Contractors performing development and or integration activities.
2. The PSP shall define the safety criteria, safety requirements and the tasks necessary to implement them, the resources needed to accomplish the defined tasks, as well as identifying the authority to implement all the activities.
3. The PSP shall define the acceptable safety risk for the scope addressed by the plan.
4. The Contractor shall submit comprehensive PSPs for their complete scope of supply including interfaces. The Contractor PSP shall document a coordinated, consistent approach to safety certification at the subsystem and integrated system level.
5. The development of the Project Safety Plans shall require a complete knowledge of the project and associated tasks, identification of required, associated safety standards and specifications. The PSPs shall include:
 - (a) A description of the safety-critical design processes that will be followed for the R211S Cab Signaling Project and specific safety standards (e.g. internal safety standards) employed for the Project.
 - (b) A description of the safety analysis methodologies that will be employed.
 - (c) A description of the safety management procedures that will be adopted throughout the design, manufacture and installation phases. This shall include description of the system safety organization and responsibilities.
 - (d) A description of the plans for safety verification and safety validation, with specific reference to the methods of verification of safety-critical software.
 - (e) Definition of the test planning processes, throughout the project life cycle from factory testing through to post implementation testing, including the assignment of responsibilities for safety related testing shall be provided in the PSP.
 - (f) Identification of any SIR responsibilities, including safety interfaces between the Project System and facilities, subsystems, equipment and components provided by others, to assure safe operation of the Project System in the SIR environment.

- This shall include the process for identifying the post implementation testing to be performed by SIR to ensure the continued safe operation of the system.
- (g) A description of the plans to document hazard identification, reporting, tracking and resolution, using the Project Hazard Log and Certifiable Items List as required.
 - (h) The milestone schedule for completion of activities and submittals required by the System Safety Program.
6. The PSP shall identify the safety activities required to direct and coordinate subcontractors.
7. The development of the PSP shall include the development of a Software Safety Plan in accordance with the requirements of IEEE 1228:1994. Where appropriate the CENELEC standards listed in Section 1.7 of this attachment shall be used, where additional guidance is required IEC61508 shall be used. The contents of the Software Safety Plan shall comply with Section 4 of the IEEE 1228:1994 standard. The plan addresses the safety issues associated with software development, including:
- (a) Software Safety Management.
 - 1. Organization and responsibilities
 - 2. Software life cycle
 - 3. Software configuration management activities
 - 4. Software quality assurance activities
 - 5. Software verification and validation activities
 - 6. Tool support and approval
 - (b) Software Safety Analyses
 - 1. Software safety analyses preparation
 - 2. Software safety requirements analysis
 - 3. Software safety design analysis
 - 4. Software safety code analysis
 - 5. Software safety test analysis
 - 6. Software safety change analysis
 - (c) Training.
 - (d) Deployment.
 - 1. Installation
 - 2. Startup and transition
 - 3. Operations support
 - (e) Maintenance.

b. Certifiable Items List:

- 1. The Certifiable Items List (CIL) for the R211S Cab Signaling Project shall be established by the Contractor for the complete project. The CIL shall identify equipment and/or functions that will affect the safety or security of the R211S Cab Signaling system. The Certifiable Items List (CIL) shall be developed in accordance with the FTA Handbook for Safety and Security Certification.
- 2. The Certifiable Items List shall identify system, equipment and module level items considered to be vital and non-vital.
- 3. The Certifiable Items shall be subjected to a documented Safety Certification Process as detailed in NYCT RSPP, and summarized above (10-Steps).

c. Operating and Support Hazard Analysis:

1. The O&SHA provides the analysis of all processes, procedures, and external systems (such as train operator) that are relied upon to mitigate R211S Cab Signaling hazards. Operations performed by the train operator, maintenance staff, or other NYCT/SIR personnel shall be considered, as well as system support and maintenance activities which have an impact on R211S Cab Signaling safety assurance. The purpose of the O&SHA is to identify those specific procedural requirements that protect passengers and/or personnel from hazards. The Operating and Support Analysis (O&SHA) shall be developed in accordance with the FTA Hazard Analysis Guidelines (Ref 12), Section 3 Operating Hazard Analysis.
2. The Operation and Support Hazard Analysis (O&SHA) shall be performed and documented on the complete R211S Cab Signaling system.
3. The operating and support hazards identified in the Preliminary Hazard Analysis shall be used as an input to the development of the O&SHA. The hazards identified at system and subsystem level shall be shown to be adequately mitigated by the relevant item at system and or subsystem level as appropriate.
4. The O&SHA identifies and evaluates hazards associated with operation and maintenance. It shall consider the system configuration, the system state, phase of activity, environment, support equipment and all other factors that could affect operational and support safety. The O&SHA shall as a minimum address:
 - (a) Facilities, support equipment, training and certification related to safety operations and maintenance.
 - (b) Activities, which occur under hazardous conditions, time periods, and the actions necessary to minimize risk.
 - (c) Changes in functional or design requirements needed to eliminate or control hazards or reduce associated risks.
 - (d) Requirements for safety devices and equipment.
 - (e) Warnings, cautions, and special emergency procedures.
 - (f) Requirements for packaging, handling, transportation, maintenance, and disposal of hazardous materials (if any).
 - (g) Requirements for safety training and personnel certification.
 - (h) Effects of commercial equipment, both hardware and software, across the interface with other components or subsystems.
 - (i) Potentially hazardous system states under operator control (hardware/software).

d. Interface Hazard Analysis (IHA)/Subsystem Hazard Analysis (SSHA):

1. The IHA and SSHA shall be performed and documented in accordance with IEEE Std. 1483 for the R211S Cab Signaling system and Subsystems. The IHA shall consider interfaces within a Contractor's scope of supply and with equipment provided by other R211S Cab Signaling subsystem Contractors for the Project.
2. The IHA shall identify each interface for the R211S Cab Signaling Subsystem, identifying the potential hazards associated with the loss of or incorrect functioning of the interface together with the mitigations in place to maintain the safety of the R211S Cab Signaling system and Subsystems.
3. The results of the R211S Cab Signaling Subsystem IHAs shall be compiled into an overall IHA for the R211S Cab Signaling system. This process is designed to ensure that all hazards associated with the interfaces of the subsystems within the R211S Cab Signaling system have been identified and adequately addressed and controlled to an acceptable level within the implementation of the R211S Cab Signaling system for the R211S Cab Signaling Project.

4. The IHA shall address:

- (a) Physical, functional, information and all other interface attributes between R211S Cab Signaling subsystems (including subsystems provided by other Contractor(s)).
- (b) Loss of or incorrect transfer of information between R211S Cab Signaling subsystems.
- (c) Timing issues associated with the transfer of information.
- (d) Redundancy management
- (e) Required alarm notifications and safe default actions for interface failures.
- (f) Testing of interfaced subsystems to ensure correct operation of the subsystems and overall system.

e. Project Hazard Log:

1. The Project Hazard Log shall comprise the complete record of all hazards identified for the Project. This shall include system level hazards, subsystem hazards, interface hazards and any other hazards. The Contractor shall define a layered structure of hazard records which shall ensure complete capture of all hazard information between system and subsystem levels.
2. The hazard management process will be central to the safety program for the Project. The Preliminary Hazard Analysis shall be used as the initial input to the Hazard activities. Each hazard identified shall be recorded within the Hazard Log, which shall act as the central record of all hazards associated with the implementation of the Project.
3. The Contractor shall compile a Hazard Log addressing all identified R211S Cab Signaling hazards, including those associated with the R211S Cab Signaling subsystem interfaces and system interfaces.
4. The Contractor shall detail all system level hazards as well as any requiring external input. All such hazards shall be provided as input to the system level Project Hazard Log, which shall be administered by the Contractor.
5. **The hazard management process shall include:**
 - (a) Traceability of source of hazard
 - (b) Traceability of hazard analyses and mitigation actions
6. All hazards identified shall be entered into the respective R211S Cab Signaling hazard logs as they are identified. Follow-up analyses shall be used to update the hazard status.
7. The hazard log shall include hazards related to EMC. EMC hazards generated internal to the R211S Cab Signaling equipment, from other systems, and from external causes (other sources such as two-way radios) shall be considered.
8. The mitigation of hazards assigned to NYCT shall be formalized through the Hazard Mitigation Form (HMF). A Hazard Mitigation Form (HMF) is attached as Appendix A to this Section.
9. Hazard log databases/spreadsheet shall be developed in an application compatible with Microsoft Office. The following information that shall be provided at a minimum in the hazard log:
 - (a) Log Number
 - (b) Subsystem
 - (c) Source of Hazard
 - (d) Hazard Title

- (e) Hazard Description
 - (f) Accident/Mishap
 - (g) Safety Requirement
 - (h) Causes identified from the hazard
 - (i) Analysis reference to the full hazard description
 - (j) Status of the Hazard (Open, Closed, Cancelled)
 - (k) Responsible Body
 - (l) Initial Risk Index (Severity and Probability)
 - (m) Final Risk Index (Severity and Probability) Status
 - (n) Reference Documentation Information
 - (o) Mitigation Status
10. All identified hazards will be assigned severity and probability of occurrence categories in line with the guidance provided in MIL-STD-882E, as follows:
- (a) **Category I: Catastrophic** – a failure which may cause death or whole system loss
 - (b) **Category II: Critical** – a failure which may cause severe injury, major property damage, or major system damage which may result in mission loss
 - (c) **Category III: Marginal** – a failure which may cause minor injury, minor property damage, or minor system damage which may result in delay or loss of system availability
 - (d) **Category IV: Minor (Negligible)** – a failure not serious enough to cause injury, property damage, or system damage, but which will result in unscheduled maintenance or repair
11. Hazard probability and severity shall be assigned by the System Safety Engineer. When assigning the probability of occurrence, the absence of probability data calls for qualitative assignments of the following:
- (a) **A: Frequent** - Likely to occur frequently
 - (b) **B: Probable** - Will occur several times in the life of an item
 - (c) **C: Occasional** - Likely to occur sometime in the life of an item
 - (d) **D: Remote** - Unlikely but possible to occur in life of an item
 - (e) **E: Improbable** - So unlikely, it can be assumed occurrence may not be experienced
 - (f) **F: Eliminated** – hazard eliminated by design of the equipment.

12. The following matrix provides the graphical ideology of the probability and severity relationships. This matrix was referenced from the hazard risk index definition, provided from MIL-STD 882E.

FREQUENCY OF OCCURRENCE	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
F - Eliminated	1F	2F	3F	4F

- a) Unacceptable, 1A, 1B, 1C, 2A, 2B, 3A – Shall be eliminated.
- b) Undesirable, 1D, 2C, 2D, 3B, 3C – Shall only be accepted when risk reduction is impracticable and with the acceptance of NYCT.
- c) Acceptable with review, 1E, 1F, 2E, 2F, 3D, 3E, 3F, 4A, 4B – Acceptable with review by NYCT.
- d) Acceptable without review, 4C, 4D, 4E, 4F.

13. The project Hazard Log shall include hazards pertinent to cutover phases, and be identified as such.

f. Fault Tree Analysis

1. R211S Cab Signaling Fault Tree Analysis shall be prepared and submitted at system and subsystem level and shall be used as part of the evidence to support compliance with the quantified safety requirements.
2. The FTA analysis shall provide a structured means of identifying faults associated with R211S Cab Signaling, which must be mitigated, and shall identify the R211S Cab Signaling functions requiring fail-safe implementation.
3. The FTA shall identify faults, starting with the top level R211S Cab Signaling system design and the Preliminary Hazard Analysis (PHA) identified hazards, clearly identifying the logical combinations of faults which are contributors to the hazard, and subsequently developed to the subsystem and interface level.
4. The system-level Fault Tree Analysis terminal events shall be used as the top-level events of detailed Fault Tree Analyses, which analyze the hardware, and software of each R211S Cab Signaling subsystem performing vital functions. Fault Tree Analysis terminal events shall be reviewed for possible transfer to the Hazard Log for action, tracking, and review.
5. The Fault Tree Analysis shall be developed in accordance with NRC Fault Tree Handbook (NUREG-0492) (Ref 12). The Fault Tree Analysis deliverables shall contain, as a minimum, the following elements:
 - (a) A discussion of the analytic techniques used to generate the fault tree.

- (b) Explanation of the types of faults considered part of the R211S Cab Signaling and those, which are external to the R211S Cab Signaling, if any.
 - (c) A comprehensive Fault Tree Analysis diagram, using a graphical tool, which is suitable for the presentation of the tree logic in a clear and understandable manner. The symbols used and their meaning shall be explained in the text. Each fault or hazard shall be uniquely identified by a reference number.
6. Reference from the unique terminal faults to where their resolution is addressed (e.g., further safety analysis, specific design techniques, Safety Verification and Validation (V&V), test).
 7. The Contractor shall submit Fault Tree Analyses to identify any elements that when combined, result in Category I events.

g. Software Verification and Validation Plan

1. The Software Verification and Validation Plan shall incorporate the approach to safety-critical validation of the ability of the R211S Cab Signaling system and R211S Cab Signaling subsystems (verified to have been implemented in a fail-safe manner) to operate in a safe manner.

h. System Verification and Validation Plan

1. The System Validation Plan shall identify the safety validation tests to be performed. The Safety Validation Tests shall be those, which confirm the resolution of hazards, and demonstrate that R211S Cab Signaling operates in a safe manner. Tasks must be distinctly identified as being safety-critical. Results of safety V&V shall be clearly identified within the V&V reports.
2. The V&V Plan shall state the approach to safety-critical validation tests and safety demonstration tests.
3. The R211S Cab Signaling Test Plans shall demonstrate the testing process to ensure that all elements introduced as part of the R211S Cab Signaling system and R211S Cab Signaling subsystems can be introduced safely, having been appropriately tested.
4. Safety-critical test results shall be included as part of the required test reports the safety testing results which illustrate the successful completion of safety-critical validations and tests but clearly identified from other reported results at the unit, subsystem, and system level, as defined per the Test Plan(s).

i. Preliminary Hazard Analysis (PHA)

1. The Preliminary Hazard Analysis shall be compiled using analysis generated by the Contractor for the Project. The PHA shall be coordinated by the Contractor and shall incorporate consideration of R211S Cab Signaling designs, operating concepts, and maintenance and support processes of the complete scope of supply for the Project. The PHA shall include consideration of interface hazards across the complete Project lifecycle including design, implementation, testing, V&V, operation and maintenance and post deployment support. The PHA shall identify methods or actions for eliminating, minimizing, or controlling each hazard, as well as the recommended approach for eliminating, controlling, or minimizing each hazard.
2. The PHA shall include:
 - (a) Safety design criteria related to safety-critical commands and responses, such as inadvertent commands, failure to command, and untimely commands.
 - (b) Potential contribution to system safety incidents of software anomalies or failures.
 - (c) Hazardous Components (fuels, energy sources, hazardous materials).

- (d) Safety related interfaces such as material compatibility, electromagnetic interference, inadvertent activation, initiation or propagation of fire or explosion, and the potential effects or failure of hardware and/or software controls.
- (e) Safety impacts of hardware controls, software controls, electromagnetic interference (EMI), and inadvertent activation of controls or generation of R211S Cab Signaling commands.
- (f) Environmental Constraints and their effect on personnel and equipment. Elements to be considered include drop, shock, vibration, temperature extremes, exposure to toxic/hazardous substances, noise, electrostatic discharge, ionizing/non-ionizing radiation.
- (g) Operating, test, maintenance and emergency procedures and their association with human performance and potential human error.
- (h) Training requirements pertaining to safety operations and maintenance.
- (i) Support equipment, safety related equipment, and interlocks etc.
- (j) Fail-safe design (hardware and software) approach and safety-related equipment, safeguards, including approaches for ensuring data integrity during data input/sensing, storage, retrieval, transmission, and usage.
- (k) Interface issues associated R211S Cab Signaling Subsystems/System. Interface issues shall include post implementation changes to hardware and or software.

j. Final Safety Report

1. The Project Final Safety Report shall comprise the comprehensive demonstration of the safety of the complete scope of supply for system as implemented on the Project. The Final Safety Report shall provide a summary of the results of the overall analysis, safety verification, safety validation, and system safety demonstration for the complete R211S Cab Signaling system. The Final Safety Report shall provide evidence that the safety program has been completed in accordance with the requirements of this specification.
2. The Final Safety Report shall incorporate the Safety Analyses, Hazard Log, V&V evidence and any other relevant outputs from the R211S Cab Signaling Safety Program. The report shall contain evidence of the system safety analyses performed for the system and subsystems.
3. The Final Safety Report for the Project shall be structured such that the demonstration of safety shall be shown to rest with the competent authority for each item provided under the scope of the project (subsystem, system).
4. The report shall document the calculations and methodology to show that the Project System satisfies the MTBHE requirement defined in Section 3.8.
5. This report shall document design features and actions taken to minimize risk to the specified level.
6. This report shall address all risk reduction actions taken during system design, production, test, operation, and maintenance, including mitigation of faults caused by the following:
 - (a) Operating scenarios.
 - (b) Failures of plant and equipment.
 - (c) Latent design errors in system hardware and software.
 - (d) Installation errors.
 - (e) Human reaction to situations and events resulting from failures, unusual operating situations, and events beyond SIR's direct control.
 - (f) Post implementation changes to the software or hardware.

- (g) Interface and compatibility issues associated with software and hardware changes.
- 7. The report shall contain the evidence of the resolution of hazards, as reviewed and approved by NYCT. The evidence of resolution of hazards shall consist of the satisfactory closure of the items as listed in the Project Hazard Log and the achievement of certification of the items on the Certified Items List.
- 8. The report format shall be as approved in advance by SIR/NYCT. The Final Safety Report shall be submitted in draft form during the Critical Design Review phases of the project. The Final Safety Report shall be considered draft until such time as the R211S Cab Signaling system is safety certified.
- 9. After initial NYCT/SIR System Safety Certification Board (SSCB) certification, the Final Safety Report shall be revised and re-submitted whenever the characteristics of the territory, any R211S Cab Signaling subsystem, system interface or the R211S Cab Signaling system are modified in a way that impacts system safety.

k. Subsystem Hazard Analysis (SSHA)

1. A Subsystem Hazard Analysis (SSHA) shall be documented to verify safety compliance and identify hazards associated with each R211S Cab Signaling Subsystem.
2. As an extension of the Preliminary Hazard Analysis, the main focus of the SSHA shall be on the faults recognized within the R211S Cab Signaling Subsystems.
3. Methods or actions for eliminating, minimizing, or controlling each hazard, as well as the recommended approach for eliminating, controlling, or minimizing hazards identified during this analysis shall be documented in the SSHA.
 - (a) Possible independent, dependent and simultaneous events or failures and system interactions that could create increased risk.
 - (b) Effects of reasonable human errors
 - (c) Determination of/that:
 1. Potential effect on system safety from the functional, interoperable relationships between Subsystems
 2. Safety design criteria has been satisfied Hardware (HW), Software (SW), and facilities
 3. Implementation of safety recommendations and corrective actions will not impair or degrade safety performance of HW, SW and will not create additional hazards.
 - (d) The SSHA is performed and documented to verify compliance with safety requirements and identify hazards associated with the design of subsystems. This includes hazards caused by component failure modes, critical human error inputs, and hazards resulting from functional relationships between equipment compromising each subsystem. The following issues shall be considered during the performance of a SSHA:
 1. Modes of failure including reasonable human errors, single point and common mode failures, and the effects of failures on subsystem elements.
 2. Potential contribution of hardware and software controlled events, faults and occurrences.
 3. Satisfaction of all safety design criteria.
 4. Integrating safety testing into hardware and software testing programs.
 5. System level hazards attributed to subsystems are controlled.
6. Input information from other subsystems that is required to perform the functions of this R211S Cab Signaling Subsystem in a safe manner.

I. Failure Modes and Effects Analysis (FMEA)

1. The Failure Modes and Effects Analysis (FMEA) report analyzes each unit of Class I, as defined in AREMA, fail-safe hardware to the level of the electronic components. A FMEA shall be provided for each item of vital hardware. The FMEA shall be developed in accordance with IEC 60812 (Ref. 13).
2. The FMEA is a qualitative analysis used to identify and analyze single-point failure modes, and their combinations, in Class I hardware circuits to the level of the electronic components. The purpose is to verify safe operation under conditions of hardware failure, power supply anomalies, and also, to the extent possible, under conditions of abnormal inputs.
3. Any Class I component failures identified as the cause of a hazard shall be analyzed in the FMEA, and, if determined to be fail-safe, shall be considered sufficient to close the hazard.
4. Each FMEA shall, at a minimum, address the following:
 - (a) Single point hardware failures as induced or simulated for all circuit components, their effects on the hardware circuit, their effects on the overall system, and the means by which the failure is detected. The FMEA shall address all modes of failure relevant to the component, including changes in component values outside normal tolerances. No single point failure shall be shown to cause an unsafe condition.
 - (b) The effects of all failure modes shall be classified as self-revealing or non-self-revealing. All combinations of failures shall be shown to not result in unsafe conditions, except for combinations of simultaneous independent self-revealing failures. Failures that are not self-revealing shall be analyzed in all combinations with all other failures (excluding combinations with two self-revealing failures). In the instance of a non-self-revealing failure, a subsequent failure cannot be considered as independent.
 - (c) If the analysis of a non-self-revealing failure in combination with all other failures (excluding combinations with two self-revealing failures) is deemed not to be required, the reasons justifying this decision shall be documented in the FMEA.
 - (d) Show that if any unsafe condition results from a combination of two or more failures, then those failures are independent and self-revealing.
 - (e) The FMEA deliverable shall, as a minimum, present text to describe the FMEA approach taken and justifications where needed. It shall present results in a tabular format containing the following elements:
 1. Description of the circuit or module under analysis.
 2. Item identifier and component description and designation.
 3. Failure mode examined.
 4. Effect on circuit performance and/or other components.
 5. Means of failure manifestation and determination if failure is self-evident.
 6. System reaction to failure or other evidence.
7. Determination of the fail-safe acceptability of system reaction, or requirement for design modifications (to be transferred to the Hazard Log for tracking).

m. Safety Concepts Document

1. The Safety Concepts document shall describe the application of the system level concepts which assure R211S Cab Signaling system and subsystems safety, specifically: fail-safe design (hardware and software) approaches used in the implementation of processor-based safety-critical equipment; operational

safeguards; and methods of ensuring safety-critical data integrity. R211S Cab Signaling vital functions must be implemented using concepts, which can be verified as being both correct and sufficiently robust to mitigate the hazards of the system.

2. The safety concepts for processor-based system shall be in accordance with the IEEE Standard for Verification of Vital Functions in Processor-Based Systems 1483-2000.
3. The Safety Concepts document shall explain the safety design approach and underlying principles at the system level and at the safety-critical subsystem level.
4. The Safety Concepts document shall define the design methodologies upon which the implementation of the requirements will be based, consistent with the stated concepts. Safety concepts which address the following topics shall be discussed, as a minimum, in the Safety Concepts document:
 - (a) Dependence on the existing vital train control system, such as SIR Signaling System interfaces.
 - (b) The need or absence of need for vital design, specific safety analysis, test, and/or operating/maintenance procedures to achieve safety of the data link (wayside to cab code system) shall be discussed. The quantifiable measures to be applied to the protection shall be identified (e.g., vital protection for “n” bits in error). The margin of protection against environmental effects and electromagnetic interference shall be projected for later validation.
 - (c) Vital processor-based equipment performing safety-critical functions.
 - (d) Fail-Safe hardware providing vital inputs to R211S Cab Signaling or execution of R211S Cab Signaling outputs.
 - (e) Vital enforcement of R211S Cab Signaling operating modes (as applicable), and fail-safe response to failures of safety-critical R211S Cab Signaling equipment.
 - (f) Dependence on partitioning of the system into vital subsystems, vital interfaces, and subsystems which are non-vital, and the rationale for determining vital and non-vital subsystems. Based on the partitioning of functions, those subsystems performing vital functions, thus requiring fail-safe implementation shall require detailed safety analysis.

3.0 REQUIREMENTS.

3.1 System Safety Program Management Requirements.

The requirements below shall be included in the Contractor’s PSP:

- a. The Contractor’s Safety Manager shall have overall responsibility for ensuring the implementation and management of the R211S Cab Signaling system PSP. This individual shall also be responsible for ensuring all staff is informed of the importance of safety and their respective safety responsibilities.
- b. Proper management techniques shall be used to maximize the visibility of system safety activities and associated results to all Project participants. This shall facilitate the timely identification and resolution of hazards and help minimize the existence of unsafe system aspects.
- c. The Contractor shall conduct periodic, documented audits to ensure that the respective Project Safety Plans are followed. All detected non-conformances shall be addressed and cleared. The safety reviews/audits shall:
 1. Address system safety concerns in a timely fashion as identified through their safety activities or by other Project participants
 2. Discuss possible means of resolving those concerns through the incorporation of special system features, design/procedural changes, or other means.
 3. Assign action items for the resolution of those concerns.

- d. These audits shall also be used to track progress, track problems related to the implementation of the system safety program and to allow all personnel to remain closely informed of safety activities and responsibilities. The results of these audits shall be reviewed by SIR.
- e. The Contractor shall ensure adequate competence, independence and continuity of personnel responsible for the safety of the Project. Specifically, the Contractor shall ensure that there is sufficient independence between system developers and the safety program staff.
- f. The Contractor shall designate a single individual, within their organization, as the System Safety Manager for the work. This individual shall be vested with single point responsibility for all R211S Cab Signaling system safety issues involved in performing the work, and shall coordinate with NYCT on all issues relating to safety.
- g. The individual nominated to the role of System Safety Manager within each organization shall have the appropriate stature, qualifications, experience, and reporting authority within the organization. Specifically, the System Safety Manager shall have a separate reporting chain to an executive-level senior manager of the organization, independent of the R211S Cab Signaling project design, development and test teams. The qualifications of each nominated individual shall be presented for approval by the Engineer.
- h. The Contractor shall identify, analyze and classify inherent risks in each type of technology used in the applicable subsystems. For the software elements this shall include the risks inherent in each part of the software (for example: operating system, and application software), and the methodologies and tools used for their development. These shall be discussed in the System Safety Concepts document.
- i. The Contractor shall ensure that the test and commissioning program demonstrates the ability of the R211S Cab Signaling system and Subsystems to safely provide all of the functionality defined in these Specifications. The test program shall include the requirements of post implementation testing and those tests required to ensure the safe implementation of modifications in a multiple Supplier environment. The testing process shall be in accordance with FRA 49 CFR 236 Subpart H. The testing program shall respond to the requirements identified within item 18 of the Product Safety Plan requirements of this FRA standard. Note that this includes post-deployment maintenance requirements.
- j. The Contractor(s) shall coordinate the test and commissioning program with NYCT to ensure that sufficient time and resources are applied to achieve the required testing.
- k. The Contractor shall support external audits of system safety activities by NYCT/SIR and ISA staff. Support shall include allowing NYCT/ISA site visits to discuss safety issues and to observe design/safety activities, and providing documentation, as available, for review/audit.
- l. Safety roles and responsibilities shall be established for each subcontractor. The Contractor shall coordinate and monitor the system safety activities of all subcontractors to ensure the safe interface and integration of subcontractor products and the proper integration of all safety activities for the entire system.
- m. The subcontracts established under the Project shall ensure back to back requirements are flowed down to the subcontractors including all applicable safety requirements; safety management system, safety analyses, hazard management and resolution, verification and validation activities, safety deliverables, audits, and other relevant activities. The Contractor shall ensure coordination of all safety activities within their scope of supply to meet the safety objectives and milestones as defined in this specification.
- n. Safety Program monthly reports shall include:
 1. The status of system safety activities with respect to the Project schedule (Safety Progress Report).

2. Upcoming Safety Submittals and Safety activities planned for the next three periods.
 3. Identified hazards for which adequate mitigation has yet to be provided, in the form of an updated Hazard Log.
 4. Safety issues requiring discussion with NYCT/ISA staff.
 5. System safety incidents, which have occurred on the Project since the last report.
- o. The schedule shall include planned relationship between safety activities, the design and testing tasks, which depend on successful completion of safety tasks, and overall Project milestones. Estimated start and completion dates shall be provided for all system safety program activities, associated reports and submittals, and reviews.

3.2 Additional Safety Assurance Requirements.

The safety analysis of the vital design techniques incorporated in the Project System shall be traceable to both the Project and concept-specific safety requirements and shall identify the hazards being addressed. The safety program shall demonstrate compliance with the following.

- a. Fail-Safe Equivalence. – Safety critical (vital) functions shall be implemented in a manner which is fail-safe. Processor-based designs which are equivalent to fail-safe will be considered for performing safety-critical functions when their fail-safe equivalence is explicitly shown by use of acceptable safety assurance concepts, and then proven by undertaking safety analysis and safety verification in accordance with this Specification. The system analysis shall demonstrate that the probability of any failure, or combinations of failures, which could result in an unsafe condition shall satisfy the safety design criteria as per this Specification.
- b. Implementation of fail-safe equivalent functions shall follow an explicitly defined safety assurance concept. Concepts will be acceptable if defined in adequate detail in the System Safety Concepts document and presented to the Engineer for approval.
- c. To verify that the safety assurance concept, as implemented, adequately mitigates the effects of hardware failures and/or software errors, the safety assurance concept methods of verification shall address, as a minimum, the following list of potential processor-based system faults caused by hardware failures and/or software errors. Other methods appropriate to the concept(s) used shall be defined in the System Safety Concepts document and conducted to sufficiently determine the level of safety assurance of the design.
 1. Incorrect or ambiguous system inputs
 2. Inputs not present at the prescribed time
 3. Incorrect system outputs
 4. Outputs not present at the prescribed time
 5. System output when necessary inputs are not present
 6. Changed memory contents
 7. Changed clock rate
 8. Data not current
 9. Failure to exit from loop
 10. Arithmetic error
 11. Sign error
 12. Entry to or exit from a routine at the wrong time
 13. Illegal entry to a routine
 14. Improper execution of instructions
 15. Skipping of program segments

16. Latent faults
17. Common cause faults
18. Transient faults
19. Other faults particular to the specific technology
20. Clear identification of unused code
21. Faults resulting from system/subsystem concurrency issues.

3.3 Design Safety Implementation Requirements.

- a. Human factors issues shall be taken into consideration in the design of the safety-critical and safety related equipment. The Human Factors analysis shall comply with the guidelines of FRA 49 CFR 236 Subpart H Appendix E, or equivalent as approved by NYCT. The system design shall minimize the impact of human error on the R211S Cab Signaling operation, eliminating manual intervention in all operations where it can be avoided. Where unavoidable, all human intervention actions shall be designed to be intuitive to the user. Human Factors analysis shall be integrated into the safety analyses throughout the safety program, including O&SHA.
- b. Security is an important element in the design and development of products to address issues such as developing measures to prevent hackers from gaining access to software and developing measures to preclude sudden system shutdown. The safety program shall identify the methods used in development of the system and subsystems to prevent security issues including those detailed above. The description of the security processes shall be included in the Project Safety Plans. The Contractor shall coordinate with the Contractor(s) to ensure that the security approaches are compatible. The interface issues shall be addressed to ensure ongoing safe, secure operation of the R211S Cab Signaling system and subsystems by NYCT/SIR.
- c. Safety-critical elements of the Project System shall be designed with sufficient margin to operate in a fail-safe manner over the entire range of environmental requirements, as appropriate for the location of the element. All safety analyses shall consider the effects of environmental variations on the system.
- d. All data communication within the Project System that are used to transfer safety-critical data shall be designed to provide adequate levels of error detection for this purpose.
- e. Certain equipment and components are declared to be fail-safe by their compliance with existing codes and standards for these particular devices (e.g. vital signaling relays) and may be used, in an appropriate manner, in the design of a safety critical system element. It shall be the responsibility of the Contractor to present the safety certifiable evidence of the inherent fail-safety of the devices to be used.
- f. The Contractor shall provide metrics for timing and loading. These metrics will reflect the design criteria for the R211S Cab Signaling system, taking due account of spare capacity and timing constraints requirements identified in this Technical Specification. The metrics for the timing and loading issues shall be provided by the Contractor at PDR for approval by NYCT.

3.4 Software Safety Implementation Requirements.

- a. Safety-critical system functions may be performed utilizing logic resident in software. Safety-critical functions either: directly impact on the safety and integrity of the system; are relied upon to provide reasonable continuity of service; or are required to be available for support of an emergency situation. The impact on the safety of the system may be different in each case, and the contribution of a particular software subsystem to an identified hazard shall be evaluated using the safety verification and validation techniques in these Specifications.

- b. The design and development of safety-critical software shall be in accordance with recognized national or international software standards applicable to critical, high integrity systems. Where software is employed to perform a safety-critical function, then that software shall have been developed to a rigorous interpretation of this design and development processes, and confirmed by satisfying the requirements of these Specifications.
- c. Safety-critical decision processes within the software shall be structured to ensure minimum complexity and allow rigorous safety verification, safety validation, and testing. The dependence of safety of the system on a single software decision process, logic path, or critical data element should be minimized or avoided where possible. The above requirements shall be verified by the Contractor performing documented analysis and testing of the safety-critical software.
- d. Where vital and non-vital software is to be implemented on a single hardware platform, then all of the software shall meet the requirements for vital software unless appropriate techniques, acceptable to the Engineer, are used to ensure vital software is sufficiently partitioned to be unaffected by the non-vital software.

3.5 Software Safety Verification and Validation Requirements.

The following shall be included in the Safety Verification and Validation Plan (SV&VP):

- a. Where vital software is included in the R211S Cab Signaling design, it shall be necessary to conduct software safety verification and safety validation activities as part of the Software V&V to assure software-based functions/algorithms being used are correct (the desired ones) and are implemented in a safe manner.
- b. Plans for conducting software safety V&V shall be clearly defined in a NYCT-approved Software V&V Plan. This plan shall be coordinated with the Software Development Plan and the Software Quality Assurance Plan so objectives and relationships between software development, software V&V, software safety V&V, and software quality assurance activities are clearly defined. Software development phases include software requirements, architectural design, detailed design, implementation, integration and test.
- c. Evidence of the Software Safety Verification and Validation shall be presented within the safety certification documentation

3.6 System Safety Validation Requirements.

- a. System safety validation shall be performed on the overall R211S Cab Signaling system. System safety validation activities shall be conducted to demonstrate that the correct system has been implemented such that the overall integrated system operates safely in its intended environment – specifically that the system meets all qualitative and quantitative system safety requirements, and does not compromise the safety of the existing SIR system.
- b. Plans for conducting System V&V shall be clearly defined in a NYCT-approved System V&V Plan. This plan shall be coordinated with the system development, test and commissioning activities so objectives and relationships between system test and development assurance activities are clearly defined. System development phases include requirements, architectural design, detailed design, implementation, integration and test.
- c. Results of system V&V activities shall be included along with other project documentation, but shall be clearly designated as applying to safety aspects.
- d. System V&V shall include analyses, testing, inspections and/or walkthroughs directed to the safety aspects of the development and implementation phase.
- e. V&V procedures shall address hardware as well as software development to assure that safety is fully integrated into the development process. V&V shall provide appropriate methods for the overall R211S Cab Signaling system.

- f. Testing is an important aspect in the system development and system V&V process, and shall be conducted on individual equipment as well as integrated systems. Tests shall include normal range testing (i.e. exercising test cases under various load and throughput conditions) and boundary value testing (i.e., checking execution at parameter limits). Tests shall also be directed to the hazards identified from the verification to show that hazards are mitigated where possible.
- g. Testing of the overall system shall encompass functional and “black box” techniques. The primary intent is to show, via testing, the overall system is “fit for purpose” from a safety standpoint. This shall include the reliability and availability of the system to perform the required operational and safety functions.
- h. Safety validation shows that the integrated system performs safety-critical functions in a safe manner under all anticipated operating conditions (e.g., normal operation, hardware failures, external influences); and confirms that all unacceptable hazards as identified by the safety analyses have been eliminated or mitigated to acceptable levels.
- i. Safety validation of modifications to one or more R211S Cab Signaling Subsystem shall be addressed by the software verification and validation processes.

3.7 System Safety Testing Requirements.

- a. System safety test activities shall be conducted to complete the safety verification and validation process. The post implementation testing requirements appropriate to maintenance shall be reflected in the maintenance procedures.
- b. The Contractor shall comply with the requirements of FRA 49 CFR 236 Subpart H, Product Safety Plan items 17 and 18.
- c. Initial Implementation Testing: a description of initial implementation testing procedures necessary to establish that safety-functional requirements are met and safety-critical hazards are appropriately mitigated.
- d. Post-Implementation Testing: a description of post-implementation testing (validation) and monitoring procedures, including the intervals, as well as a description of the record keeping necessary to ensure the safety of the system that is associated with periodic maintenance, inspections, tests, repairs, replacements, adjustments, and the system’s resulting conditions.
- e. The Contractor shall submit the regression testing requirements to NYCT/SIR for approval. This shall include the process describing the development of the regression testing requirements for each release along with the minimum regression test requirements for each system element. The requirements for regression testing shall be enforced following the first release of the system for shadow mode, all subsequent system modifications shall be the subject of approved regression testing. The acceptance of the regression testing shall form part of the certification process.
- f. Safety Verification Testing:
 - 1. Verification testing shall be performed on system hardware and integrated hardware/software portions to supplement verification analyses and help demonstrate safety critical functions have been implemented in a sufficiently robust and fail-safe manner. These tests shall involve all classes of hardware and software associated with implementing safety critical and safety related functions, including any tests described in the methods of verification section(s) of the System Safety Concepts document deliverable.
 - 2. Tests shall be conducted for three major purposes. First, tests shall be conducted to demonstrate safe performance of the safety functions under conditions of normal operation with no component failures. Second, tests shall be conducted to demonstrate safe performance of safety functions under conditions of hardware

failure that could not be confirmed through analytical means. Third, tests shall be conducted to demonstrate safe performance of the safety functions under conditions of abnormal inputs and other abnormal, but possible, operating conditions.

3. All verification testing shall be directed to demonstrate safety-critical functions have been implemented in a fail-safe manner. The results of verification testing shall be included with the relevant subsystem implementation safety analysis reports.
4. Safety verification testing shall include the process required to repeat safety verification testing in the event of modifications to one or more elements of the R211S Cab Signaling system and subsystems, i.e., regression testing.

g. Subsystem/System Safety Validation Testing

1. The Contractor Safety / RAMS Departments shall thoroughly review the test plans, procedures and test results. Where appropriate the Safety / RAMS departments shall require additional tests to be conducted in order to assure and demonstrate that each subsystem and the integrated subsystems perform the correct safety system functions and operate safely over the anticipated operating conditions. These tests shall be performed primarily as part of the Contractor safety verification and validation process.
2. Anticipated operating conditions include normal operation, random hardware failure and external influences including abnormal/improper inputs, power supply anomalies and other electrical, mechanical and climatic conditions as required by this Specification.
3. Testing under conditions of normal operation shall be directed to the safe performance of the correct safety subsystem and system functions within the normal range of input and other operating conditions and with no component failures.
4. Testing under conditions of hardware failure shall be directed to the safe performance of the correct safety subsystem and system functions with inserted/simulated hardware failures in particularly critical areas (as identified by the Hazard Log) and with normal input/operating conditions.
5. Testing under conditions of abnormal/improper inputs and other external influences is a type of "robustness" testing which shall demonstrate the safe performance of subsystem and system functions under stress conditions – abnormal or improper inputs and other abnormal operating conditions.
6. Overall, the testing shall demonstrate that the system operates safely in a large representative set of scenarios and responds to identified failures in a safe manner. The purpose is to ensure that the design has been implemented in a robust manner to be safe within the full range of operational demands and environmental conditions. Safety validation tests shall be specifically reported in accordance with approved test plans, and shall clearly describe the successful completion of each test conducted.

h. Factory/Field Safety Demonstration Testing

1. The Test Program forms part of the overall safety process, by demonstrating performance in line with the design expectations.
2. The Contractor's Safety/RAMS departments shall thoroughly review the test plans, procedures and test results. Where appropriate, the Safety/RAMS Departments shall require additional tests to be conducted in order to assure and demonstrate that each subsystem and the integrated subsystems perform the correct safety system functions and operate safely over the anticipated operating conditions. All tests

(including those identified by the Safety/RAMS departments) shall be included in the Test Program.

3.8 System Safety Performance Requirements.

- a. Achievement of System Safety is a primary design and performance requirement for the R211S Cab Signaling system, which must perform in a safe manner under all operating conditions.
- b. The Contractor shall allocate quantified safety requirements to each R211S Cab Signaling Subsystem. The allocation shall take into account the functions required from each R211S Cab Signaling Subsystem as well as the requirement to meet or exceed the overall system requirement.
- c. Qualitative Safety Requirements
 - 1. The R211S Cab Signaling Supplier shall accomplish the design and implementation of the system including the development of procedures and other means in such a manner to assure the system safely performs the correct safety critical functions.
- d. Quantitative Safety Requirements
 - 1. The R211S Cab Signaling equipment and wayside elements located within any contiguous portion of a one-way route, which can be traversed by a train traveling at the specified maximum authorized speed for one hour, shall have a total calculated aggregate MTBHE of at least 10⁹ operating hours.

The System Safety documentation shall support these calculations and substantiate the methodology used to arrive at the result.

4.0 SUBMITTALS AND APPROVALS

- a. The following table provides the submittal table for the safety program. All submittals listed shall be submitted to NYCT/SIR for approval.
- b. Contractor(s) shall be responsible for preparation and delivery of all submittals.

SUBMITTAL SCHEDULE

Item No.	Para Ref	Submittal	Due by		
			PDR ¹	IPDR ¹	CDR ¹
1	2.1.a	Project Safety Plan	X	X	
2	2.1.b	Certifiable Items List	X		
3	2.1.c	Operating and Support Hazard Analysis		X	X
4	2.1.d	Interface Hazard Analysis	X		
5	2.1.e	Project Hazard Log ²	X	X	X
6	2.1.f	Fault Tree Analysis ³		X	X
7	2.1.g	Software Verification and Validation Plan		X	
8	2.1.h	System Verification and Validation Plan		X	
9	2.1.i	Preliminary Hazard Analysis (System Hazard Analysis)		X	X
10	2.1.j	Final Safety Report ⁴ (FSR)			X
11	2.1.k	Sub-System Hazard Analysis		X	X
12	2.1.l	Failure Mode and Effects Analysis		X	X

13	2.1.m	Safety Concepts Document	X	X	
14	2.1.e	Cutover Safety Analysis (include in the Project Hazard Log			X

¹ PDR = Preliminary Design Review, IPDR = In-process Design Review, CDR = Critical Design Review.

² The Project Hazard Log shall be delivered monthly until final acceptance the system

³ The initial delivery of the Fault Tree Analysis is required at PDR. Updates shall be submitted as required.

⁴ In addition to the CDR submittals, the FSR shall be submitted prior to each required safety certification.

END OF SECTION

Attachment 14-C: St. George Interlocking & Cable Plan, drawing number SOXC005-C, Holly Interlocking Track Arrangement & Cable Plan , drawing number HLXC006-C, and Tottenville Interlocking Track Arrangement & Cable Plan, drawing number TNXC011-C

Attachment 14-D: R44 Cab Signal Braking Model S-80220

Appendix A – Hazard Mitigation Form

HMF



New York City Transit

SIR R211S ATC

SAFETY MITIGATION FORM

Action Assignee:

Reference:

Target Date:

SIR R211S ATC Hazard Log cross-reference:

Entry #:

Date:

Safety Requirement ID.

Description of the hazard:

The following action has been identified to mitigate the hazard:

Action Required:

Type of mitigation:

- Design
- Implementation

- Test
- Rules & Procedures
- Maintenance

- Inspection
- Verification
- Other

List any documents (with REFERENCE) that are required to support the mitigation action:

Describe action undertaken / Comments:

I certify that the actions above have been completed for the identified SIR R211S ATC hazard mitigation

Name: _____

Title: _____

Signature: _____

Date: _____

Reference to other relevant Hazards / Mitigations (SMF) if appropriate:

Hazard Log Amended -

Appendix B – Certifiable Items List (Examples)

Id.	Name	Type	Safety Level	Responsible Party
Cab Signaling System	Cab Signaling System	SYSTEM	Vital	Supplier
ATS	Automatic Train Supervision	Subsystem	Non-Vital	SIR
DCS	Digital Communications System	Subsystem	Non-Vital	R211S Cab Signaling Supplier
SYSTEM	R211S Cab Signaling System	System	Vital	R211S Cab Signaling Supplier
Wayside	Track Circuits	Subsystem	Vital	NYCT/SIR
Operating Rules	Train Operator Rules Dispatcher Rules	Document	Safety Related	NYCT
Operating Procedures	Train Operator Procedures Dispatcher Procedures	Document	Safety Related	NYCT
Maintenance Manuals	Carborne Wayside	Document	Safety Related	R211S Cab Signaling Supplier
Maintenance Procedures	Carborne Wayside	Document	Safety Related	R211S Cab Signaling Supplier
Training	Train Operation Wayside Dispatcher Maintenance	Document	Safety Related	R211S Cab Signaling Supplier

Appendix C – 49 CFR236 subpart H Product Safety Plan Requirements Review

Part H Product Safety Plan Intent

1.0 PRODUCT DESCRIPTION

A description of the “product” including a list of all product components and their physical relationship in the subsystem or system.

2.0 OPERATING ENVIRONMENT

A description of the operations for which the product is designed to be used, including train movement density, operating rules, and operating speeds.

3.0 OPERATIONAL CONCEPT

A description of the product functionality and information flows.

4.0 SAFETY REQUIREMENTS

A list and descriptions of all functions which the product performs to enhance or preserve safety.

5.0 SYSTEM ARCHITECTURE

A description of how the product architecture satisfies the safety requirements.

6.0 HAZARD LOG

A description of all safety-relevant hazards to be addressed during the life cycle of the product, including maximum threshold limits for each hazard.

7.0 RISK ASSESSMENT

A risk assessment, as prescribed in § 236.909 and Appendix B of *FRA Part 236 Subpart H*, to show with a high degree of confidence that the introduction of the product will not result in risk that exceeds the current conditions. This includes consideration of:

- Risks associated with the current conditions that are no longer present as a result of implementing the product
- New risks created by the product that are not present with the current conditions
- Risks neither newly created nor eliminated whose nature (probability of occurrence or severity) is nonetheless affected by the change

8.0 HAZARD MITIGATION ANALYSIS

A description of all hazards to be addressed in the system design and development, mitigation techniques used, and system safety precedence followed.

9.0 SAFETY ASSESSMENT AND V&V PROCESS

A description of the safety assessment and validation and verification processes applied to the product and the results of these processes, describing how the subject areas identified in Appendix C of *FRA Part 236 Subpart H* are either addressed directly, addressed using other

14-B Reference

2.1.j – Final Safety Report

2.1.m – System Safety Concepts Document

2.1.a – Project Safety Plan

2.1.j – Final Safety Report

2.1.m – System Safety Concepts Document

2.1.m – System Safety Concepts Document
Safety analyses requirements detailed in Section 2.1

2.1.m – System Safety Concepts Document
Safety analyses requirements detailed in Section 2.1

2.1.m – System Safety Concepts Document

2.1.e Project Hazard Log

2.1.j – Final Safety Report
Safety analyses requirements detailed in Section 2.1

2.1.e Project Hazard Log

Section 3 – Requirements

2.1.a – Project Safety Plan

2.1.m – System Safety Concepts Document

2.1.j – Final Safety Report

Safety analyses requirements detailed in Section 2.1

Part H Product Safety Plan Intent

14-B Reference

safety criteria, or not applicable. These subject areas include:

- Normal operations
- Systematic failures
- Random failures
- Common mode failures
- External influences
- Modifications
- Software
- Closed loop principle
- Human factors engineering

10.0 SAFETY ASSURANCE CONCEPTS

A description of the safety assurance concepts used in the product design, including an explanation of the design principles and assumptions;

11.0 HUMAN FACTORS ANALYSIS

A description of human-machine interfaces and a description of functions performed by humans in connection with the product to enhance or preserve safety, with an analysis in accordance with Appendix E of *FRA Part 236 Subpart H*, or approved equal.

12.0 TRAINING REQUIREMENTS

A description of the specific training necessary to ensure the safe and proper installation, implementation, operation, maintenance, repair, inspection, testing, and modification of the product

13.0 TEST EQUIPMENT

A description of the specific procedures and test equipment necessary to ensure the safe and proper installation, implementation, operation, maintenance, repair, inspection, testing, and modification of the product. These procedures, including calibration requirements, shall be consistent with or explain deviations from the equipment manufacturer’s recommendations

14.0 APPLICABILITY OF FRA PART 236 SUBPARTS A-G

Analysis of the applicability of the requirements of subparts A-G to the product that may no longer apply or are satisfied by the product using an alternative method, and a complete explanation of the manner in which those requirements are otherwise fulfilled

15.0 SECURITY

A description of the necessary security measures for the product over its life-cycle;

2.1.a – Project Safety Plan

2.1.m – System Safety Concepts Document

3.3 – Design Safety Implementation Requirements

2.1.c – Operating and Support Hazard Analysis (O&SHA)

3.3 – Design Safety Implementation Requirements

2.1.c – Operating and Support Hazard Analysis (O&SHA)

Safety requirements detailed in Sections 2.1 and 3

2.1.a – Project Safety Plan

2.1.j – Final Safety Report

3.3 – Design Safety Implementation Requirements

Part H Product Safety Plan Intent

16.0 WARNINGS

A description of each warning to be placed in the Operations and Maintenance Manual and of all warning labels required to be placed on equipment as necessary to ensure safety.

17.0 INITIAL IMPLEMENTATION TESTING

A description of initial implementation testing procedures necessary to establish that safety-functional requirements are met and safety-critical hazards are appropriately mitigated.

18.0 POST-IMPLEMENTATION TESTING

A description of post-implementation testing (validation) and monitoring procedures, including the intervals, as well as a description of the record keeping necessary to ensure the safety of the system that is associated with periodic maintenance, inspections, tests, repairs, replacements, adjustments, and the system's resulting conditions.

19.0 ASSUMPTIONS

A description of any safety-critical assumptions regarding availability of the product, and a description of all backup methods of operation.

20.0 CONFIGURATION / REVISION CONTROL

A description of the configuration/revision control measures designed to ensure that safety-functional requirements and safety-critical hazard mitigation processes are not compromised as a result of changes.

14-B Reference

2.1.c – Operating and Support Hazard Analysis (O&SHA)

2.1.e – Project Hazard Log

Safety requirements detailed in Sections 2.1 and 3

Safety requirements detailed in Sections 2.1 and 3

2.1.e – Project Hazard Log

2.1.a – Project Safety Plan

2.1.j – Final Safety Report

2.1.m – System Safety Concepts Document

Safety requirements detailed in Sections 2.1 and 3

Section 26

Open Gangway Test Train (R211T)

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26. Open Gangway Test Train

26.1. General Requirements and Scope

26.1.1. General Requirements

26.1.1.1. This section defines the requirements for the Open Gangway Test Train (R211T) to be developed in coordination with the NYCT R211A cars, as defined in Section 1.1.3 c).

26.1.1.2. Requirements for the R211T shall include, but are not limited to, those related to Performance, Function, Design, Maintainability, and Validation of the test train.

26.1.1.3. The R211T shall be developed with a minimum of changes from the base R211A car subsystems.

26.1.1.4. All requirements of the R211A Specification Sections 1 through 24 shall apply to the R211T cars, except as specifically noted in this section as changes or new requirements.

26.1.1.5. This section is written to include a subsection which matches each main section of the R211A Specification. Each subsection identifies changes to be made to the R211A Specification for the R211T and additional requirements for the R211T, or notes that the R211A Specification remains unchanged for the R211T.

26.1.1.6. Submittal, test, and mock-up requirements generally have not been revised from the R211A Specification. Where a document, test, or mock-up has been approved, performed satisfactorily, or created on identical equipment for the R211A or R211S under this Contract, a repeat for the R211T will not be required, subject to NYCT approval.

26.1.1.7. Supplements to existing documents, such as Operating and Maintenance Manuals, that provide appropriate content applicable to the open gangway shall be created by the Contractor and delivered to NYCT.

26.1.1.8. Upon completion of the evaluation period of the R211T, the Contractor and gangway supplier shall participate in the following:

- a) A review and evaluation of customer and user feedback gathered as part of the R211T evaluation.
- b) A teardown inspection of the open gangway system and its components at the end of service testing.

26.1.1.9. Requirements for the R211T are not applicable to the R211S Staten Island Railway (SIR) cars.

26.1.2. Changes to R211A Section 1 Requirements

26.1.2.1. Delete Section 1.2.3 in its entirety and replace with the following: "Not used."

26.1.2.2. Replace Section 1.3.1 with the following: "The primary scope of supply is to design, build, test, and commission a 10-car (2-Unit) test train for open gangways (and other technical developments) for evaluation and testing. These cars will be designated as R211T."

26.1.2.3. Delete Section 1.3.2 in its entirety and replace with the following: "Not used."

26.1.2.4. Replace Section 1.3.3 with the following: "Additional items within the main car scope of supply for the R211T include the following if they differ from the R211A supplied items:"

26.1.2.5. Add to Section 1.7.1 the following definition: "Open Gangway - An open gangway is an enclosed flexible walkway, semi-permanently connected to the ends of adjacent cars, to allow passengers to freely move between cars through openings in the ends of the cars, or to stand in the open gangway area, while protecting the passengers from the external environment."

26.2. R211 TS Section 2: Design and Performance Criteria

- 26.2.1. Replace Section 2.2.1.8 with the following: “The end of each car, except the cab ends of A1 and A2 cars, shall be equipped with an open gangway which, when coupled, shall form a safe and unobstructed passageway for passengers and train crew between cars.”
- 26.2.2. Add Section 2.2.1.9: “The open gangway shall protect passengers in the open gangway area between cars under all operating and environmental conditions specified in Appendix A (Fixed Facilities Description).”
- 26.2.3. Add Section 2.2.1.10: “The open gangway shall be designed such that passengers may safely stand in the open gangway under all normal operating conditions.”
- 26.2.4. Add Section 2.2.2.4: “As part of the Preliminary Design Review (PDR) package, the Contractor shall provide an estimate of the number of seats in the A and B Cars, if different than the numbers specified in 2.2.2.1 and 2.2.2.2.”
- 26.2.5. Replace Section 2.4.1.1 with the following: “In a five-car Unit, the average car weight shall not exceed 83,300 lbs. (37,784 kg). This weight shall exclude customer furnished equipment (e.g. CBTC and flexible displays), but shall include all equipment supplied by the carbuilder to interface with such equipment.”
- 26.2.6. Replace Section 2.9.2.1 with the following: “With the car stationary, with windows and doors closed, and with all auxiliary equipment operating simultaneously under normal operating conditions, the car interior noise level shall not exceed 72 dBA when operating in a tunnel section, except that the noise level within 6 feet of, and inside, the open gangway, shall not exceed 74 dBA.”
- 26.2.7. Replace Section 2.9.2.2 with the following: “With the car operating at 40 mi/h (64 km/h) in a tunnel section, and under any acceleration or deceleration condition, interior noise shall not exceed 80 dBA, except that the noise level within 6 feet of, and inside, the open gangway, shall not exceed 82 dBA.”
- 26.2.8. Replace Section 2.9.2.3 b) with the following: “Not less than 1 ft. (305 mm) from the ceiling, end walls or side walls, including the open gangway area.”
- 26.2.9. Replace Section 2.12.3.3 with the following: “Car end-caps, floors, and the open gangway shall be designed to prevent the propagation of an underfloor fire to the car interior.”

26.3. R211 TS Section 3: Carbody Structure

General Requirements

- 26.3.1. Add to Section 3.1.2 h): “Open Gangway Test Train – Section 26.”

Equipment Support Performance Requirements

- 26.3.2. Replace Section 3.2.14.1 with the following: “Under the loading specified, all carbody-mounted equipment supports, including open gangway attachment points, regardless of mounting location, and any portion of the equipment carbody to which the equipment supports are attached shall not exceed their fatigue limit for the design life of the car. Fatigue life shall be demonstrated by analysis. The allowable stresses and margins of safety shall be per Section 3.2.2. Where multiple equipment is connected to the same structural member, the effects of the combined loading shall be considered in the analysis.”
- 26.3.3. Replace Section 3.2.14.2 with the following: “Fatigue design loads shall consider equipment loads generated from the shock and vibration environment denoted in Section 2.9.6, open gangway loads generated due to relative movements between cars, and loads due to equipment with rotating mass.”

- 26.3.4. Replace Section 3.2.14.7 with the following: “The above requirements shall apply to the mounting brackets of all equipment boxes, equipment racks, open gangway attachment points, or other structural members connecting equipment to the carbody. Where multiple equipment is connected to the same structural member, the effects of the combined loading shall be considered in the analysis and test.”
- 26.3.5. Replace Section 3.2.14.8 with the following: “Structural connections in equipment supports, including open gangway attachment points shall be subject to the requirements of Sections 3.4.4 and 3.4.5.”
- 26.3.6. Add Section 3.2.14.12: “The open gangway carbody attachment points shall withstand all forces imparted by the open gangway, including those resulting from negotiating all applicable track conditions on the system, loads from jacking and lifting, loads from AW3 passenger loading, and loads imparted by NYCT’s car washing equipment without permanent deformation.”

Anti-climber Functional Requirements

- 26.3.7. Replace Section 3.3.2.2 with the following: “The cab end anti-climber shall be compatible with all existing NYCT Division B equipment and bumper blocks.”

Gutter and Splash Guard Functional Requirements

- 26.3.8. Replace Section 3.3.10.2 with the following: “Open Gangway designs shall include features to prevent rain or car wash water from accumulating on the roof of the Gangway. Water runoff from the gangway shall be directed away from passengers at station platforms.”

General Design Requirements

- 26.3.9. Add Section 3.4.1.9: “The non-cab end structure of the carbody including the end frame and floor shall be configured and reinforced to accept the installation of the open gangway assembly.”
- 26.3.10. Renumber existing Sections 3.4.1.9 through 3.4.1.13 as 3.4.1.10 through 3.4.1.14 respectively.

General Connection Design Requirements

- 26.3.11. Section 3.4.3.2, add the following to the end: “k) Open gangway to carbody connection.”

Anti-climber Design Requirements

- 26.3.12. Replace Section 3.4.7.1 with the following: “An anti-climber shall extend laterally over the full width of the cab end frame, and as wide as the open gangway design allows at the non-cab end, and shall be attached to the end sill or CEM equipment.”
- 26.3.13. Replace Section 3.4.7.2 with the following: “The cab end anti-climber top surface shall have a diamond plate texture and shall be painted with a safety yellow anti-slip paint. Adhesive backed, non-skid tape or sheets are not permitted.”
- 26.3.14. Replace Section 3.4.7.3 with the following: “The distance from the edge of the anti-climber top surface to the vertical face of the cab end bonnet shall not be less than 3.75 inches (95 mm) on both sides of the car at A Car No. 1 ends.”
- 26.3.15. Replace Section 3.4.7.4 with the following: “A recess in the A Car No. 1 end bonnet may be provided to provide the necessary dimension.”
- 26.3.16. Add Section 3.4.7.6: “An anti-climber, designed in coordination with the open gangway design and providing functionality described in Section 3.3.2, shall be applied to the open gangway ends of the car. The Contractor may propose alternate methods to prevent telescoping of the cars in a collision

in coordination with the Crash Energy Management (CEM) requirements of Section 2.8 for NYCT review and approval. Design validation shall be in accordance with Sections 3.6.18 and 3.6.19.”

End Frame Design Requirements

- 26.3.17. Replace Section 3.4.10.3 with the following: “Two primary center collision posts shall be located at each side of the end doors on the cab ends, spaced approximately 1/3 distance from each corner but less than 40 inches (1.02 m) apart. Two primary collision posts spaced to accommodate the open gangway design shall be provided at non-cab ends.”
- 26.3.18. Replace Section 3.4.10.4 with the following: “Two primary side collision posts shall be located at the juncture of each front end and side frame at cab ends. A combined center and side collision post at open gangway locations may be proposed for NYCT approval.”

Equipment Support - Design Requirements

- 26.3.19. Replace Section 3.4.18.1 with the following: “Equipment mounting hangers and brackets, including open gangway attachment points, shall be attached to the carbody structure by mechanical fasteners, resistance welding, or other welding as approved by NYCT.”
- 26.3.20. Replace Section 3.4.18.4 with the following: “All equipment mounting provisions, including equipment support beams and open gangway attachment points, shall be analyzed to confirm compliance with Section 3.2.14.”

Equipment Support Maintenance Requirements

- 26.3.21. Replace Section 3.5.2.1 with the following: “Equipment, including the open gangway, shall be supported so that both bolts and nuts are accessible if the equipment requires removal and replacement for other than damage due to an accident.”

Anti-climber Compression Load Test Requirements

- 26.3.22. Replace Section 3.6.14.1 with the following: “Each anti-climber configuration and carbody structure shall be tested under the loads of Section 3.2.9. Three tests shall be performed: the first of the anti-climber and its attachment to the end sill, and the second and third test to permit, by superposition and extrapolation, validation of the anti-climber combined load case analysis.”

Collision Post Elastic Load Test

- 26.3.23. Replace Section 3.6.16.1 with the following: “The ability of the carbody structure to resist the collision post elastic loads specified in Section 3.2.10 shall be tested. Six separate tests shall be conducted. Elastic load cases shall include the following collision post load cases:”
- a) Cab end primary center collision post in the longitudinal direction.
 - b) Non-cab end primary collision post in the longitudinal direction.
 - c) Cab end side collision post in the longitudinal direction.
 - d) Non- cab end side collision post in the longitudinal direction.
 - e) Cab end primary side collision posts in the transverse direction.
 - f) Non-cab end primary side collision posts in the transverse direction.”

Alternate test cases based on the Open Gangway design may be proposed for NYCT review and approval. See 26.3.18.

Primary Center Collision Post Elastic-Plastic Load Test

- 26.3.24. Replace Section 3.6.17.1 with the following: “The cab and non-cab end primary collision post, or Open Gangway combined primary and side collision post, structures shall be loaded to the ultimate load capacity in the longitudinal direction as specified in Section 3.2.10.”
- 26.3.25. Replace Section 3.6.17.2 with the following: “The test specimens shall be full scale structural models of a cab and non-cab end of a car. The structural models shall contain all structural elements required to support the primary collision posts, including the end underframe and roof extending from the forward end of the end frame to the bolster.”

26.4. R211 TS Section 4: Coupler Systems

- 26.4.1. Add Section 4.1.3.5: “The link bar shall incorporate a platform as necessary for support of the open gangway floor and/or bellows. See Section 26.”
- 26.4.2. Add Section 4.3.2.14: “Open gangway supports applied to the link bar (if required) shall not interfere with car and open gangway coupling or uncoupling operations.”
- 26.4.3. Add Section 4.4.2.7: “Wear resistant plates incorporating a visible wear indicator, and having a minimum life of one SMS cycle (7 years), shall be supplied on the link bar open gangway support (if required).”
- 26.4.4. Renumber existing Sections 4.4.2.7 through 4.4.2.17 as 4.4.2.8 through 4.4.2.18 respectively.
- 26.4.5. Add Section 4.5.5: “Wear resistant plates (if required) shall be easily replaced with commercially available hand tools.”
- 26.4.6. Add Section 4.5.6: “Installation and removal procedures for the R211 link bar shall be supplied as part of the Open Gangway Maintenance Manuals.”
- 26.4.7. Renumber existing Sections 4.5.5 through 4.5.9 as 4.5.7 through 4.5.11 respectively.

26.5. R211 TS Section 5: Cab and Cab Controls

- 26.5.1. No change from the R211A Specification.

26.6. R211 TS Section 6: Side Door System

- 26.6.1. Replace Section 6.4.11.2 with the following: “On each B Car, Crew Key Switches shall be provided inside and outside the car at diagonally opposite sides of the car at locations approved by NYCT. Location of crew key switches will be indicated in the PDR package for open gangway design if these locations will differ from the R211A cars.”

26.7. R211 TS Section 7: Heating, Ventilation and Air Conditioning (HVAC)

- 26.7.1. Replace Section 7.2.1.1 g) with the following:
“Car body heat transmission (U Factor):
Car body, insulation, and open gangway designed to meet the requirements of Section 15.2.2.”
- 26.7.2. Replace Section 7.3.4.8 with the following: “The diffusers shall be designed to provide uniform air distribution throughout the car and the open gangway.”
- 26.7.3. Replace Section 7.3.4.10 with the following: “If required to provide conditioned air to areas such as the vestibules and open gangway not fed by the main duct, individual supply ducts with diffusers, fed from both sides of the main center distribution duct, shall be routed to the affected areas.”

26.8. R211 TS Section 8: Lighting Systems

Changes to R211A Section 8 Requirements

26.8.1. Replace Table 8.1 with the following:

Table 8.1 – Interior Lighting Levels, Normal Conditions

Measurement Location	Height Above Floor	Light Intensity
45 degree plane centered on front edge of any seat, any orientation	33 inches (0.838 m)	35 foot-candles (377 Lux)
45 degree plane for passengers standing anywhere within the aisles, or open gangway, any orientation	55 inches (1.397 m)	35 foot-candles (377 Lux)
Average intensity on floor in passenger aisles, doorway areas, and open gangway areas	0 inches (0 m)	20 foot-candles (215 Lux)
Train Operator’s console, with overhead and reading lights on	Operator’s console height	20 foot-candles (215 Lux)

26.8.2. Replace Table 8.2 with the following:

Table 8.2 – Interior Lighting Levels, Emergency Conditions

Measurement Location	Height Above Floor	Light Intensity
Average intensity on floor in passenger aisles, doorway areas, and open gangway areas	Floor level	1 foot-candle (10.8 Lux)
Train Operator’s console, with overhead and reading lights on	Operator’s console height	10 foot-candles (108 Lux)

26.8.3. Replace Section 8.3.1.1 with the following: “Interior lighting shall be uniform throughout the car and open gangway, and neutral white in color, with a correlated color temperature between 3,500°K and 4,200°K. Any color difference between individual light emitting elements shall not be perceptible.”

26.8.4. Replace Section 8.6.3 with the following: “Lighting intensity and lighting color shall be simulated on a mock-up for NYCT approval. The mock-up shall use the same arrangements, including inter-car open gangway, materials, and dimensions proposed for the series car so that the effect of multiple light sources, their reflection and absorption can be realized and, if necessary, corrected. The mockup defined in Section 20.6 may be used for this purpose.”

26.8.5. Replace Section 8.6.4 b) with the following: “Lighting system tests on a completed car including intercar open gangway, that demonstrate compliance with the lighting performance and emergency lighting duration requirements of this section.”

26.9. R211 TS Section 9: Auxiliary Electric Equipment and Distribution

- 26.9.1. Replace Section 9.4.16.7 with the following: "In B Cars, the circuit breaker panels shall be located adjacent to the open gangway on the No. 1 end."

26.10. R211 TS Section 10: Propulsion System

- 26.10.1. No change from the R211A Specification.

26.11. R211 TS Section 11: Trucks and Suspension System

- 26.11.1. No change from the R211A Specification.

26.12. R211 TS Section 12: Friction Brake and Air Supply Systems

- 26.12.1. No change from the R211A Specification.

26.13. R211 TS Section 13: Communications

- 26.13.1. Replace Section 13.4.1.5 with the following: "The sound pressure level throughout the passenger compartment and open gangway, at a height of 64 inches (1.63 m) shall not vary by more than 3 dB for a pink noise signal over the octave band centered at 4 kHz."

26.14. R211 TS Section 14: Train Control System

- 26.14.1. No change from the R211A Specification.

26.15. R211 TS Section 15: Carbody Equipment and Interiors

Thermal Insulation Requirements

- 26.15.1. Replace Section 15.2.2.2 with the following: "Heat transfer through the carbody and open gangway, using only the floor heaters (or the radiant floor heating system, if used), shall not exceed 12 BTU/hour/°F (22.7 kJ/hour/°C) per foot (305 mm) of carbody length, under the environmental conditions specified in Appendix A (Fixed Facilities Description), with the car stationary."

Door General Requirements

- 26.15.2. Replace Section 15.4.1.6 with the following: "The upper portion of each cab storm door shall incorporate a fixed rectangular window as specified in Section 15.6.5."

Door Environmental Sealing Requirements

- 26.15.3. Replace Section 15.4.3.1 with the following: "The cab storm door panel(s) and doorways shall be adequately weather-stripped for service speeds up to 60 mi/h (97 km/h) with the worst case possible combination of climatic conditions as described in Appendix A (Fixed Facilities Description)."
- 26.15.4. Replace Section 15.4.3.3 with the following: "Cab storm doors shall be equipped with an approved weather seal, which shall be applied to edges of the doors as required to meet environmental sealing."
- 26.15.5. Replace Section 15.4.3.8 with the following: "Not used."

Bi-parting End Door Requirements

- 26.15.6. Replace Section 15.4.5 in its entirety with the following: "Not used."

Threshold Plate Requirements

- 26.15.7. Replace Section 15.4.7.8 with the following: “The side door threshold plate shall incorporate guides for the sliding doors. The door threshold plates shall extend sufficiently into the door pocket and align with the door pocket door guide.”

Cab Storm Door and Bi-parting End Door Window Requirements

- 26.15.8. Replace Section 15.6.5 with the following: “Cab Storm Door Window.”
- 26.15.9. Replace Section 15.6.5.1 with the following: “Windows shall be provided in the cab storm door. See Section 15.4.1.6).”
- 26.15.10. Replace Section 15.6.5.2 with the following: “The window shall be clear, vandal resistant, laminated safety glass, maximizing clear viewing between Units.”
- 26.15.11. Replace Section 15.6.5.3 with the following: “The top and bottom of the window shall align with the other end facing windows, and the window shall be as wide as practicable.”

Inter-car Barrier Functional Requirements

- 26.15.12. Replace Section 15.7.1.1 with the following: “An inter-car barrier system shall be provided on each side of the cab storm door to protect individuals while passing from Unit to Unit, independent of car speed and relative alignment.”
- 26.15.13. Replace Section 15.7.1.2 with the following: “An inter-car barrier system shall also be provided at each corner of the cab end of the carbody to warn, deter, and protect individuals from inadvertently walking off the boarding platform between Units. This system shall also discourage passengers from attempting to enter the car ends between Units directly from the platform. Between cars within a Unit, the gap between the open gangway and the platform edge shall be closed sufficiently to prevent individuals from falling into the gap between cars.”
- 26.15.14. Replace Section 15.7.1.3 with the following: “Inter-car barrier designs adjacent to the cab storm doors shall be stable and easy to grab while considering the effects of carbody motion.”
- 26.15.15. Replace Section 15.7.1.4 with the following: “Open areas between the Units shall be minimized by the inter-car barrier systems, while still allowing for access of the train crew to the wayside from between Units, via the cab storm doors.”
- 26.15.16. Replace Section 15.7.1.5 with the following: “The overall inter-car gap design shall minimize both the open area/gaps between Units and tripping hazards in the walkway between Unit cab storm doors.”
- 26.15.17. Replace Section 15.7.1.6 with the following: “The barrier systems shall be designed to permit coupled Units to negotiate all conditions of vertical and horizontal curvature, turnouts, and crossovers encountered in the NYCT system (see Appendix A (Fixed Facilities Description)).”
- 26.15.18. Replace Section 15.7.1.8 with the following: “Inter-car barriers on A Car No. 1 ends shall be easily separated (locks shall be provided to prevent un-authorized detachment) while the cars are standing on any track configuration from tangent to the minimum radius curve (see Appendix A (Fixed Facilities Description)).”
- 26.15.19. Replace Section 15.7.1.10 with the following: “Not used.”
- 26.15.20. Replace Section 15.7.2.2 with the following: “Not used.”

Step Requirements

- 26.15.21. Replace Section 15.8.2.1 with the following: “Stainless steel, two-step climbing steps shall be provided at the A Car No. 1 ends.”

Grab Handle Requirements

- 26.15.22. Replace Section 15.8.3.2 with the following: “Stainless steel grab handles shall be fastened to the outer face of the car at the A Car No. 1 ends to facilitate access from the roadbed using the steps defined in Section 15.8.2.”

Decal Requirements

- 26.15.23. Replace Section 15.14.1.1 with the following: “The location, layout, size, text, color and application of graphics shall be as shown in the renderings in Appendix E-1 and approved by NYCT. Changes necessary to accommodate the open gangway shall be proposed for NYCT approval.

Additional Open Gangway Requirements

- 26.15.24. Replace the Section 15.16 title with “Open Gangway Requirements” and delete the existing text and deliverables table in Section 15.16.

Open Gangway General Requirements

- 26.15.25. Add section 15.16.1 containing “Open Gangway General” requirements.
- 26.15.26. Add Section 15.16.1.1: “Inter-car open gangways shall be applied to all car ends except the cab ends of the A1 and A2 cars to protect passengers in the area between cars under all operating and environmental conditions specified in Appendix A (Fixed Facilities Description).
- 26.15.27. Add Section 15.16.1.2: “For evaluation purposes, each Unit within the R211T shall be equipped with a different design of open gangway. Design 1 shall have a smooth, vandal resistant, interior surface. Design 2 shall be optimized for through passageway. Both open gangway designs shall be submitted to NYCT for approval. [CDRL]”
- 26.15.28. Add Section 15.16.1.3: “The open gangway passage shall be as wide and high as practical, presenting a smooth car inter-car exterior profile, and maximizing passenger throughput.”
- 26.15.29. Add Section 15.16.1.4: “The open gangway shall allow for safe unrestricted relative movement between cars under any track alignment found on the B Division and with any track condition permissible under the standards defined in Appendix C-5 (Track Standards and Reference Manual MW-1). The Contractor shall be responsible for collecting and analysing data related to existing conditions to allow validation of the design. See also Section 1.5.1.”
- 26.15.30. Add Section 15.16.1.5: “The open gangway shall not be damaged nor interfere with the carbody structure under any operational movements.”
- 26.15.31. Add Section 15.16.1.6: “All open gangway components or interfaces applied to the No. 2 ends of the A (cab) cars and the No. 1 and No. 2 ends of B (non-cab) cars shall be identical to allow any car to couple with any other car equipped with an open gangway of the same design.”
- 26.15.32. Add Section 15.16.1.7: “Neither the interior nor the exterior of the open gangway (top) shall retain water.
- 26.15.33. Add Section 15.16.1.8: “Special attention shall be paid to ensure that the design, construction and installation of the open gangways shall allow the completed cars to meet the following requirements of this Specification:
- a) Heating and cooling requirements specified in Section 7, Heating, Ventilation and Air Conditioning.
 - b) Watertightness requirements of Section 24.9.2.”

- 26.15.34. Add Section 15.16.1.9: "Exterior open gangway bellows and sealing elements shall meet the elastomer requirements of Section 19.6."
- 26.15.35. Add Section 15.16.1.10: "Interior and exterior safety and operational signage in the open gangway area shall be proposed for NYCT review and approval. The signage shall be based on industry standards and the requirements of Section 15.14."

Open Gangway Strength and Support Requirements

- 26.15.36. Add Section 15.16.2 containing "Open Gangway Strength and Support" requirements.
- 26.15.37. Add Section 15.16.2.1: "The open gangway shall withstand the loads induced by car relative movement and aerodynamic effects encountered in service up to the maximum operating speed without permanent deformation or premature fatigue failure."
- 26.15.38. Add Section 15.16.2.2: "Open gangway carbody attachment design shall meet the requirements of Section 3.2.14."
- 26.15.39. Add Section 15.16.2.3: "Exterior open gangway bellows shall be capable of withstanding the forces from NYCT's car washing apparatus (water pressure, bristle force) and no portion of the open gangway exterior shall be capable of being entrapped by the car wash brushes."
- 26.15.40. Add Section 15.16.2.4: "The stiffness of elements used on the floor and the passage sides of the open gangway shall provide support to passengers standing in the open gangway. The Contractor shall demonstrate through the use of analysis and test that the level of passenger support is sufficient."
- 26.15.41. Add Section 15.16.2.5: "Vertical support of the open gangway floor or bellows (if required) shall be provided by the link bar or other approved method. See Section 4, Coupler Systems."
- 26.15.42. Add Section 15.16.2.6: "Portions of the open gangway remaining attached to the cars shall be supported when cars are uncoupled such that the open gangway is not damaged."

Open Gangway Smoke, Flame, and Toxicity Requirements

- 26.15.43. Add Section 15.16.3 containing "Open Gangway Smoke, Flame, and Toxicity" requirements.
- 26.15.44. Add Section 15.16.3.1: "All materials used in the construction of the open gangways shall comply with the flammability, smoke emissions and toxicity requirements of Section 19.1.10."
- 26.15.45. Add Section 15.16.3.2: "Fire resistance of the open gangway shall be determined by analysis or representative testing in accordance with NFPA 130 Sections 8.4.1.15 and 8.5.2, unless otherwise approved. Performance criteria for the fire performance of the open gangway design shall be in accordance with NFPA 130 Sections 8.5.1.3.2 (1) and 8.5.1.3.3. The design shall be confirmed to meet the fire endurance rating requirements prior to the Contractor's procurement of production material. [CDRL]"

Open Gangway Interior Lining and Fittings Requirements

- 26.15.46. Add Section 15.16.4 containing "Open Gangway Interior Lining and Fittings" requirements.
- 26.15.47. Add Section 15.16.4.1: "The interior surface of the Design 1 open gangway shall be covered from ceiling to floor with interior side wall lining panels and ceiling panels in accordance with the applicable requirements of Section 15.9. Alternate designs may be proposed for NYCT review and approval"

- 26.15.48. Add Section 15.16.4.2: "The finish of the interior surfaces of the open gangway shall be coordinated with the car interior linings to provide a similar appearance. Open gangway interior finishing shall be subject to review and approval by NYCT."
- 26.15.49. Add Section 15.16.4.3: "The Design 1 open gangway interior lining shall exhibit minimal deflection and gaps under worst case car movements."
- 26.15.50. Add Section 15.16.4.4: "The open gangway interior lining shall avoid passenger obstructing protrusions, eliminate passenger pinch points, and minimize dirt and debris collection points."
- 26.15.51. Add Section 15.16.4.6: "Grab rails shall be fitted to the inside of the open gangway as required for standing passenger comfort and safety. See Section 15.11.1 and 15.11.3 for grab rail requirements."
- 26.15.52. Add Section 15.16.4.7: "The open gangway lighting shall meet the performance requirements of Section 8, Lighting Systems."

Open Gangway Floor Requirements

- 26.15.53. Add Section 15.16.5 containing "Open Gangway Floor" requirements.
- 26.15.54. Add Section 15.16.5.1: "Open gangway floor plates must allow standing passengers to ride safely in the gangway area while the car is in motion."
- 26.15.55. Add Section 15.16.5.2: "The open gangway floor surface shall meet the surface friction requirements of Section 15.3.1.1 without the use of adhesive backed anti-skid tapes."
- 26.15.56. Add Section 15.16.5.3: "The interface between the car floor and open gangway floor shall not create steps which produce a tripping hazard or violate ADA requirements under any operational conditions."
- 26.15.57. Add Section 15.16.5.4: "The open gangway floor shall not deflect vertically more than 0.38 inch (10 mm) or exceed 125% of the yield strength in any component under a uniformly distributed AW3 standing passenger floor pressure load. Floor strength calculations shall be submitted to NYCT for review and approval. [CDRL]"
- 26.15.58. Add Section 15.16.5.5: "Provisions shall be incorporated in the open gangway flooring to protect against lifting of the floor plates in the event of a collision with deflection minimized to reduce the possibility of foot injury to standing passengers."
- 26.15.59. Add Section 15.16.5.6: "Wear pads, easily replaceable with commercially available tools, shall be incorporated to prevent abrasion wear due to movement between open gangway floor sheets."

Open Gangway Barrier and Safety Appliance Requirements

- 26.15.60. Add Section 15.16.6 containing "Open Gangway Barrier and Safety Appliance" requirements.
- 26.15.61. Add Section 15.16.6.2: "The open gangway design shall incorporate a car isolation barrier at each end of the car that can be deployed to prevent passenger movement between cars and through the open gangway. The Contractor shall propose a lockable, vandal resistant, isolation barrier design and function for NYCT approval. The barrier itself shall comply with the requirements of Section 19.1.10." [CDRL]
- 26.15.62. Add Section 15.16.6.3: "Deployment of the barrier shall be accomplished manually by NYCT personnel without the use of any tools, and the barrier shall remain deployed until released using a NYCT standard car key."
- 26.15.63. Add Section 15.16.6.4: "The barrier shall be stored within a locked enclosure, openable by a NYCT Standard Car Key, when not in use."
- 26.15.64. Add Section 15.16.6.5: "The Contractor shall demonstrate the operation of the inter-car barrier through the use of a mock-up. Reference Section 20.6.1."

Open Gangway Maintenance Requirements

- 26.15.65. Add Section 15.16.7 containing “Open Gangway Maintenance” requirements.
- 26.15.66. Add Section 15.16.7.1: “Open gangway design and construction shall be vandal and graffiti resistant and easily cleaned by materials listed in Appendix C-3 (NYCT Cleaners and Related Material Qualified for Car Equipment Use), unless otherwise approved by NYCT.”
- 26.15.67. Add Section 15.16.7.2: “The open gangway connection to the carbody structure shall be accessible to maintenance personnel to permit removal and installation of the open gangway assembly.”
- 26.15.68. Add Section 15.16.7.3: “The open gangway assembly as a whole shall have a minimum service life equal to two SMS cycles (14 years). Maintenance of wearing parts shall be kept to a minimum, and shall not be required between SMS cycles. No lubrication shall be required.”

Open Gangway Deliverable Requirements

- 26.15.69. Renumber Section 15.16 as 15.17.
- 26.15.70. Add the following entries to the table in Section 15.17:

<u>CDRL</u>	<u>Ref</u>	<u>Deliverable</u>	<u>Timing</u>
15-9	26.15.27	Open gangway designs	PDR
15-11	26.15.45	Open gangway fire resistance	IPDR
15-13	26.15.57	Open gangway floor deflection calculation	IPDR
15-12	26.15.61	Barrier design and functional description	PDR

26.16. R211 TS Section 16: Trainline and Car Control Architecture

- 26.16.1. No change from the R211A Specification.

26.17. R211 TS Section 17: Monitoring and Diagnostics

- 26.17.1. No change from the R211A Specification.

26.18. R211 TS Section 18: Software Systems

- 26.18.1. No change from the R211A Specification.

26.19. R211 TS Section 19: Materials, Processes, and Workmanship

- 26.19.1. Replace Section 19.6.1.6 with the following: “The following elastomeric parts shall be of neoprene unless otherwise specified or approved:

- a) Glazing Rubber.
- b) Door Seals.
- c) Door Nosing.
- d) Open Gangway Seals.
- e) Other parts exposed to the outdoor ambient environment, except where otherwise specified.

26.19.2. Replace Section 19.6.6.1 with the following: "Gaskets and seals used around all door mating edges, door, and window seals, open gangway seals, and glazing strips shall be of neoprene material or NYCT approved equal material. "

26.20. R211 TS Section 20: Project Management

26.20.1. Add R211T requirements to Attachment 20-1:

Spec Ref	Content
26	R211T - OPEN GANGWAY TEST TRAIN
	<ul style="list-style-type: none"> • Arrangement and details of open gangway Designs 1 and 2 • Arrangement and details of inter-car barrier to close the open gangway for car isolation • Methods and procedures for car separation with open gangway

26.20.2. Section 20.6.1.6, add the following to the end: “i) Open Gangway.”

26.20.3. Replace Section 20.6.1.7 with the following: “As an alternate to providing individual mock-ups, the Contractor may combine the Train Operator's cab, A Car front end, passenger area, side doorway area, open gangway, and between-Unit-barriers into one mock-up.”

26.20.4. Move existing section title “Mock-up Alternate Full-Scale 3D Digital Demonstration” and renumber existing Sections 20.6.1.38 and 20.6.1.39 as 20.6.1.40 and 20.6.1.41.

26.20.5. Add new section title after Section 20.6.1.37 as follows: “Open Gangway”

26.20.6. Add Section 20.6.1.38: “A full-scale mock-up of a complete inter-car open gangway and related equipment shall be constructed for both designs of open gangway. The materials used for the open gangway shall be production material and the mock-up shall be fully functional.”

26.20.7. Add Section 20.6.1.39: “The mock-up shall be used to evaluate aesthetics, ergonomics, space utilization, accessibility, pinch points, and cleanability. The Contractor shall also demonstrate the level of passenger structural support in the open gangway, and operation of the car isolation barrier to close the open gangway.”

26.21. R211 TS Section 21: Reliability, Maintainability and Safety Requirements

26.21.1. Add to Section 21.3.3.2 the following: “v) Open Gangway Test Train related hazards.”

26.22. R211 TS Section 22: System Support

26.22.1. Replace Section 22.5.5.18 with the following:

“The T/O training modules shall contain diagnostics and isolation procedures to teach T/Os how to facilitate multiple malfunction scenarios, including the following:

- a) Brake Pipe Rupture.
- b) Coupler Pipe Rupture.
- c) Brake In Emergency (BIE) Carborne Tripping Device-Train Recharges/Train Does Not Recharge.
- d) Stuck Brakes-Service Brakes, Parking Brakes.
- e) Recovery of Dead Train.
- f) Passenger Emergency Handle Unit – Pulled in Station-Pulled Between Stations.
- g) Emergency Brake Handle-Train Does Not Charge.
- h) Door Obstruction, Cutting Out Doors.

- i) Defective Door, No Obstruction found/Obstruction Found.
- j) Isolating an Open Gangway Car – Application and Restoration of Open Gangway Barrier (including establishment of locked indication).
- k) Programming of Train Operator’s Display.
- l) Procedure for Installation of Coupler Adapter.
- m) Brake Release Bypass Operation.
- n) Main Reservoir Rupture.
- o) Side Door Bypass.
- p) Special Charge Feature.
- q) Train Operators Display (TOD) for Troubleshooting.”

26.22.2. Add new Section 22.7.2.13: “The Contractor shall provide tools and fixtures to support the maintenance and replacement of inter-car open gangway assemblies.”

26.23. R211 TS Section 23: Quality Assurance Requirements

26.23.1. Add to Section 23.7.1.11 FAI items: “o) Open Gangway;”

26.23.2. Renumber 23.7.1.11 o) as 23.7.1.11 p).

26.24. R211 TS Section 24: Test Program

26.24.1. Replace Table 24-2 in Section 24.5.1.1 with the following:

Table 24-2: System Qualification Tests

Test	Frequency	TS Reference
Door System	One Set of Each Type (One System)	6.6.1.3
HVAC System and Controls	One System	7.7
Propulsion System	One Car Set	10.6.10
Friction Brake System	One Car Set	12.6.7, 12.6.9, 12.6.10 to 12.6.12
Communications System	One Train Set	13.14
Network System	One Train Set	16.6.2
EMC Lab Tests	One Car Set	24.5.2
Open Gangway Endurance Testing	One of each Open Gangway design	24.5.3

- 26.24.2. Insert new section 24.5.3. **“Open Gangway Endurance Testing**
- 24.5.3.1 The Contractor shall perform accelerated life / endurance testing of the Open Gangway assembly.
 - 24.5.3.2 The test setup shall be representative of a complete connection between cars, including all interfaces between the Open Gangway and carbody, and car equipment, including any intercar connections that could be affected by Open Gangway movements.
 - 24.5.3.3 The test shall be performed using intercar movement data which is representative of the conditions that will be experienced when navigating the NYCT B Division, including yards and shops.
 - 24.5.3.4 Initial testing shall confirm the Open Gangway assembly can navigate the worst-case track geometry features of the NYCT B Division, including yards and shops, without incurring damage, introducing unsafe conditions, or causing undue narrowing of the intercar passageway.
 - 24.5.3.5 Accelerated life testing shall be performed to demonstrate the endurance of the Open Gangway assembly. This testing shall be representative of daily operating movements of a train negotiating the NYCT B Division and shall be continued until destruction, to establish a predicted life for the Open Gangway.
 - 24.5.3.6 The test protocol shall be based on data collected from the NYCT system, using the most representative daily route, or routes, and subject to NYCT approval.
 - 24.5.3.7 Passenger loading on the gangway floor shall be represented by weights applied to the floor.
 - 24.5.3.8 The effects of ultra-violet light on exposed rubber elements shall be simulated throughout the test, to simulate aging due to such exposure.
 - 24.5.3.9 Any routine maintenance recommended by the open gangway supplier shall be performed at the appropriate intervals during the test.
 - 24.5.3.10 The initial endurance test period shall be representative of at least 16 years in service, during which time there shall be no failures which would require replacement of the gangway assembly.
 - 24.5.3.11 Upon completion of the initial endurance testing period, the test shall continue for an additional 9 years simulated service, or until gangway life ending failure, whichever occurs first, to verify design margin and to identify potential failure modes.”
- 26.24.3. Add Section 24.6.2.4: “The watertightness test shall be performed on each fully installed open gangway.”
- 26.24.4. Replace Section 24.6.3.1 with the following: “The first A and B Car, including the open gangway, shall undergo an air leakage smoke bomb test with the interior positively pressurized.”
- 26.24.5. Replace Section 24.6.5.1 with the following: “A car climate room test shall be performed on an A Car agreed upon between NYCT and the Contractor. Provided that it conforms to production cars in configurations relevant to the test, the mock-up car may be used for the climate room test. Measurement of air volumes shall be performed on the first B Car, unless it can be adequately demonstrated on the A Car. The climate room test shall demonstrate the HVAC system's ability to comply with the temperature control and operational performance requirements of Section 7.2. Test cars shall include relevant portions of the inter-car open gangway. A waiver may be requested from inter-car open gangway testing, subject to NYCT review and approval, if the Contractor can demonstrate compliance through analysis.”

- 26.24.6. Replace Section 24.6.11.1 with the following: "The first completed car of each type shall be coupled to the appropriate adjacent cars and checked for proper truck, drawbar, coupler, open gangway, and cable and hose clearance under the worst case geometric requirements for these elements."
- 26.24.7. Replace Section 24.6.11.2 with the following: "Car ends shall be checked for proper intercar and open gangway clearances."
- 26.24.8. Replace Section 24.6.11.3 with the following: "The couplers and drawbars shall be checked for proper vertical and horizontal swing, and for clearance from the truck, open gangway, undercar components, anti-climber, and ground (top of rail)."
- 26.24.9. Replace Section 24.6.11.6 with the following: "The inter-car barriers between Units and both inter-car open gangway designs shall be checked for proper function at entry to and exit from curves, and in reverse curves. All open gangway interior, exterior, and underfloor surfaces and linkages shall be checked for smoothness of operation and clearance."
- 26.24.10. Replace Section 24.7.4.8 with the following: "All inter-Unit barriers and both open gangway designs shall be checked for operation and clearances. The open gangway floor plates and sidewall shall be monitored for gaps openings between open gangway components, plate lifting as a result of body roll, and noises indicating excessive movements."
- 26.24.11. Replace Section 24.9.2.1 with the following: "For each car within a Unit, all areas of the car sides, ends, and roof, including doors and windows, open gangway, and undercar, shall be subject to a complete watertightness test."