SECTION 13  WAYSIDE SIGNALING AND HIGHWAY-RAILROAD GRADE CROSSING WARNING SYSTEMS

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SECTION 13 WAYSIDE SIGNALING AND HIGHWAY-RAILROAD GRADE CROSSING WARNING SYSTEMS

13-1 DESCRIPTION OF WORK

The work under this Section consists of designing, providing, manufacturing, delivering, installing, modifying, inspecting, testing and making operational the block signaling and highway-railroad crossing warning systems for the Sacramento Regional Transit Project. The work includes, but is not limited to, the following:

A. Providing and installing, relocating, or modifying signals, track circuits, switch-and-lock movements, route selectors, relays, timers, local control panels, control equipment, vital and non-vital microprocessors, event recorders, wayside cabling, instrument houses, equipment cases and subsystems, power utility interconnections, express signaling cable system, conduit and pull box system, and associated materials on the new and modified ABS system territories.

B. Installing Owner-furnished wayside TWC equipment (VECOM COMPACT-CT System or Equivalent System) at new signal system locations. Modifying wayside TWC equipment at existing Signal System locations.

C. Re-configuring and adjusting 100 HZ double rail track circuits on the existing ABS system territory. Performing an analysis of the 100 HZ power distribution system.

D. Providing and installing or modifying line circuits and equipment tagging.

E. Providing and installing or modifying circuits and equipment necessary to interface with the existing ABS system.

F. Providing and installing or modifying wayside signs for speed indications, begin block, end block, approach begin block, RT milepole, street name, emergency notification, and resume speed reflectors.

G. Providing and installing highway-railroad grade crossing warning equipment to provide crossing warning for light rail operations at highway crossings delineated in the Plans. The highway-railroad grade crossing warning systems includes flashing lights, crossing indicators, pedestrian-activated warning signs, queue-activated warning signs, cantilevers, crossing gates, bells, signs, track circuits, wayside cabling, conduits, pull boxes, instrument houses, equipment cases, crossing push button boxes, junction boxes, relays, timers, vital and non-vital microprocessors, event recorders/analyzers, TWC equipment, nearside crossing controls, push buttons, interface connections to traffic signals, interface...
connections to UPRR, associated materials, equipment appurtenances, and subsystems.

H. Providing and installing express and local cabling and the associated junction boxes, risers, conduits, pull boxes and fittings as shown on the Plans and as otherwise required for complete and functional wayside signaling and highway-rail crossing warning systems.

I. Removal and salvage of existing block signaling and highway-railroad grade crossing warning equipment not required under the final system configuration.

J. Testing of the block signaling and highway-railroad grade crossing warning systems.

K. Performing operations, maintenance, and engineering training for all block signaling and highway-railroad grade crossing warning systems provided and installed under this Contract.

L. Providing, installing, and testing Signal System functions required for future use by RT. Examples of future functions identified in the Technical Specification and on the Plans are: TWC System - express and local train service indications; and interlocking control system - remote routing controls.

M. Providing and installing or modifying circuits and equipment as necessary to provide interim UPRR railroad operations through the existing UPRR railroad highway-railroad grade crossing during all stages of construction.

N. Providing test equipment, tools, and software required for maintenance, testing, and implementing application logic changes for the Signal System equipment supplied under this Contract.

O. Making interconnections to the fiber optic cabling system for serial interconnection between adjacent microprocessor locations and for data transmission to remote locations as shown in the Plans.

P. Providing and installing equipment as necessary to provide bridge lighting and bridge warning systems.

13-2 GENERAL REQUIREMENTS

13-2.01 Definitions and Abbreviations

The following definitions and abbreviations are in addition to those indicated in the State Standard Specifications and AREMA C&S Manual:

A. Abbreviations
### Definitions

1. **Application-Dependent Logic** - Application-Dependent Logic is defined as the set of logical instructions necessary to describe the intended operation of a system to equipment used to implement the system's functions, expressed in a form meaningful to and dependent upon that equipment. Application-Dependent Logic includes those functions that are not inherent in the equipment used for implementing system functions, but rather those that vary from application to application. It also includes descriptions and/or values of functions and parameters required by the specific equipment used for implementing the system functions.

2. **Checked Redundancy** - Checked Redundancy is a Safety Assurance Concept in which two or more processors, executing identical software in independent, identical hardware environments, compare results, requiring two or more to be identical before allowing a permissive action or condition to be initiated or maintained. Safety assurance under the Checked Redundancy concept is dependent upon, among other factors, software correctness and completeness, software architecture and algorithmic logic, the extent to which
hardware failures are detected by comparison of results from two or more systems, the degree to which the systems are independent, and the vitality of the comparison mechanism.

3. Vital (CLASS I) Hardware - Vital (CLASS I) Hardware is hardware, the failure of which can adversely affect system safety. Further, if the safe implementation of a Vital Function is dependent, in whole or in part, on the absence of certain failures or sets of failures in a hardware circuit or device, then that hardware is also defined as Vital (CLASS I) Hardware. Vital (CLASS I) Hardware is hardware whose failure modes and characteristics can be accurately identified, predicted and exhaustively tested. The assurance of the safe implementation of Vital Functions by hardware designated as Vital (CLASS I) Hardware can be determined using FMEA methods.

4. CLASS II Hardware (Non-Vital Hardware used to Implement Vital Functions) - Hardware whose failure modes may adversely affect the safe implementation of a Vital Function but not designed as Vital (CLASS I) Hardware is defined for purposes of this Contract as CLASS II hardware, i.e., Non-Vital Hardware used to implement Vital Functions. Failure modes in CLASS II hardware are revealed or otherwise accounted for by means other than Vital (CLASS I) Hardware design techniques. These means may include software-driven self-checking and/or comparison of independent hardware circuits, and numerical techniques.

5. CLASS III Hardware (Hardware used to Implement only Non-vital Functions) - CLASS III hardware is defined as hardware whose operation under normal or failure conditions has no effect on the safe implementation of any Vital Function.

6. Closed-loop Principle - System Design adhering to the Closed-loop Principle must require that all conditions necessary for the existence of a permissive state or action be verified with an acceptable level of safety present before the permissive state or action can be initiated. Likewise, the requisite conditions must be verified, with an acceptable level of safety, to be continuously present for the permissive state or action to be maintained. This is in contrast to allowing a permissive state or action to be initiated or maintained in the absence of detected failures.

7. Diversity and Self-Checking - Diversity and Self-Checking are Safety Assurance Concepts in which critical operations are performed in diverse ways, using diverse software operations and/or diverse hardware channels, and critical system hardware is tested with Self-Checking routines. Permissive outputs are allowed only if the results of the diverse logical operations correspond and the self-checks reveal no failures. Safety assurance in systems using the concepts of Diversity and Self-Checking is dependent upon, among other factors, the completeness of the anticipated set of hardware failures that the diverse operations and self-checks are intended to reveal, and the effectiveness of the diverse operations and tests in revealing them. In addition, Diversity and Self-Checking are dependent on software correctness and completeness, the software architecture and algorithmic logic, and the vitality of the diverse operations comparison mechanism.
8. Engineer - Sacramento Regional Transit District (RT) Assistant General Manager of Engineering and Construction, or authorized representative.

9. Fail-safety - Fail-safety in the context of these Technical Specifications is defined as the property of the system that assures systems safety (i.e., that assures the safe implementation of all Vital Functions), under all conditions, including the occurrence of hardware failures and the execution of Software Errors. Safe implementation of Vital Functions includes the requirement that the system default to a state known to be safe upon the occurrence of a hardware failure or the execution of a software error.

10. Furnish or Provide: The use of the terms “furnish” or “provide” means to supply referenced equipment or services.

11. MTBHE (Mean Time Between Hazardous Events)- A hazardous event is defined as the occurrence of an unsafe condition that exposes passengers, personnel or equipment to injury or damage. MTBHE is the mean time between such events. MTBHE is used as a measure of the safety assurance of a system. It is calculated using the probability that an event will cause an unsafe condition and the mean time between all such events. These events include the effects of Software Errors as well as hardware failures.

12. Non-vital Software - Non-vital Software is defined as software whose normal operation has no effect on the implementation of any Vital Function. Since the execution of errors in Non-vital Software operating in the same processor as Vital Software could affect the safe implementation of a Vital Function, Non-vital Software executing in the same processor as Vital Software must meet the same design, implementation, and analysis requirements as Vital Software.

13. Numerical Assurance - Numerical Assurance is a Safety Assurance Concept in which permissive decisions are represented by large unique numerical values, constructed by combining numerical values representing each of the critical constituents of a permissive decision. The presence of restrictive system states and the allowance of permissive actions are verified numerically. Safety assurance in systems using the Numerical Assurance concept is dependent upon, among other factors, the accuracy and uniqueness of the numerical data structures and the vitality of the mechanism that performs the numerical verification.

14. N-Version Programming - N-Version Programming is a Safety Assurance Concept in which two or more software processes each execute unique, independently-written software programs in the same or in multiple hardware environments. Each of the system’s permissive results are compared and their correspondence is assumed to provide safety assurance. Safety assurance under the N-Version Programming concept is dependent upon, among other factors, the independence of the various systems' software, the depth of the result comparison, system hardware independence, and the vitality of the mechanism comparing the diverse operations.

15. Owner - Sacramento Regional Transit District (RT).

16. Provide or Furnish: The use of the terms “provide” or “furnish” means to supply referenced equipment or services.

17. Safety Assurance Concept - The Safety Assurance Concept is the concept under which a processor-based vital system is designed such that Fail-safety
is assured. There are a number of concepts under which vital systems are
designed and implemented. Some Safety Assurance Concepts include:
Checked Redundancy, N-Version Programming, Diversity and Self-Checking,
and Numerical Assurance.

18. Signal System - RT wayside block signaling and highway-railroad/pedestrian
grade crossing warning systems and/or UPRR highway-railroad/pedestrian
grade crossing warning system.

19. Software Errors - Software Errors include errors in the high-level structural
software logic, errors in the logic of algorithms, coding errors, errors in
database and application data structures, and errors of omission. "Error-free
software" is defined for the purpose of these Technical Specifications as
being free of Software Errors that could adversely affect the safe
implementation of a Vital Function. For the purpose of these Technical
Specifications, it is assumed that software does not and cannot fail. Software
may be erroneous in the logical organization of its architecture or algorithms,
or in its coding, or required logical functions may be omitted, but software
does not fail in the sense that it worked correctly at some point but is no
longer correct due to a change. A failure of the processor, its peripherals, the
memory devices in which the software is stored, or any physical component
that impairs or inhibits correct execution of the software, is considered a
hardware failure.

20. System Design and Implementation – System Design and Implementation of
the hardware and software components, for the purpose of safely
implementing the Vital Functions, include the following: (a) the delineation
between functional implementation in hardware and in software, (b) system
hardware design that includes processor selection, hardware circuit design,
delineation among CLASS I, II, and III Hardware, circuit component decisions
relating to safety assurance and all logical decisions involving hardware, (c)
software design that includes language selection, high-level software
architecture design, logical algorithm design, functional routine design,
delineation between Vital and Non-vital Software, implementation of
primordial logic and all logical decisions involving software, (d) hardware
implementation that includes the partitioning of the hardware circuitry into
Printed Circuit Boards (PCB)s or their equivalent, printed circuit layout, non-
safety related component specification and selection, and overall system
packaging, and (e) software implementation that includes the coding of the
software structures, algorithms and routines in the selected language and the
compilation of the coded software into machine readable code.

21. TWC System - The system that provides bi-directional digital data
communications between the train and wayside signal system.

22. Vital Function - A Vital Function is a system function, the correct performance
of which affects the safety of passengers, personnel and/or equipment. In
addition, a Vital Function is a system function, the incorrect performance of
which allows a hazardous situation to exist that in turn may, immediately or
subsequently, adversely affect the safety of passengers, personnel and/or
equipment. The incorrect performance of a Vital Function is defined as
allowing a more permissive system state to exist, or a more permissive action
to be taken, than overall system conditions permit. Also, a Vital Function is one that is determined to be implemented fail-safely.

23. Vital Software - Vital Software is defined as that software required for the implementation of a Vital Function. In addition, Vital Software is any software whose execution could affect the implementation of a Vital Function.

13-2.02 Regulations, Codes, and Standards

All work must conform to or exceed the following regulations, codes, and standards:

A. National

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREMA</td>
<td>American Railway Engineering and Maintenance of Way Association</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>EIA</td>
<td>Electronic Industries Association</td>
</tr>
<tr>
<td>ETL</td>
<td>Electrical Testing Laboratories</td>
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<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
</tr>
<tr>
<td>NEC</td>
<td>National Electrical Code</td>
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<tr>
<td>NEMA</td>
<td>National Electrical Manufacturers Association</td>
</tr>
<tr>
<td>NETA</td>
<td>National Electrical Testing Association</td>
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<tr>
<td>NESC</td>
<td>National Electrical Safety Code</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriter's Laboratories, Inc.</td>
</tr>
</tbody>
</table>

The following parts of the Code of Federal Regulations, Title 49, Transportation apply to all work including design, installation, and testing:

- Part 212: State Safety Participation Regulations
- Part 219: Control of Alcohol and Drug Use
- Part 228: Hours of Service of Railroad Employees
- Part 234: Grade Crossing Signal System Safety
- Part 235: Instructions Governing Application for Approval of a Discontinuance or Material Modification of a Signal System or Relief from the Requirements of Part 236

B. State

The following General Orders of the California Public Utilities Commission apply:
1. G.O.26-D Clearances of Railroads and Street Railroads as to Side and Overhead Structures, Parallel Tracks, and Crossings.
2. G.O.52 Construction and Operating Power and Communication Lines for the prevention or Mitigation of Inductive Interference.
5. G.O.95 Overhead Electric Line Construction.
8. California MUTCD
10. APTA Manual of Standards and Recommended Practices for Rail Transit Systems

C. State of California Title 8
   1. Electrical Safety Orders
   2. High Voltage Electrical Safety Orders
   3. Industrial Safety Orders

13-2.03 **Operating Environment**

All equipment, devices, and materials must be capable of being operated and maintained at the specified performance levels without impairment resulting from the impact of the environment throughout the range of worst values indicated below:

A. Temperature: Ambient outdoor temperature will range from 20 to 115° F.

B. Humidity: Relative humidity will range from 28 to 100 percent, including conditions of condensation.

C. Wind: Maximum wind velocity will be 55-mph continuous and 80-mph gusting.

D. Rainfall: Maximum rainfall in 24 hours will be 4 inches.

E. Seismic: Zone 4 as defined in the Uniform Building Code.

F. Lightning: Isokeraunic level will be 5 per year.
G. EMI: A portion of the Signal System will be installed in the vicinity of high voltage transmission lines. The environment will also include the 750 VDC traction power system, and the vehicle propulsion systems. Any of the above may result in electromagnetic or electrostatic interference.

13-2.04 Products

Materials and equipment provided under this Contract must be new and be standard products of manufacturers regularly engaged in the production of such materials and equipment for the applications as shown on the Plans and as specified in this Section, and must be the manufacturer's latest-approved design that complies with the requirements of the Contract.

Unless otherwise specifically provided in the Contract, reference to any equipment, material, article or patented process by trade name, make or catalog number must be regarded as establishing a standard of quality for the work, and must not be construed as limiting competition. Contractor may use any material, article or process that, in the judgment of RT, is equal to that named and is approved by RT for the purpose intended. The Contractor must provide at its own expense all information necessary or related thereto for evaluation as required by RT. RT will be the sole judge as to the comparative quality and suitability of proposed alternative equipment, articles or material and its decision thereof will be final and binding on the work hereunder.

RT's specification of a brand name, component or equipment in the Contract Documents does not relieve Contractor from its responsibility to produce the work in strict accordance with the performance warranty and contractual requirements. Contractor must notify RT in writing of any inappropriate brand name, component, or equipment that may be called for in the Technical Specifications or on the Plans and propose an appropriate substitute for consideration by RT.

A. Standards

1. Unless otherwise noted in the Contract Documents, all electrical equipment used for distribution of AC and DC power must conform to the provisions in Section 86-1.02 of the State Standard Specifications and applicable portions of the following:
   a. NESC (National Electrical Safety Code)
   b. OSHA (Occupational Safety and Health Administration).

2. The label of, or listing by, UL is acceptable as sufficient evidence that materials and equipment conform to the requirements of UL. A certification or published specification data statement by a manufacturer listed as a member of NEMA or ANSI, to the effect that materials and equipment conform to the specified NEMA or ANSI standards, is acceptable. In place of such stamps, label, or listing, Contractor may submit a certificate from a nationally-recognized testing agency satisfactory to the Engineer, certifying that the material or equipment has
been tested according to the methods of the specified agencies and conform to the requirements specified.

B. Utility Interface

Contractor is responsible for coordinating all Utility requirements with the local Utility and ensuring that all the requirements of the Utility are complied with in the manufacture, installation, and interconnection of the instrument houses and relay cases.

C. Equipment

1. Equipment Arrangement: Arrangements and locations of equipment, devices, and components must be as indicated on the Plans unless otherwise specified in this Section. Contractor must submit detailed arrangement and location drawings for the Engineer’s acceptance prior to any fabrication work. The arrangement must provide at least the minimum specified space and must result in optimum accessibility for maintenance. Equipment, devices, and components must be arranged to be conveniently accessible and easily visible. Grouping must be neat, modular, and logical, with related functions in close proximity. Devices must be plumb and square with the lines of the panel and mounted as recommended by the manufacturer. Contractor must take care to avoid wiring congestion.

2. Accessibility: All equipment and components must be readily accessible for inspection, maintenance, adjustment, and reading of data. All devices, including protective relays, from which data are to be read must be mounted on the front panels. Devices mounted on the front panels and elsewhere are limited to a height of 78 inches. The minimum height for panel-mounted devices is 18 inches from the instrument house, or relay case floor. All other devices must be readily accessible on the surface of the equipment or by opening a hinged door or panel without removing another device or equipment.

3. Equipment Integrity: Equipment as assembled for operation must have no openings that would allow the accidental entry of hand tools and the like.

4. Equipment Reparability: Equipment provided under this Contract must be field repairable to the maximum extent possible, to facilitate on–site maintenance and repair by RT, using its own facilities and personnel. Repair or replacement of equipment must be possible without returning the equipment to the manufacturer’s facilities, unless return is necessary for Warranty purposes.

5. Equipment Temperature Operational Range: All equipment specified or required to implement the Signal System requirements must be capable of rated performance through an operating temperature range of –40°C to +71°C unless otherwise authorized by the Engineer.

D. Finish
Unless otherwise indicated, all steel surfaces of the instrument house or relay case, must be painted in accordance with the requirements specified in this Section. As a minimum, Contractor must thoroughly clean and treat surfaces of all equipment with rust-inhibiting, phosphatizing coating prior to the application of an accepted powder coating paint process. The interior and exterior of the instrument house or relay case must be finished by Contractor as specified in this Technical Specification. The exterior of the new houses and cases must be coated by Contractor with an anti-graffiti coating.

13-2.05 Construction Staging

Contractor's attention is drawn to the fact that the Plans indicate the final Signal System configuration to be designed, supplied, installed, modified, and tested under this Contract. Contractor must submit, for RT's acceptance, a Construction Staging Plan(s) to expedite construction by Contractor and cutover to the existing RT block signaling, and UPRR highway-railroad grade crossing warning systems. RT will evaluate the Construction Staging Plan for reliability, recoverability from service disruptions, and protection of revenue operations. RT reserves the right to reject the Construction Staging Plan based solely upon RT's interpretation. Contractor's Construction Staging Plan must be based on the Contract Document requirements, Typical Circuits, and review of the Signaling Reference Drawings and existing RT as-built application logic from 47<sup>TH</sup> Avenue Station (S541IH) to Meadowview interlocking (235IH). The existing RT application logic is available for review at RT during the bid period. RT's acceptance of Contractor's Construction Staging Plan will be based on the requirements of these Technical Specifications for design, materials, submittals, testing, training, As-Built Plans, and all other requirements of the wayside block signaling and highway-railroad grade crossing warning systems.

Contractor's Construction Staging Plan(s) must be based on keeping the RT block signaling and RT and UPRR grade crossing warning systems fully operational, except during any Scheduled Interruption Periods identified in the Contract Documents.

The major Signal System construction stages that involve keeping the RT block signaling and RT and UPRR highway-railroad grade crossing warning systems fully operational are: (1) the interim and final cutover of the RT/UPRR shared highway-railroad grade crossing warning system, (2) interlocking/terminal cutover, (3) existing block Signal System modifications; and (4) re-adjustment of existing 100 Hz double rail track circuits.

Full compensation for all additional design, submittals, equipment, temporary equipment, installation, testing, training, and materials not shown on the Plans, or specified in the Contract Documents that are necessary to complete the installation of the various construction stages required to complete the Contract, are considered as included in the Contract lump sum price for Construction Staging, and no additional compensation will be allowed therefor.

A. Highway-Railroad Grade Crossing Warning Systems
Contractor must design, provide, manufacture, deliver, install, modify, and test the highway-railroad grade crossing warning system equipment necessary to support the interim and final cutover of the RT/UPRR shared highway-railroad grade crossing. Contractor must locate existing underground signal and communications cables to ensure that they are not disturbed until required by the accepted Construction Staging Plan.

Interim cutover of the highway-railroad grade crossing warning systems is required when the existing UPRR equipment must be replaced or removed for construction purposes. At each interim cutover stage of construction, Contractor must have all necessary new highway-railroad grade crossing warning system equipment in place to support that cutover.

Contractor may propose the use of temporary highway-railroad grade crossing control system signaling cases, if required, to support Contractor’s accepted schedule for interim cutover to the RT/UPRR shared highway-railroad grade crossing warning system. If accepted, any temporary cases and equipment must be removed during final cutover. Full compensation for temporary cases and equipment, if used, will be considered as included in the Contract lump sum price for construction staging, and no additional compensation will be allowed therefor.

B. Existing Signal System Modifications

Contractor must design, provide, manufacture, deliver, install, modify and reprogram existing equipment and test the block signaling system equipment required for the 47TH Avenue Station to Meadowview Station modifications specified in this Section and shown in the Plans. These designs must include all construction and testing stages necessary to operate Meadowview Station as a terminal and allow pre-revenue operations, dynamic testing, integrated testing and pre-revenue operations, etc. The final Signal System configuration must not include any interim/temporary designs.

13-2.06 Contract Circuit Plans

The Plans include typical microprocessor hardware, typical microprocessor application logic relay equivalents, and relay circuit schematics that apply to the primary systems to be provided by Contractor.

Prior to making modifications to existing signaling systems, Contractor must obtain copies of the most current as-built circuit plans and application logic from RT and UPRR. Where existing signaling may be affected by Contractor work, Contractor must verify the correctness of the information shown on As-Built Plans to assure that the proposed modifications are appropriate and that no unsafe condition will result from Contractor’s modifications.
The Plans included in the Contract Documents are not complete in all details. They must be used by Contractor as a guide in preparing its detail circuits, non-vital and vital application logic, equipment layouts and installation details and must be modified to meet the individual requirements of the equipment Contractor proposes to supply under this Contract. The Plans do not show all repeater relays or microprocessor requirements and other equipment that may be required. Contractor must determine the number and type of repeater relays and any other equipment necessary and must provide those relays and equipment. The Plans do not show the contact numbers, relay or instrument house terminal designations, or fuse and resistor sizes, and ratings. Examples of microprocessor requirements not shown in the Plans are as follows: all data bits necessary for serial communications between the vital and non-vital microprocessor; serial and parallel input and output assignments, chassis IDs/keying and jumper and switch settings; application logic required to prevent masking of the vital application logic by the non-vital application logic; circuit board part numbers/serial numbers; PROM/EPROM/EEPROM checksums; serial and parallel input/output charts, interface relays to the TWC System if the microprocessor and TWC System I/O are not compatible, interface relays to the existing VHLC at Meadowview interlocking (235IH) if the proposed microprocessor is not serially compatible, etc. Contractor must include all information necessary for proper maintenance and troubleshooting of the Signal System.

Contractor must show all of the above information on its detailed circuit plans, as well as show wire nomenclature, terminal designations, timer settings, and all other information required to produce complete and legible circuit plans, as required by these Technical Specifications and as shown in the Plans.

No circuit will be deemed to have met the requirements of these Technical Specifications for function and safety until it has been tested and verified in the field in accordance with Sub-section 13-8, “Commissioning.” Any circuit changes made or additional equipment required to meet the functional and safety requirements of these Technical Specifications is considered as a part of Contractor’s detail design responsibility and no additional compensation will be paid for such work.

Contractor must submit, for acceptance of the Engineer, the repeater relay assignment guidelines it proposes to follow. Contractor’s repeater relay assignment guidelines must conform to industry standards.

13-2.07 Removing and Salvaging Equipment

Contractor must remove and salvage existing Signaling System equipment in compliance with the provisions in Section 86-7, “Removing, Reinstalling or Salvaging Electrical Equipment,” of the State Standard Specifications, as specified in the Contract Document and as shown on the Plans:

A. Existing RT equipment for the wayside block signaling system must be removed and salvaged by Contractor as indicated on the Plans. Existing equipment must
be inventoried by Contractor, and any equipment not reused must be delivered by Contractor to RT. The Plans indicate existing equipment that can be reused.

B. Existing RT and UPRR equipment for the highway-railroad grade crossing warning system must be removed and salvaged by Contractor as indicated on the Plans. Existing equipment must be inventoried by Contractor, and any equipment not reused must be delivered by Contractor to RT. The Plans indicate existing equipment that can be reused.

Contractor must notify the Engineer of any equipment that is damaged prior to removing the equipment. Damaged equipment that is allowed to be reused must be repaired by Contractor.

13-2.08  **Signal System Safety Requirements**

The safety requirements for the Signal System are as specified in this Section and as shown on the Plans.

Contractor must comply with the safety, design, implementation and analysis requirements contained in these Technical Specifications in the construction of all Signal System hardware and software which either performs, or could affect the performance of, Vital Functions.

Passenger and train safety must be Contractor’s paramount design consideration. All control methods, circuitry, mechanical equipment, and operating procedures provided under this Contract for vital operation must conform to this requirement. Whenever an unsafe condition could develop from an equipment failure or a procedural error, fail-safe design techniques must be used to prevent the occurrence of the unsafe condition.

A. Fail-Safe Design

1. Fail-Safe Design Principle

   As used in these Technical Specifications, the fail-safe principle means that whenever an equipment failure, a human error or a failure to act, or an adverse environmental condition affects the specified operation of a system involved with the safety of life or property, that system must revert to a state known to be safe.

   The failure of a circuit or of equipment that results in an indication of a dangerous or restrictive condition, whether or not there is in fact actual danger, has met the fail-safe requirement of these Technical Specifications. Conversely, a failure that results in an indication of safe or of a less restrictive condition when a dangerous condition exists has not met the fail-safe requirements.
Self-detecting failures that could create unsafe conditions must cause trains to stop or follow a specified sequence of operation known to be safe. Failures that are not self-detecting must not cause unsafe conditions, even in combination with subsequent failures of any type.

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

2. Failure Modes

The Signal System must be based on principles that permit the attainment of fail-safe operation in all known or discovered failure modes.

The term Vital, when used in these Technical Specifications, means any function, application, or technique whose purpose it is to maintain the safety of life and property.

The failure of any of the Vital Signal System components must not in any way affect the safety of train operation. System Design must include means of protecting the equipment from malfunction or damage due to voltage transients on or induced in the wiring. The equipment must also be protected from damage from accidental over voltage or voltage reversal. The equipment must also be immune to the existing or possible extraneous frequencies or energy that may be present:

a. Closed Loops - Fail-safe circuits must employ the closed loop principle and must protect against open circuits, shorted circuits, grounded circuits, damaged or dirty contacts, a relay failing to respond when energized, a loss of power supply energy or any combination of these.

b. Vital Relays - Relays used in Vital circuits must be "Vital" as set forth on the Plans and as specified in this Section.

c. Vital Line Circuits - All line circuits that control Vital Functions must be two-wire, double-break circuits. All circuits of a Vital nature must be energized from ungrounded power supplies.

d. Grounds - Any component or wire becoming grounded or any combination of such grounds must not cause unsafe conditions.

e. Spurious Oscillations - Spurious oscillations from any electronic equipment or component thereof, whether passive or active, must not cause an unsafe condition.

f. Filters - Filters used in fail-safe circuits must be designed to prevent undesired signals from passing through the filter at a level that could cause unsafe conditions, even in the event of component failures within the filter.

3. Equipment Failures and Conditions
Contractor, in producing a fail-safe design, must consider the following and other possible equipment failures and conditions:

a. Vital Relays - Open coils, shorted coils, loss of bias, fused contacts, or high contact resistance.
b. Non-vital Relays - Open coils, shorted coils, fused contacts, high contact resistance, armature sticking, and broken springs.
c. Transformers - Open primary, open secondary, shorted turns, primary to secondary shorts, or combinations of these conditions.
d. Resistors - Increase in resistance or decrease in resistance.
e. Capacitors - Shorted, open, or electrolyte leakage.
f. Transistors - Shorted, open, leakage, or a loss of Beta.
g. Diode - Shorts, opens, or reverse leakage.
h. Coils - Open or shorted turns.
i. The loss or degradation of power sources.
j. The effects of electrical interference.
k. Presence of abnormal signal levels, electrical noise levels, frequencies and delays in any electronic equipment.
l. The absence of or abnormal input signals.
m. Opens or shorts in internal circuitry.
n. Drift or instability of amplifiers, receivers, transmitters, oscillators, switching circuits, and power supplies.
o. Mechanical shock or vibrations.
p. The deterioration of contacts, connectors, solder connections, terminals, printed circuits, circuit adjusting devices, and mechanical devices.

4. Procedural Error and Neglect

Contractor must consider and minimize, in producing a fail-safe design, the possibility of unsafe failures arising from procedural error and neglect, including:

a. The careless adjustment of equipment and controls.
b. The removal of components and/or assemblies.
c. The incorrect assembly of equipment.
d. Insufficient maintenance in all categories.

B. Safety Design, Implementation, and Analysis Requirements

Contractor is responsible for assuring the safety of the Signal System Design. As a minimum, Contractor must adhere to the following design, implementation, and analysis requirements:

1. System Design Requirements
Each individual system and subsystem responsible for the safe implementation of Vital Functions must meet the following design requirements:

a. Contractor must strictly adhere to the Closed-loop Principle in the design of systems responsible for the safe implementation of Vital Functions.

b. The System Design must clearly distinguish among CLASS I, II, and III hardware and between Vital and Non-vital Software.

c. Contractor must provide means by which Vital Functions implemented within the system can be completely tested without interference or masking by any intervening non-vital logic. For example, if non-vital wayside interlocking routing logic prohibits illogical requests from being made to the Vital interlocking logic, Contractor must provide means to circumvent the intervening non-vital logic during testing of the vital relay logic functions, such that the vitality of the Vital relay logic can be challenged.

2. System Hardware Design Requirements

System hardware design requirements are as follows:

a. Vital Hardware (CLASS I)

Contractor must design and designate as Vital Hardware (CLASS I) the hardware that meets the definition specified in this Section.

Contractor must submit Vital Hardware design and implementation standards for acceptance by the Engineer.

Contractor's Vital Hardware design and implementation standards must:

(1) Not conflict with any requirements of these Technical Specifications, and

(2) Be complete, such that Vital Hardware designed and implemented to those standards conforms to all requirements of these Technical Specifications.

Vital Hardware must be designed to Contractor's Vital Hardware design and implementation standards.

Vital hardware circuits must be designed to enable exhaustive and comprehensive analysis using failure mode and effects analysis (FMEA) techniques as specified in this Section.
Hardware designated as Vital Hardware must be clearly identified and delineated from all other system hardware on Contractor's circuit schematics and system block diagrams.

b. Non-Vital Hardware used for the Implementation of Vital Functions (CLASS II)

Contractor must design and designate as CLASS II hardware the hardware that meets the definition specified in this Section.

Hardware designated as CLASS II hardware must be designed such that all failures and/or combinations of failures within that hardware are accounted for, to the extent considered reasonable and as accepted by the Engineer, by demonstrating that those failures either:

(1) Have no adverse effect on the safe implementation of Vital Functions, or
(2) Are detected and, once detected, subsequent action assures that no unsafe effect is produced. In this case, the detection of hardware failures that could have an unsafe effect must be accomplished by continually proving that the failure has not occurred.

Hardware designated as CLASS II hardware must be clearly identified and delineated from all other system hardware in Contractor's hardware circuit schematics and system block diagrams.

c. Hardware not used for Vital Functions (CLASS III)

Hardware not used for the implementation of Vital Functions and not designated as either CLASS I or II Hardware must be designated CLASS III Hardware.

CLASS III Hardware must be designed so that it can be proven that operation of or failure within that hardware has no effect on the implementation of Vital Functions.

CLASS III Hardware must be identified in Contractor's hardware circuit schematics and system block diagrams as all hardware not designated CLASS I or CLASS II hardware.

3. System Software Design Requirements

System software design requirements are as follows:

a. Vital Software
Contractor must design and designate as Vital Software the software that meets the definition specified in this Section.

Software designated as Vital Software must be designed such that, to the extent considered reasonable and as accepted by the Engineer, it can be demonstrated that:

(1) Vital Software is implemented using a design concept that assures safe operation in the presence of hardware failures and/or Software Errors.

Software designated as Vital Software must be clearly identified and delineated from all other system software in Contractor's software system block diagrams and by individual routine in the software listings.

Contractor must submit Vital Software design and implementation standards for acceptance by the Engineer.

Contractor's Vital Software design and implementation standards must:

(1) Not conflict with any requirements of these Technical Specifications, and
(2) Be complete, such that Vital Software designed and implemented to those standards conforms to all requirements of these Technical Specifications.

Vital Software must be designed to conform to Contractor's Vital Software design and implementation standards.

Vital Software components must be designed to enable exhaustive and comprehensive analysis, as specified in this Section.

b. Non-Vital Software

Software not involved in the implementation of any Vital Function must be designated Non-vital Software, as defined in this Section.

Non-vital Software must be implemented within an architecture that assures that failures in the execution of the Non-vital Software caused by either hardware failures or Software Errors will have no unsafe effect on the safe implementation and execution of Vital Functions.
Non-vital Software must be identified in Contractor's software listing and system software block diagrams as all software not designated Vital Software.

4. System Implementation Requirements

Implementation requirements are as follows:

a. Hardware Implementation Requirements

System hardware designed and designated as vital hardware (CLASS I) must be implemented in a fail-safe manner, using Contractor's Vital Hardware design and implementation standards.

Implementation of Vital Hardware (CLASS I) must specifically include separation of PCB traces and components, detailed specification of components, and the separation and demarcation of CLASS I, II, and III circuits.

b. Software Implementation Requirements

Contractor must demonstrate that the coding of all software routines and the transformation of the software code into machine language by compilation, assembly, or interpretation is free of errors that could produce unsafe effects.

5. Analysis Requirements

Contractor must provide definitive and comprehensive proof of the safety and safety assurance of the wayside Signal System and, in particular, the processor-based portions of the system.

Contractor must provide a complete safety analysis of the Signal System. The safety analysis must show how and to what degree the safe implementation of each Vital Function performed by the Signal System is assured.

Contractor must analyze each portion of the Signal System with regard to those factors in Contractor's design upon which the safe implementation of Vital Functions is dependent.

Contractor's analyses must generally conform to the applicable requirements of MIL–STD–882C and strictly conform to IEEE 1483 unless otherwise specified in this Section. All hazard analysis submittals must conform to the guidelines established in MIL-STD-882C. Contractor is not responsible for the analyses of Owner-furnished equipment.
The minimum additional requirements of the analysis, beyond those work products specified by IEEE 1483, are as follows:

a. Identification of Vital Functions

Contractor's analysis must identify all Vital Functions performed by the Signal Systems. These Vital Functions must be implemented by the CLASS I and/or CLASS II hardware and/or Vital Software system components.

(1) System Safety Program Plan (SSPP)

Contractor must develop a System Safety Program Plan to define the overall program for assuring that the system safety requirements are satisfied. This plan should outline the safety organization responsible for implementing the plan, as well as the overall safety program process and associated milestones.

(2) A Preliminary Hazard Analysis (PHA)

Contractor must perform a PHA must on each non-identical individual Signal System subsystem and the Signal System as a whole. The PHA must be used by Contractor to identify all hazardous conditions and the faults that precipitate them, as well as specific ways to prevent the occurrence of any hazardous conditions or faults identified. The PHA must comply with the requirements specified in this Section.

The faults identified by Contractor in the PHA must in turn be used by Contractor to identify all Vital system functions.

The PHA must address, as a minimum, the following subsystems, interfaces, and potential hazard areas:

i. Interlocking Control – Signal lighting, switch control and correspondence, route locking and route integrity, route protection, traffic locking, and interface to the highway-railroad grade crossing system warning system.

ii. Automatic Block Signal Control – Signal lighting, electric switch lock control and correspondence, route integrity, traffic locking, and interface to the highway-railroad grade crossing warning system

iii. Train Detection and Train Separation

iv. Highway-railroad Grade Crossing Warning System Control – Train detection, signal lighting, gate control
warning time, UPRR interface, traffic signal interface, and interface to the RT block signal system.

v. Interface between the RT-furnished TWC Wayside system and the block signaling and highway-railroad grade crossing warning systems. RT will provide Contractor with potential TWC System failure modes to be used in Contractor's analyses. In general, Contractor must consider the RT-furnished TWC equipment as non-vital and it must be assumed to have all failure modes that non-vital equipment can have, for example, false output or false input, etc.

vi. Interface between the control center system and the wayside block signal system.

An FTA, as specified in IEEE 1483, must branch through all system hardware and software components to a level sufficient to identify those components that affect the safe implementation of all Vital Functions associated. Components thus identified comprise the CLASS I and II hardware and Vital Software system components.

(3) Interface Hazard Analysis (IHA) – The IHA must demonstrate that no hazard related to a Signal System interface and any RT facility or equipment has an unacceptable hazard risk.

(4) Operating Hazard Analysis (OHA) – The OHA must demonstrate that no hazard related to operation and maintenance of the Signal System has an unacceptable hazard risk. The OHA must also identify recommended RT operating rules and procedures necessary to reduce hazard risk to an acceptable level.

(5) Subsystem Hazard Analysis (SSHA) – Contractor must perform SSHAs on each subsystem as required to demonstrate that FTA, IHA, and OHA hazards are adequately resolved.

b. Classification of Hardware and Software Components

Contractor must divide the system hardware and software into classifications in preparation for detailed analysis.

All hardware and software components affecting the safe implementation of a Vital Function, as identified in the FTA must be classified as CLASS I, II, or III hardware or Vital or Non-vital Software.
c. Analysis of Vital (CLASS I) Hardware

Contractor must provide a FMEA on all hardware designated as CLASS I Hardware.

The FMEAs must be performed in accordance with the minimum requirements for the FMEA of Vital Hardware, as specified in this Section.

d. Analysis of CLASS II Hardware

Contractor must provide an analysis showing that all possible failures in all CLASS II Hardware that could adversely affect the safe implementation of a Vital Function are accounted for.

Analysis of hardware designated as CLASS II hardware must show that all failures and/or combinations of failures within that hardware, to the extent considered reasonable and as accepted by the Engineer, are accounted for by either: (a) showing that it has no unsafe effect on the implementation of Vital Functions, or (b) showing that it is detected and, once detected, subsequent action assures that no unsafe effect is produced.

The types of analyses Contractor must provide may depend upon the Safety Assurance Concepts used, the System Design, and the factors upon which safety is dependent; however all analyses must be in strict conformance with IEEE 1483.

e. Analysis of CLASS III Hardware

Contractor must provide an analysis proving that operation of or failure within that hardware designated as CLASS III hardware within a Signal System subsystem has no adverse effect on the safe implementation of any Vital Functions.

f. Analysis of Vital Software

Contractor must provide an analysis on all software designated as Vital Software. The analysis must be well structured, systematic and comprehensive, and in strict conformance with IEEE 1483.

g. Analysis of Non-Vital Software

Contractor must provide an analysis of all Non-vital Software, executed in the same processing equipment as Vital Software. The
analysis must demonstrate that the Non-vital Software has no adverse effect on the safety of the system.

h. Calculation of MTBHE

Contractor must provide an analysis showing the calculation of MTBHE, as defined in this Section for all Signal System elements, in accordance with IEEE 1483.

i. Vital Relay Based Equipment

Contractor must perform a circuit analysis to assure that the implemented logic is correct and that the implementation of the relays is correct to provide the highest degree possible for system safety. The analysis must also assure that no additional functionality is implemented or required for normal and abnormal operating conditions. This analysis must also assure that non-vital relay and/or microprocessor interfaces are implemented properly to provide the highest degree possible for system safety. This analysis must also include analysis of the components used to time delay the de-energization of a vital relay to assure that the components selected provide the highest degree possible for system safety. This analysis must be performed for each instrument house or relay case location unless otherwise authorized by the Engineer.

j. Vital and Non-vital Application Logic Analysis

Contractor must perform analysis on all Vital and Non-vital application logic (primordial logic analysis – PLA) using a well-structured, systematic, and comprehensive methodology. The analysis must assure that the Contract Documents are accurately interpreted and that all functions are properly implemented, including provisions for future functions identified in this Section. This analysis must also assure that interfaces to other Signal System subsystems and external Signal System subsystems, for example, microprocessor serial port timing issues (nominal and worst case), equipment reaction times (nominal and worst case), and future control center interface are implemented to provide the highest degree possible for system safety. All application logic must be analyzed and all application logic statements must be explained/accounted for in the analysis. This analysis must include all timer calculations and the rationale for the timer calculation and associated timer ranges. Contractor must verify all times shown in the Plans. This analysis must be performed for each instrument house location unless otherwise authorized by the Engineer.
C. Minimum Requirements for a Failure Mode and Effects Analysis of Vital (CLASS I) Hardware

Failure Modes and Effects Analysis (FMEA) must be performed on all Vital Hardware. The FMEAs must be submitted to the Engineer for acceptance. Previous FMEAs performed on proposed equipment, and independent third party reviews and audits of the proposed equipment, will be considered subject to the Engineer's acceptance.

Vital Hardware is hardware, the failure of which can adversely affect system safety. Further, if the safe implementation of a Vital Function is dependent, in whole or in part, on the absence of certain failures or sets of failures in a hardware circuit or device, then that hardware is defined as Vital Hardware. Vital Hardware is hardware whose failure modes and characteristics can be accurately identified, predicted and exhaustively tested. The occurrence of failure modes that could have unsafe consequences must be eliminated, prevented or otherwise accounted for by design; they cannot be not accounted for by probability calculations based on reliability statistics of components.

The assurance of the safe implementation of Vital Functions by hardware designated as Vital Hardware must be determined using FMEA methods. As a minimum, the following failure modes and conditions must be analyzed in the FMEA performed on all hardware designated as Vital Hardware.

1. General

   All failure modes of all components must be analyzed and tested by being induced or simulated on the physical hardware circuit, fabricated in final form.

   If Contractor determines that testing all failure modes of all components is not required, Contractor must provide documented justification to that end and submit it for acceptance by the Engineer.

   The FMEA must show that no single failure mode produces an unsafe condition.

   The FMEA must classify all failure modes as self-revealing or non self-revealing.

   The FMEA must show that all combinations of failures produce no unsafe condition, other than combinations of independent self-revealing failures.

   If Contractor determines that analysis of a non-self-revealing failure in combination with all other failures is not required, Contractor must provide documented justification to that end and submit it for acceptance by the Engineer.
The FMEA must show that if any unsafe condition results from the combination of two or more failures, those failures are all self-revealing and wholly independent.

2. Operational Circuit Modes

Operational circuit modes not necessarily related to component failures, such as self-oscillation, acceptance of spurious signals, vulnerability to electrical or mechanical shock, and any phenomena that may mimic signals normally indicating safe conditions, must be analyzed by Contractor.

Further, the effects of variations in power supply voltages, switching transients and ripple, possible coupling of circuits through common power supply effects, and the potential for abnormal circuit configurations that could occur as a result of the opening of circuits where three or more components are connected to a common mode, must be analyzed by Contractor.

Filters must be analyzed by Contractor to show that undesired signals are prevented from passing through the filter at levels that could cause unsafe conditions, even if there are component failures within the filter.

Any component or wire becoming grounded or any combination of such grounds must not cause an unsafe condition.

3. Component Failure Modes

Component failure modes must be analyzed individually by Contractor and must include the following:

a. Resistor - Open; Short; Resistance increase over plus tolerance, to open; and Resistance decrease under minus tolerance, to short.

b. Potentiometer - Open; Short; Resistance increases over plus tolerance, to open; Resistance decreases under minus tolerance, to short; increase in contact resistance of slider; and change in division ratio.

c. Diode - Open; Short; and Leakage current.

d. Capacitor - Open; Short; Increased leakage to short; Increased dissipation factor; Increased capacitance; and Decreased capacitance.

e. Zener Diode - Open; Short; Reference voltage drift; and Leakage current.

f. Transistor - Open, element to element; Short, element to element; Leakage current, element to element; Increased gain, if not employed for switching; Decreased gain; and High frequency emitter-follower oscillation.
g. Thyristor - Open, element to element; Short element to element; Leakage current, element to element; Change in holding current; and dv/dt false turn-on effects.

h. Transformer - Open primary; Open secondary; Turn-to-turn short, primary; Turn-to-turn short, secondary; Interwinding short; Winding to core short; and signal feed-through with winding ground points opened, interwinding capacitance feed-through.

i. Inductor - Open; Short; Turn-to-turn short; Winding to core short; and Ratio of normal signal level to saturating signal level.

j. Relays - Back contact fails to open when relay is energized; Front contact fails to close when relay is energized; Back contact fails to close when relay is de-energized; Front contact fails to open when relay is de-energized; Change in timing characteristics; Insulation failure, contact-to-contact or contact-to-coil; Arc suppression failure; Excessive current on contacts; and Insulation failure to frame or ground.

k. Optically Coupled Isolators - No output; Diminished band width, no response to higher frequency signals; Current transfer ratio degradation; Intermittent operation; Unstable detector stage amplification; Increased detector stage leakage current; Input to output short; Output stuck high; Output stuck low; and Degradation of the isolation between input and output.

l. Multiple Components Connected to Common Bus - Abnormal circuit configurations due to circuit openings at various points along the bus; and Abnormal return current paths and voltage drops due to openings at various points along the bus.

m. Adjacent Printed Circuit Board (PCB) Traces - Trace-to-trace shorts and shorts between connector contacts must be considered component failure modes and must be analyzed. Adjacent PCB traces and connector contacts that could cause an unsafe condition if shorted must be identified in the analysis. Such adjacent PCB traces and/or connector contacts must conform to the following minimum requirements:

(1) Minimum spacing between traces or connector contacts not conformally-coated must be 0.250 inch.
(2) Minimum spacing between conformally-coated traces must be 0.10 inch.

n. Components with Fail-Safe Characteristics - Certain components have fail-safe characteristics accepted by the signaling industry, for example, four terminal capacitors, film resistors, wire wound resistors, and four terminal resistors. If such components are used, Contractor must submit adequate documentation for the failure modes to be analyzed for these components.

For any components used in Vital Hardware circuits that are not included in the list in the immediately-preceding paragraph,
Contractor must submit proposed failure modes, with adequate documentation, to the Engineer for acceptance.

**13-2.09 Electromagnetic Compatibility (EMC) Requirements**

**A. General**

EMC is the ability of equipment and systems to perform without causing or being affected by electromagnetic interference (EMI). The following considerations must be incorporated by Contractor into the design of the Signal System:

1. Selection of train detection and other wayside Signal System frequencies to minimize frequency interference and crosstalk.
2. Coordination of the RT and UPRR train detection and other wayside Signal System frequencies based on the electromagnetic characteristics of the vehicle propulsion control, vehicle auxiliary power system, traction power, TWC vehicle and wayside systems, and communications apparatus.
3. Shielded cables, twisted pair conductors, and rigid steel conduit must be used by Contractor as part of the EMI mitigation plan.
4. Proper grounding and bonding of apparatus, conductor shields, and raceways to maximize shielding and to minimize circulating currents in shields.
5. Surge protection against lightning and other natural sources of the EMI.
6. Routing of raceways to minimize the EMI, also taking into consideration the effect of other system and subsystem apparatus in proximity to the wayside signal system apparatus, local utilities, radio stations, and other non-railway EMI sources.
7. Coordination of train detection and other wayside signal system frequencies based on the electromagnetic characteristics of the UPRR railroad signaling and communications equipment.

**B. Emission Limits**

The Signal System equipment must tolerate vehicle, traction power, and other electromagnetic emissions within the limits specified in the Contract Documents and must continue to operate safely and normally.

Contractor must maintain a margin of 6db between projected interference levels and the Signal System equipment susceptibility levels. Any decrease in the margin must be approved as a deviation in accordance with the provisions in the General Conditions.

1. Radiated Emission Limits

Radiated emissions, as measured by the procedures given in "Radiated Interference in Rapid Transit Signaling Systems, Volume II: Suggested
Test Procedures, Urban Mass Transportation Administration (UMTA)-MA-06-0153-85-11" must, as a minimum, conform to the following limits:

a. Between the frequencies of 0.01 mega Hertz (MHz) to 30 MHz, the maximum limit is a straight line from 122 db above one microvolt/meter/MHz bandwidth to 84 db above one microvolt/meter/MHz bandwidth.

b. From 30 MHz to 88 MHz, the maximum limit is 58 dB above one microvolt/meter/MHz bandwidth.

c. From 88 MHz to 1000 MHz, the maximum limit is 68 dB above one microvolt/meter/MHz bandwidth.

These limits must not be exceeded when measured at a distance of 30 meters from the track centerline, with the vehicle in any achievable operating mode.

2. Conductive Emission Limits

Conductive emissions, as measured by the procedures given in "Conductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures, UMTA-MA-06-0153-85-6, Method RT/CE02A, Conductive Emission Test, Vehicle", must not exceed the current limits defined as follows:

a. 10 ampere RMS limit from 30 Hertz (Hz) to 50 Hz
b. 1 ampere RMS limit from 50 Hz to 70 Hz
c. 10 ampere RMS limit from 70 Hz to 90 Hz
d. 1 ampere RMS from 90 Hz to 110 Hz
e. 10 ampere RMS from 110 Hz to 320 Hz
f. Emissions limit then follows a continuous curve through 10 amps at 320 Hz, 0.08 amp at 2 kilo Hertz (KHz), 0.016 amp at 4 KHz and 0.0046 amp at 7 KHz.

The above limits must be met by each individual piece of equipment, as well as with the simultaneous operation of all equipment.

3. Inductive Emission Limits

Inductive emissions, as measured by the procedure given in "Inductive Interference in Rapid Transit Signaling Systems, Volume II, Suggested Test Procedures, UMTA-MA-06-0153-85-8", must not exceed the following limits: 20 millivolts (mV), 30 Hz to 1 KHz, and 10 mV from 1 KHz to 100 KHz.

The above conditions must be met by each individual piece of equipment as well as with the simultaneous operation of all equipment.
13-2.10 Qualifications of Signaling Personnel

Contractor must have the manufacturer(s) of the Vital microprocessor equipment provide, at a minimum, the detailed circuit design, application logic programming, checking of all vital signaling functions and the preparation of the Signal System safety assurance submittals.

Contractor must have the manufacturer of the vital microprocessor equipment conduct and/or witness the on-site inspection and testing of the Signal System as defined in this Section of these Technical Specifications.

Contractor must have the manufacturer of the vital microprocessor equipment assign a signal engineer to the Project. The signal engineer must have at least 5 years of design experience with the Vital microprocessor equipment and must be qualified in all aspects of the Signal System as related to this Project. Contractor must have an agreement with the manufacturer(s) of the vital microprocessor equipment for the services of the signal engineer for the duration of the Contract. Within 3 days of NTP, Contractor must submit to RT the name and qualifications of the proposed signal engineer(s) along with 3 reference contacts for recently-completed projects by the proposed signal engineer(s) and the agreement between the manufacturer and Contractor for the services of the engineer.

The Engineer's decision concerning the proposed signal engineer's qualifications will be final. If RT determines the signal engineer(s) does not satisfy the criteria set out above, Contractor must, within 10 days after receipt of rejection notice, submit the resume and agreement for an alternate signal engineer(s) for RT review. Contractor must not begin signaling-related work prior to the signal engineer(s) having been accepted by the Engineer.

The RT-accepted signal engineer(s) must not be removed from the Project or his or her duties assigned to other personnel without the prior written acceptance of the Engineer.

Contractor must ensure that the signal engineer(s) performs the duties identified in this Section. The signal engineer(s) must participate in all Signal System design-related review meetings. The signal engineer(s) must be directly responsible for the preparation of the detailed design, application logic software, various analysis and reports, test procedures, and signaling related submittals. The signal engineer(s) must review all submittals for correctness and completeness prior to submittal to RT. The signal engineer(s) must direct and certify the successful completion of all tests on signaling equipment and systems prior to releasing the systems for service. The signal engineer(s) must be responsible for ensuring that all applicable test documentation is completed prior to, or immediately after, in-service testing is completed.

13-3 Submittals and Reviews

13-3.01 General
In addition to the requirements specified in Section 6, General Conditions, and Section 7, Special Conditions of the Contract Documents, Contractor must submit to the Engineer, for acceptance, drawings and technical data in the English language required for the manufacture and installation of the wayside block signal and highway-railroad grade crossing warning systems as specified in the Technical Specifications and as shown on the Plans. Whenever it is stated in this Section that Contractor must “submit” drawings, documents, Product Data, Samples or any other item to the Engineer or to RT, it is understood that the submittal is subject to the requirements specified in General Conditions Section 6.45, “Project Submittals and Deliverables,” regardless of whether the words “for review”, “for acceptance”, “for the Engineer's acceptance”, or similar language is included in the sentence or statement.

Contractor's drawings and data must show design dimensions, connections, and other details necessary to assure that the Plans are accurately interpreted.

The drawings and data must show proper connections and interfaces with adjoining work in detail. Where adjoining work so requires, drawings must be submitted for acceptance at the same time so that connections can be accurately checked.

All requests for acceptance of material and equipment, and submissions of drawings and data must indicate the corresponding number of the Section and Paragraph of the Technical Specification and reference to the Plans number under which each of the above are required.

For all drawings submitted under this Section, individual drawing numbers must be assigned to each drawing produced and must be identified clearly in the title block. The format for assigning drawing numbers will be provided to Contractor 30 days from NTP. Revision numbers must be shown on the drawing and must be dated.

Each drawing must have a title block identifying the Client, the Contract number, the drawing contents, and Contractor's name.

Standard ANSI, IEEE, and AREMA device symbols and nomenclature must be used on drawings submitted under this Section. Standards between organizations must not be combined on one drawing.

For this Section 13 only, in addition to the hardcopy versions of the submittals, Contractor must also provide an electronic copy of each submittal. Drawing files must be in AutoCAD version 2008 or Current and must be complete with all associated reference files and “.ctb” plot style files. Text documents and microprocessor application logic must be provided in MSWord 2003 or current or MSExcel 2003 or current compatible formats, except that information from pre-published documents may be provided in an electronic format that can be read using Acrobat Reader, version 10 or current.

13-3.02 Drawing Schedule
Contractor must provide a Drawing Schedule to the Engineer within 60 days after NTP for grade crossing warning systems and within 90 calendar days after NTP for the wayside block signal system. The Drawing Schedule must show the drawings Contractor intends to provide and the scheduled time of submittals of the drawings to the Engineer for acceptance. The Drawing Schedule must be updated and a copy sent to the Engineer by the fifth day of each month.

13-3.03 Existing Drawings

The Engineer will provide Contractor with reproducible circuit drawings of the applicable portion of the existing RT and UPRR Signal System. Contractor must mark the drawings to show the changes required. All drawings requiring modification must be submitted as part of the set of which they will become a part, under the same submittal procedures specified for the new drawings in the set. When the system testing has been completed, Contractor must prepare and submit hard copy and electronic CAD file As-As specified in the Contract Documents for all drawings modified under this Project. Drawings for the existing RT signal system are available in AutoCAD.

13-3.04 Drawing Arrangement

The drawings prepared for submittal must be organized into sets, one per equipment location. Contractor must provide an 11"x17" set of circuit plans associated with that enclosure for each instrument house, relay case, and junction box in addition to the submittal requirements specified elsewhere in the Contract Documents. These circuit plans must be placed by Contractor in an 11"x17" notebook. Each drawing set must include an Index and the following, at a minimum:

A. Track plan(s) drawn to scale of 1" = 40', showing a single line track plan and the location, chaining, outline, and installation details of all wayside equipment, including signals, flashers, crossing indicators, gates, bells, cantilevers, impedance bonds, traction power bonding, track circuits, switches, instrument houses, relay cases, junction boxes, cabling, TWC loops, RT milepost, signs, traction power substation negative returns, bridge lighting, bridge warning system, and push button stands. Details shown must include mounting requirements, clearances, rail connections, foundations, stations, bridge abutment faces, and all data necessary for a complete physical installation. Signal control limits and grade crossing approaches must also be shown. Track Plans must be continuous and submitted as a set. Each location must have Track Plans for that location only included with the drawing set. Track Plans must also identify UPRR milepost and the CPUC Number at each highway-railroad grade crossing.

RT CPUC proposed Grade Crossing Numbers are required for each grade crossing. Contractor must request the final RT CPUC numbers from RT.
B. Track circuit drawing(s) showing all track circuits for the locations. The track circuits must be placed on the drawing so that their physical placement on the drawing coincides with the actual location of the track circuit.

C. Line circuit drawing(s) showing all line circuits terminating at the location, with circuits continuing westward/northward to the left-hand side of the drawing and circuits continuing eastward/southward to the right.

D. Signal control circuit drawing(s), including control of flashers, crossing indicators, and gates.

E. Signal lighting circuit drawing(s), including lighting of flashers, crossing indicator, and gate lamps.

F. Switch control circuit drawing(s).

G. Drawing(s) of repeater and miscellaneous circuits.

H. Grade crossing control, indication, and lighting circuit drawings(s).

I. TWC System drawings. RT will provide final typical wayside TWC System drawings for Contractor’s use in completing the partially-complete site-specific drawings included in the Plans per the schedule specified in Technical Specification Section 8-2 for furnishing TWC System information. RT will provide the programming Mask for each existing TWC location north of 47TH Avenue Station. Contractor must modify and/or install the programming Mask in the existing and new TWC Systems affected or installed under this Contract.

J. Vital and Non-vital microprocessor system drawings, including Relay equivalent arrangement/requirements. Local Control Panel (LCP) and event recorder system drawings.

K. Power distribution drawing(s), including energy bus loops for all equipment.

L. Instrument house, case and junction box layout drawing(s) showing the physical position and material reference number of each piece of equipment.

M. Terminal board layout drawing(s) for each terminal board at the location showing each terminal, terminal number, and nomenclature of each wire connected to it.

N. Physical layout drawing(s) of each instrument house, relay case, and junction box showing door position, racks, shelves, terminal boards, relay contact usage, and cable entrances.

O. Wiring diagrams.

P. Underground conduit installation and pull box installation details.
Q. Bridge Lighting and Bridge Warning system drawings.

Contractor’s drawings must be arranged similarly to the existing RT Signal System as-built for relay based and microprocessor based locations. RT will provide the format for assembling the location plans, track plans, and junction box plans no later than 60 days after NTP. The existing RT As-Built drawing format does not include relay equivalents. Contractor must propose modifications to the RT format to incorporate the relay equivalents. Material lists, catalog information, spare parts list, Shop Drawings, and drawings that are not specifically associated with any one location need not be included in each drawing set, but must be included in the design submittals as outlined in these Technical Specifications. Contractor’s attention is directed to the requirements for As-Built hardware plans and application logic requirements for microprocessor based locations as identified in Section 13-5.32, Vital and Non-Vital Microprocessor, subsection A, General, Item number 11.

13-3.05 Design Submittals

Contractor must provide the Engineer with circuit drawings, application logic and relay equivalents, wiring diagrams, and instrument housing layout plans and any other pertinent data for acceptance of Contractor’s design and the type of material, apparatus, and equipment to be provided. One of the drawing sets must be reproducible and the prints must be black line on a white background. Detailed requirements for the Design Submittals are as follows:

A. Within 90 calendar days following NTP, Contractor must submit a construction staging plan describing the proposed method of transition to the new Signal System. The plan must include a description of the work to be performed in each instrument house, relay case, and junction box, and list the work that will be done to place the new systems in service. The plan must be in accordance with all applicable requirements of the Contract Documents.

B. Contractor must provide, with all submitted drawings, two copies of an updated Drawing Schedule. The Drawing Schedule must contain the current transmittal date, the Contract number, Contractor’s name, the drawing number, and the dates of previous submittals of the drawing and a brief description of the revisions made.

C. Revised drawings and logic network printouts submitted to the Engineer must show the latest revision(s) encircled and the circles marked with "X"s and "O"s. The "X"s must indicate a deletion from the drawing and the "O"s must indicate an addition to the drawing. After receiving a submittal back from the Engineer, Contractor must revise the drawings. Contractor must not submit a drawing to the Engineer with a previously-reviewed revision still indicated with the "X"s and "O"s.

D. The Engineer will return a copy of the data or drawings received for review or acceptance, with comments, to Contractor as specified in the Contract.
Documents. Upon acceptance of drawings, Contractor must submit drawings marked "For Construction and Record."

E. Drawings submitted for review and returned with comments by the Engineer must be resubmitted by Contractor within 30 calendar days after receiving the Engineer's comments. Re-submittals must address all of the Engineer's previous comments and/or concerns by: (1) incorporation of the correction, (2) providing a detailed written explanation of why Contractor feels the Engineer's comment is not applicable; or (3) a detailed description of how the submittal content has been otherwise modified in order to address the Engineer's concerns.

F. Within 120 calendar days following the NTP, Contractor must submit catalog data, drawings, and proofs of compliance with applicable standards for the type of material intended to be supplied and installed under this Contract.

G. Contractor must submit mechanical drawings and/or Shop Drawings of all equipment to be delivered and installed to the Engineer for acceptance in advance of manufacture so that an orderly processing of the drawings, with the necessary acceptance, may occur prior to the manufacture of the equipment.

H. Contractor must submit circuit drawings and wiring diagrams of equipment to the Engineer for acceptance at least 60 days prior to the planned manufacture. Also, Contractor must submit additional circuit drawings and wiring diagrams of equipment to the Engineer for acceptance at least 60 days in advance of when Contractor plans to place the equipment in service so that RT can verify that what is finally installed matches the factory acceptance test. These drawings must reflect the latest revisions and changes made because of field checks and conditions.

I. Contractor must submit, within 30 days after placing equipment in service, final circuit drawings of the equipment placed in service, to the Engineer. When changes are made to equipment previously placed in service, Contractor must submit those drawings that are affected, with the changes shown as a revision, to the Engineer within 5 days after the change is made.

Contractor must maintain a complete set of Circuit drawings for each location in the location during construction, testing, cut over, and until As-Builts are provided. These circuit drawings must reflect all modifications. Temporary markups on circuit plans must be indicated by Green=In and Red=Out or by “X”s and “O”s.

J. Contractor must submit, within 90 days after NTP, hardware submittals associated with the interim and final configuration of the highway-railroad grade crossing warning systems. Design submittals for these highway-railroad grade crossing warning systems must be submitted within 120 days after NTP.

Contractor must provide a professional engineer, registered in the State of California, to review and sign-off Contractor's Signal System plans and application logic prior to their
use for final installation and testing. The professional engineer must also sign and seal final as-built plans and application logic.

13-3.06 Submittal Details

A. Scope

Contractor must submit Shop Drawings, hardware Product Data, procedures, and reports, as specified in the Contract Documents, for all materials proposed to be used for this Project, including materials specified in this Section.

Performance data or a sample of each type of component or product proposed as an equivalent to those in this Section specified must be submitted to the Engineer in accordance with the procedures specified in the Contract Documents.

Contractor must obtain the Engineer's review with no exceptions taken for products or materials before proceeding with manufacture or procurement of the product or material.

B. Relays and Plugboards

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance, prior to manufacture of the equipment:

1. Relay specifications and drawings showing contact stacking arrangements, contact stab application details, and mounting and supporting arrangements for all relay types supplied for this Contract.
2. Applicable AREMA Office Records Test Form for each vital relay provided under this Contract. All information required must be typed on the form for field verification by the Engineer. Cards must be filed by serial number and must be submitted as directed by the Engineer.

Test results must be submitted prior to delivery of the equipment.

C. Electrical Grounding

Contractor must submit drawings detailing the hardware, installation and termination or each type of grounding connection used.

D. Labeling

Contractor must submit, for acceptance of the Engineer, all wire and equipment tagging nomenclature and details.

E. Switch-and-Lock Movement Layouts
Contractor must submit drawings for the top line assembly of the switch machine together with a bill of materials and submit installation drawings of the switch-and-lock movement layouts showing all mounting details and connections to the track switch points for each type of installation. This submittal must be made no later than 90 days after NTP and it must identify the complete layout requirements.

Field Test procedures must be submitted prior to testing the switch mechanism.

F. Signals and Push-button Route Selectors

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance, prior to manufacture of the equipment:

1. Drawings for each type of signal and push button layout, including mounting and fastening details.
2. Scaled drawing of each faceplate layout.
3. Material ordering reference numbers with each layout.
4. Factory test and inspection procedures.

G. Track Circuits

Contractor must submit, for acceptance of the Engineer, manuals detailing the operation and adjustment of each type of track circuit and train detection device. Track circuit adjustment tables must be based upon the component makeup and configurations provided by Contractor.

H. Impedance Bonds

Contractor must submit drawings and product information for the impedance bond and each type of impedance bond layout, including mounting and fastening details.

I. Event Recorder/Analyzer

Contractor must submit manuals detailing the operation, adjustment, and maintenance of the event recorder/analyzer and associated hardware used.

J. Wire and Cable

Contractor must submit for acceptance of the Engineer a final configuration cable plan showing all working wires, spare wires, all termination points, suspension apparatus, suspension and down guying configurations, and termination wire sizes and types.

Technical data describing the wire and cable to be provided must be submitted within 90 days after NTP and must be accepted prior to ordering.
Qualification samples and certified test reports and procedures must be submitted for acceptance of the Engineer.

K. Conduit

Contractor must submit dimensioned site plans clearly defining the location, configuration, and content of each underground conduit. Dimensions must be referenced to permanent landmarks such as point of switch, catenary pole, etc. These plans must be submitted at least 30 days prior to installation. They must also be submitted in accordance with the As-Built requirements of the Contract Documents.

L. Instrument Houses and Relay Cases

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance, prior to manufacture of the equipment:

1. Drawings showing the construction, size, layout, mounting arrangement, fusing plan, and grounding arrangement of each wayside instrument house and relay case. Equipment layout drawings must be drawn to scale in sufficient detail and with critical dimensions displayed so that a determination can be made that the specified clearance dimensions are provided between equipment and adjacent surfaces.
2. Detail wiring plans for each house and case.
3. Factory test and inspection procedure for each house and wayside case.

M. Foundations

Contractor must submit 2 copies of the fabricator's records showing the date and conditions relating to the manufacture of each precast unit, which must include type of fabricator's building or enclosure, form material used, curing procedures (steam or water), temperature ranges, air entrainment content, water-cement ratio, method of finishing the units, and other pertinent information.

Contractor must submit 4 certified copies of the tests conducted by the accredited authoritative testing laboratory for acceptance of the precast units.

Contractor must submit a proposed design mix and supply certificates of compliance for each load for cement, aggregates, and mixing water to be used for cast-in-place concrete.

If Contractor proposes to provide or install foundations different from those shown on the Plans, then Contractor must submit drawings for the type of foundations, including size and details of the galvanized anchor bolts, nuts, and washers, following the process for deviations set out in General Conditions Section 6.45.4, Deviation from Contract Requirements.
N. Traction Power Bonds

Contractor must submit drawings for acceptance of the Engineer, detailing each type of power bond proposed to be used.

Contractor must submit procedures for the application of the bonds based upon the manufacturer's recommendations.

O. Automatic Highway-railroad Grade Crossing Warning Devices

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Manuals detailing operation, adjustment, and maintenance procedures.

P. Vital Microprocessor System

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Design documentation and manuals detailing operation, adjustment, and maintenance procedures.

Q. Non-vital Microprocessor System

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Design documentation and manuals detailing operation, adjustment, and maintenance procedures.

R. Local Control Panel

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Material and equipment submittals for all necessary LCP components.
4. LCP faceplate layout drawn to scale.

S. Bridge Lighting System

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Material and equipment submittals for all necessary Bridge Lighting components.

T. Bridge Warning System

Contractor must submit the following transmittals, drawings, and procedures to the Engineer for acceptance prior to ordering and or manufacturing the equipment:

1. Drawings showing layout, including installation details.
2. Material ordering reference numbers with each layout.
3. Material and equipment submittals for all necessary Bridge Warning System components.

13-3.07 As-Built Documentation

In addition to the As-Built Plan requirements specified in Section 6 of the General Conditions, within 30 days after all new Signal System is installed in the field for testing and before Final Acceptance, Contractor must submit a complete set of final As-Built Plans and application logic and relay equivalents for the Signal System to the Engineer.

The following additional requirements apply to As-Built Plans related to the Signal System:

A. Each circuit that continues on another drawing must be bracketed and noted with drawing number and routing information for the continuation of the circuit.

B. The circuit drawings must show all individual circuits. Typical circuits will not be accepted.

C. The track plans must show all cable installed with the number of conductors, the size of conductors, the type of cable, termination points of conductors, and the circuit on each conductor. Separate cable plans must be drawn if cable information cannot be shown in a neat and organized manner on the track plans.
G. Equipment layout plans must be drawn to scale and must clearly identify the location of each wayside device, pull box, and the configuration and routing of each conduit run. Each wayside device and each pull box must be identified on the drawings by type and its location must be defined relative to track stationing and offset from the nearest track. The actual routing of each conduit run must be described by reference to elevation relative to top-of-rail, depth below finished grade, and horizontal offset from the nearest track or other fixed wayside marker.

H. The Shop Drawings must be detail equipment drawings for each type of equipment installed.

I. The material list must show the part number, part name, a brief description of the part, and the submittal number under which the part was accepted for use.

J. Each sheet of the final As-Built Plans must have a unique number assigned to the drawing. RT will provide Contractor with the numbering scheme to be used for all drawings.

K. As-Built Plans for the Signal System must be similar to existing RT As-Built Plans. RT will provide Contractor with existing Signal System As-Builts to be used as a guide. The As-Built Plans for the existing Signal System will not include relay equivalents; Contractor must determine a method, acceptable to RT, for incorporation of the relay equivalents.

L. Contractor's attention is directed to the requirements for As-Built hardware plans and application logic requirements for microprocessor based locations as identified in Sub-section 13-5.32, Vital and Non-Vital Microprocessor, subsection A, General, Item number 11.

13-3.08 Manuals

Within 30 days after new equipment is installed and prior to Contract Final Acceptance, Contractor must submit to the Engineer 6 sets of installation, operating, and maintenance manuals of all equipment and systems supplied under this Contract.

13-3.09 Parts List

Contractor must submit complete ordering information for all assemblies and subassemblies. These lists must be grouped by system and subsystem and include component name, description, current price, rating accuracy, manufacturer's name, part number, and material reference number.

13-3.10 Test Plan, Procedures, and Reports

Contractor must submit a Test Plan and Test Procedures 90 days prior to the planned start of testing.
Contractor’s Test Plan, Test Procedures, and Test Reports must meet the requirements specified in the Contract Documents.

13-3.11 **Spare Parts**

A. **Wayside Signal System Spare Parts**

   Contractor must provide the following spare parts. All references to each type refer to each type of equipment provided and installed under this contract.

   1. Local Control Panel Hardware – 2 each type  
   2. 1500 Amp field tunable Impedance Bonds complete – 3  
   3. Event Recorder/Analyzer complete - 3 each type  
   4. ABS LED Signal – 12 each color  
   5. Push Button Route Selector assembly complete – 1 each type  
   6. Grade crossing Push Button assembly complete – 1 each type  
   7. Vital/ non-vital microprocessor system complete configured for control of grade crossing at near-side station – 2  
   8. Non-vital microprocessor system complete configured for control/indication of a grade crossing at a near-side station – 2  
   9. Vital processor Power Supply – 2 each type  
   10. Track Transformer – 2 each type  
   11. Crossing Gates complete with mechanisms, masts, bases, arms, wind guards, counterweights, cross bucks, LED lights – 4  
   12. Replacement Grade Crossing Bell units complete – 4  
   13. Replacement LED Grade Crossing Flasher, Active W10 Advance Warning Flasher, and Crossing Indicator assemblies, ready to install - 4 each type and aspect color  
   14. Replacement Fiberglass Crossing Arms with vertical stripes – 20  
   15. Replacement aluminum gate boards with vertical stripes – 20  
   16. Battery Charger – 2 each type  
   17. Rectifier – 3 each type  
   18. All Vital Relays and Vital Timers – 4 each type, including bases  
   19. Vital and non-vital solid state devices for control of switches, wayside signals, and grade crossing warning devices – 2 each type  
   20. Vital microprocessor including chassis, complete with a full complement of control and indication modules sufficient to replace the unit at the most complex location provided under this Project – 2  
   21. Event recorder complete with a full compliment of I/O modules sufficient to replace the unit at the most complex location provided under this project – 2  
   22. All Non-vital Relays and Non-vital Timers – 4 each type, including bases  
   23. Ground Detector – 3 each type  
   24. Battery set – 2 sets each type  
   25. Printed Circuit Boards – 3 each type  
   26. Surge Suppressor – 3 each type  
   27. AF Track Circuit – 2 each type
28. Uninterruptible Power Supply – 2

B. Recommended Spare Parts

Contractor must submit a recommended Spare Parts List, including unit prices within 180 days after NTP. The Spare Parts List must include equipment and complete assembly systems and field replaceable units within the system or assembly (for example, each type of module complete and printed circuit boards within the module; each type of relay; each type of power supply, battery charger, or rectifier; each type of transformer; each type of resistor and fuse; wayside signal complete, signal LED assembly.; impedance bond; etc.).

13-3.12 Safety Assurance Submittal Requirements

Contractor must submit the following safety assurance related submittals for acceptance by the Engineer. These submittals must be separately identified as "safety-related submittals" by Contractor.

A. High-level System Documentation

This documentation must describe the overall design of the Signal System and interfaces. Textual description must be augmented with block diagrams showing the implementation of all Vital Functions and their interaction. The description and drawings must be in sufficient detail to clearly identify the major software and hardware components.

The description and drawings must clearly distinguish, at a high-level, which of the hardware components are classified as CLASS I and II hardware and which of the software components are classified as Vital Software.

B. Detailed Design Documentation

This documentation must describe, in detail, the design of the individual Signal System components. The descriptions must begin at the level shown in the high-level system documentation and must proceed to describe the components in increasing detail. The documentation must ultimately include hardware schematics of all CLASS I and II hardware components and software listings of all Vital Software components.

Contractor must make available for review by the Engineer all system and subsystem software that performs Vital Functions. Review of this software is required in conjunction with the review of the detailed hardware and software analyses. Annotated software listings must be made available in the forms of hard copy and electronic copy.

C. Vital Function Identification and Hazard Analysis
This documentation must identify all Vital Functions implemented by the Signal System. The documentation must include all safety analyses performed on the Signal System and must comply with the requirements specified in this Section.

In addition to the document work products specified in IEEE 1483, Contractor must provide Vital Function identification and hazardous analysis documentation as follows:

1. System Safety Program Plan (SSPP)
2. Wayside Signal System Preliminary Hazard Analysis (PHA)
3. Vital (CLASS I) Hardware Analysis (FMEA)
4. Signal System Interface Hazard Analysis (IHA)
5. Signal System Operating Hazard Analysis (OHA)
6. Signal System Subsystem Hazard Analysis (SSHA)

This documentation must include the analysis of all Vital (CLASS I) Hardware contained in the Signal System and must comply with the analysis requirements in this Section.

D. CLASS II Hardware Analysis

This documentation must include the analysis of all CLASS II hardware contained in the Signal System and must comply with the analysis requirements specified in this Section.

E. CLASS III Hardware Analysis

This documentation must include the analysis of all CLASS III hardware contained in the Signal Systems and must comply with the analysis requirements specified in this Section.

F. Vital Software Analysis

This documentation must include the analysis of all Vital Software contained in the Signal Systems and must comply with the analysis requirements specified in this Section.

G. Calculation of MTBHE

This documentation must include the calculation of MTBHE, as specified in this Section for systems that are quantitatively analyzed.

H. Vital Relay Based Equipment

This documentation must include the analysis of vital relay based equipment and must comply with the analysis requirements specified in this Section.
I. Vital and Non-vital Application Logic Analysis

This documentation must include analysis of the vital and non-vital application logic and must comply with the analysis requirements specified in this Section.

13-3.13 Training Submittal Requirements

Contractor must submit for acceptance of the Engineer the training submittals required by Sub-section 13-9, Training, of this Section. Training is not required for Owner-furnished material.

13-3.14 EMI/EMC Submittal Requirements

Contractor must submit for acceptance of the Engineer, all required EMI/EMC submittals as specified in this Section. EMI/EMC submittals are required for Owner-furnished Material. Contractor must have the manufacturer of the Owner-furnished material review the EMI/EMC submittal associated with its equipment before it is submitted to the Engineer for acceptance.

13-3.15 100 HZ Power Line Analysis

Contractor must perform an analysis of the total projected load of the final configuration of the 100 Hz power line for the entire extension. This analysis must determine the calculated output distribution of the existing 100 Hz substation at Meadowview.

The analysis must include all loads on the 100 Hz power lines and must assume a train occupancy at every station platform. The analysis must show the 480 VAC 100 Hz line voltage (under the load conditions listed above) at each instrument house/relay case on the line, and the total system load. Contractor’s analysis must be submitted to the Engineer for acceptance.

13-4 FUNCTIONAL REQUIREMENTS

The functional requirements of the wayside block signal system and highway-railroad grade crossing warning systems are as described in this Section and as identified on the Plans.

13-4.01 Automatic Route Control

The system must automatically align and lock routes through interlockings and control the aspects of signals to indicate that a safe route is established for train movement through (a) absolute or permissive block protection on sections of single track; (b) permissive block protection on sections of double track; or (c) absolute block protection on a section of double track, as shown on the Plans. The ABS system will automatically align and lock switches for normal direction running (right hand running) trains only. Reverse running train routes must be selected only by the push button route selectors,
LCP or Central as shown on the Plans. The following sequence of events must occur in establishment and occupancy of a route:

A. Detection of approaching train and/or TWC route request.
B. Request for clearance through blocks in advance of a train.
C. Check that advance blocks are clear.
D. Check that no opposing traffic is in effect.
E. Check that all electric locks in advance blocks indicate locked and that their respective switch points are aligned for main line moves.
F. Establish traffic in requested direction.
G. Move and lock switches and lock movements.
H. Establish traffic locking.
I. Clear signal.
J. Upon occupancy of block, establish route locking.
K. Upon clearance of the block by the train, cancel route, and traffic locking.

13-4.02 Block Control

A block is defined as a section of track over which the red control limit of the respective block signal is extended.

The following restrictions must apply to block control logic:

A. One train and one train only may occupy a block at any one time.
B. Simultaneous clearance of a block from its opposite end must be prevented.
C. Block requests must be stored and processed as soon as clearance can be granted.
D. Block cancellation must enable time locking.

13-4.03 Signal Aspects

The following color light signal aspects must be displayed under the conditions described as follows:
A. Intermediate Signals

<table>
<thead>
<tr>
<th>ASPECT</th>
<th>INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED:</td>
<td>STOP-Block occupied.</td>
</tr>
<tr>
<td>YELLOW:</td>
<td>PROCEED-Prepared to stop at next signal or leaving block signal territory.</td>
</tr>
<tr>
<td>GREEN:</td>
<td>PROCEED-Route clear.</td>
</tr>
</tbody>
</table>

B. Interlocking Home Signals

<table>
<thead>
<tr>
<th>ASPECT</th>
<th>INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED:</td>
<td>STOP-Block occupied or opposing traffic established or interlocking not aligned and locked.</td>
</tr>
<tr>
<td>YELLOW:</td>
<td>PROCEED-With caution on main route prepared to stop at next signal; interlocking aligned and locked, or leaving block signal territory.</td>
</tr>
<tr>
<td>GREEN:</td>
<td>PROCEED-Route clear and interlocking aligned and locked.</td>
</tr>
<tr>
<td>FLASHING YELLOW:</td>
<td>PROCEED-With caution on diverging route prepared to stop at next signal, interlocking aligned and locked, or leaving block signal territory.</td>
</tr>
<tr>
<td>FLASHING GREEN</td>
<td>PROCEED-Diverging Route clear and interlocking aligned and locked.</td>
</tr>
<tr>
<td>FLASHING RED:</td>
<td>STOP-Proceed only on manual block instructions from Control. Interlocking route aligned and locked.</td>
</tr>
<tr>
<td>FLASHING LUNAR</td>
<td>PROCEED-With caution on diverging route, interlocking aligned and locked for leaving block signal territory.</td>
</tr>
</tbody>
</table>

13-4.04  Route Request and Cancel

Contractor must provide push buttons, indicator lights, and control stand, on or adjacent to each route entrance signal, as indicated on the Plans. Request for route clearance
and for route clearance cancellation must be enabled from the control stand for all
allowed routes. Contractor must provide TWC loops and controls adjacent to each
route entrance signal as indicated on the Plans. TWC route request and cancel must
be as indicated on the Plans.

13-4.05 Timer Calculations

Timer settings and timer ranges must be calculated by Contractor in accordance with
the Contract Documents requirements and per the AREMA C&S Manual
recommendations. Timer calculations must be submitted for the Engineer's
acceptance. Timer calculations and the associated rationale must be included in
Contractor's PLA. The final value for all timers must be determined during field
operating and demonstration testing. Contractor must adjust the timers to their final
value and include the final settings in the as-built documentation. These final timer
values must also be the default timer values in the processor application logic.

13-4.06 Train-to-Wayside Communications

A. General

The new Owner-furnished wayside TWC equipment will be VECOM COMPACT-
CT as supplied by VECOM USA or approved equal system.

Wayside TWC equipment, as identified in the Contract Documents, will be
provided by RT for Contractor’s installation at Interlocking Home Signals,
passenger station platforms, and other locations as identified on the Plans and
as specified in these Technical Specifications.

The TWC System must provide the functions shown on the Plans and as
specified in these Technical Specifications.

TWC System service manuals, design/programming information, and final
interface design information will be available per the schedule identified in
Section 8, Materials, of the Technical Specifications.

B. TWC System Requirements

Contractor is responsible for the following concerning the Owner-furnished TWC
System:

1. Installation and testing of the TWC System at each TWC loop location
   shown in the Plans.
2. Programming the TWC System at each TWC loop location shown in the
   Plans. RT will provide Contractor with the tools necessary for
   programming.
3. Interface to the TWC System parallel inputs and outputs and RS-485 port
to the Central Control at each TWC loop location shown in the Plans.
C. TWC System Functions

The TWC System will provide the means of train to wayside and wayside to train communications for initiation/request and/or confirmation and alarming of wayside block signaling system functions and highway-railroad grade crossing warning system functions as identified on the Plans and as specified in these Technical Specifications.

1. Wayside Block Signal System Functions include:
   a. Automatic Route Request
   b. Manual Route Request and Cancellation
   c. Wayside Alarm and other Indications Transmitted to the Vehicle TWC System
   d. Wayside Loop ID Information Transmitted to the Vehicle TWC System
   e. Wayside Over Loop Indication Transmitted to the Vehicle TWC System
   f. Transmit TWC message received/decoded from the Vehicle TWC System back to the Vehicle TWC System for confirmation/alarming.
   g. Train Number, Route ID and other information identified in the Plans sent to Central Control for Train Tracking information.

2. Highway-railroad Grade Crossing Warning System Functions

   Nearside Highway-railroad Grade Crossing Warning System Cancellation and Reactivation Request or Activation and Cancellation Request.

13-4.07 Local Control Panel

Contractor must provide local control panels at the interlocking locations as shown on the Plans. These local control panels must initiate route request and cancellation, and other functions as identified on the Plans. Local control panels must interface to the non-vital microprocessor for all controls and indications.

13-4.08 Automatic Highway-railroad Grade Crossing Warning - RT

The functional requirements of the LRT highway-railroad grade crossing warning system must satisfy the requirements of CPUC G.O. 75-C, Section 7 and the Code of Federal Regulations, Title 49, Transportation, Part 234, Grade Crossing Signal System Safety.

A. Warning Time

1. Contractor must provide delays, cancels, and interlocks with the ABS system as specified in this Section and as indicated on the Plans. The RT grade crossing approaches provide full warning time for maximum speed
trains in the normal direction of travel (right hand running). Reverse running trains must activate the crossing on the island circuit and the crossing must remain activated until the train clears the approach.

2. The bell must sound when the lights begin flashing and must continue to sound until the gates return to within five degrees of their vertical position.

B. Power Failure

Loss of utility power must not disrupt system operation for a minimum of eight hours. Excessive battery discharge must cause the gates to descend to the full horizontal position.

C. Malfunction Cut-out

Contractor must provide and install TWC loops and manual push buttons for the operation of the crossing protection systems installed under this Contract as indicated on the Plans.

D. Train Detection

Train detection for the approach track circuits must be double rail 100 Hz ac track circuits or audio frequency track circuits overlaid on the double rail 100 Hz track circuits. Train detection for the island track circuits must be audio frequency track circuits overlaid on the double rail 100 Hz ac track circuits.

E. Preemption and Advance Preemption

Preemption and advance preemption to the traffic signal controllers must be provided by Contractor as indicated on the Plans. An indication that the traffic signal controller is pre-empted must be provided as shown on the Plans and this indication must be event recorded.

F. Second Train Detection (Pump Prevention)

The Signal System must provide second train detection as shown on the Plans to prevent the highway-railroad grade crossing warning system from reactivating while the gates are partially raised.

G. Nearside Grade Crossing Requirements

Contractor must provide and install TWC loops and circuits, indicators, push button selectors, and other associated equipment at certain crossing locations as indicated on the Plans. These are at locations where conventional crossing starts would cause the crossing protection to be activated an excessive amount of time by the light rail vehicle making a station stop within the start limits.

H. Event Recorders/Analyzers
Contractor must provide and install event recorders/analyzers at each highway-railroad grade crossing location. The event recorders/analyzers must comply with the requirements specified in this Section. Contractor must design and wire circuits to monitor events as indicated on the Plans.

I. UPRR Railroad Highway-railroad Grade Crossing Interface Requirements

Contractor must provide and install all equipment necessary to interface with the UPRR grade crossing equipment as indicated on the Plans.

J. Crossing Indicator

Contractor must provide and install crossing indicators for the operation of the crossing protection systems installed under this Contract as indicated on the Plans.

13-5 MATERIALS AND EQUIPMENT

13-5.01 General

All materials and equipment for installation and for interconnection of the Signal System must be fabricated, provided, and installed by Contractor as indicated on the Plans and specified in this Section. All materials and equipment must be the products of manufacturers regularly engaged in the production of such material and equipment and must be of the manufacturer’s latest design that has shown proven revenue service performance of at least 3 years in North America. Materials and equipment must conform to the latest standards of the AREMA Communication and Signal Division Signal Manuals. Materials and equipment must be delivered to the Project site in unbroken packages, reels, or other forms of containers.

13-5.02 Owner-Furnished Materials

RT will provide Contractor with the Owner-furnished Signal System material listed in Section 8, Materials, of the Technical Specifications.

Owner-furnished materials must be accepted, inspected, stored and incorporated into the Work as specified in Section 7 of the Special Conditions.

13-5.03 Labeling

All components, subassemblies, and assemblies must be appropriately labeled by Contractor so that they may be readily identified as specified in these Technical Specifications.

All wiring must be clearly tagged and identified by nomenclature, termination location, and location of opposite end of the wire. Wire tags must be of the split sleeve type as
manufactured by Critchley Brand or Brady Wire Tags or approved equal. Labeling text must be clearly legible.

All controls and adjustments must be clearly identified as to function, and must be marked or indexed so that the control position or direction of rotation can be readily identified.

Fixed guide marks on controls or adjustments must be provided, if such controls or adjustments require presetting for a standard maintenance operation.

13-5.04 Relays

A. General Requirements for Relays

1. In general, relays must be plug-in types. Relays of each type must be uniform in design and contact assembly.
2. Relays must have a sufficient number of contacts for the number of circuits to be controlled. Each relay or relay-repeater combination must have at least 2 spare dependent front-back contacts, or 1 spare independent front and one spare independent back contact.
3. All relays and equipment specified must be capable of rated performance through an operating temperature range of – 40°C to +71°C.
4. All relays must be in dust-proof enclosures, except that provision must be made for ventilation where required for heat dissipation.
5. All relays must be equipped with front mounted voltage and current test terminals.
6. Contractor must provide test documents verifying that vital relays supplied satisfy the following test: With any one back contact welded, no front contact of the relay may make, with the application of coil, voltage up to twice the system operating voltage. In lieu of the test documents, Contractor must provide relays with non-welding back contacts, or take other precautions, which are subject to acceptance by the Engineer.
7. Contractor must provide test documents verifying that vital relay contacts used in high current applications are rated for a minimum of 150 percent of the maximum current that will be conducted through the contact. Paralleling of contacts for high current applications is allowed only with the prior written acceptance of the Engineer following the process for deviations. Each contact used in parallel must be rated for a minimum of 100 percent of the maximum current that will be conducted through the paralleled contacts.

B. General Requirements for Vital DC Relays

1. Vital relays must be of the biased-neutral, plug-in type, with a transparent dust cover made of a non-flammable composition.
2. Relays must have a nominal operating voltage of 12 volts. They must be capable of picking up and operating continuously, without damage, when energized with 7 to 21 volts.

3. Relays must conform to Section 6 of the AREMA C&S Manual, except as otherwise specified in this Section.

4. Each biased neutral vital relay must have a minimum of six dependent front-back contacts.

5. Arc suppression for vital relays must be built into the relay or into its plugboards. Arc suppression must be provided for all relays.

6. Contact arrangements must be identical for similar types of relays.

C. Switch Operating Relays

1. Vital switch operating relays used for control of switch-and-lock movements must meet the same requirements as specified for vital biased neutral relays, except that the contacts must be heavy-duty metal-to-metal construction.

2. Each contact must be equipped with a magnetic blowout feature to effectively interrupt high currents and minimize contact wear. All switch-operating relays must be identical. One normal and one reverse switch-operating relay must be provided for each switch-and-lock movement. Switch operating relays must be ALSTOM Type B, US&S Model PN150BM, Safetran System Type "ST", or approved equal.

D. Vital Overload Relays

Vital overload relays must be used to detect a switch-and-lock movement over current condition. Contractor must provide one overload relay for each switch-and-lock movement. Each overload relay must have two coils and a sufficient number of contacts to perform the function as indicated on the Plans. The time for pick up of the overload relay must be the manufacturer's recommendation, but must not exceed 10 seconds. Overload relays must be ALSTOM Type B, US&S Model PN150SO, or approved equal.

E. Vital Time Element Relays

Vital time-element relays must be of the plug-in type for nominal 12-volt dc operation. Vital time-element relays must have a minimum of 2 contacts that will close only at the end of the adjusted timing cycle, and at least 2 independent check contacts that, when closed, check the normal or de-energized position of the relay. Each vital time-element relay must have a time adjustment that can be sealed. The time adjustment must be from 0 second to 19 minutes, 59 seconds in one-second increments. When the relay is sealed, it must be impossible to change the timing interval. The timing interval must be capable of repeated operation with an error of no more than "0.5" second when the applied voltage is between 9 and 16 volts, and ambient temperature between -40° C and +60° C. Vital time element relays must be ALSTOM Microchron, Type B2, US&S PN-150EVT or approved equal. Vital slow-drop timer relays must be US&S PN-
150EVT-SD or an approved equal. Contractor must supply surge protectors, filters, or other required protection device(s) for proper operation and protection of electronic timers.

F. Vital Flasher Relay

Vital flasher relays must be of the plug-in type for nominal 12 volts dc operation. Vital flasher relays must be Safetrans part number 400700X-X equipped with Safetrans flasher module, ALSTOM Type B equipped with ALSTOM flasher module or approved equal. The flashing rate must be 45 to 60 pulses per minute for the highway-railroad grade crossing warning system and 45 to 60 pulses per minute for the wayside block signaling system.

G. Vital Slow Acting Relays

Vital slow acting relays must be of the plug-in type for nominal 12-volt dc operation. Slow acting relays, e.g., slow pickup or slow release, must have their slow acting characteristics obtained by the use of copper or aluminum washers or slugs applied to the relay core. Vital slow acting relays must be ALSTOM Type B, US&S Model PN, or approved equal.

H. Vital AC Track Relays

Vital ac relays must be plug-in type, two-element, 100 Hz, vane-type induction relays. Vital ac relays must be capable of operating continuously and successfully without resultant damage with a minimum voltage range of 100 volts to 135 volts, inclusive, applied to the local winding and with a minimum voltage range of 0.75 volt to 5 volts, inclusive, applied to the control winding.

1. Vital ac relays must meet the requirements established by AREMA Signal Section Specification, Part 6.1.35, unless otherwise specified in this Section, with the exception that these relays must be plug-in type. They must not have a screened breather and must not have binding posts.

2. Each vital AC relay must have a minimum of 6 front contacts and 4 back contacts. Each front contact must be of the silver-to-metalized carbon type.

Vital AC track relays must be US&S Model PV 250 or approved equal.

I. Vital Magnetic Stick Relays

Vital magnetic stick relays must be US&S model PP-151, Alstom type B1, Safetrans type ST1 or approved equal.

J. Non-Vital Relay

1. Contractor must provide and install non-vital relays, as required by the design and as shown on the Plans. The non-vital relays must be of the
plug-in type as manufactured by Potter Brumfield part number KRPA-14DG-12 or approved equal, unless otherwise specified in the Contract Documents or required by the design.

2. Each non-vital relay must have a minimum of 3 dependent Front-Back contacts. The movable contacts of the non-vital relays must be bifurcated.

3. The non-vital relays installed must have a nominal operating voltage of 12 volts dc, but must be operated continuously with an applied voltage ranging from 8 to 21 volts without damage or a change of pick-up or drop-away values.

4. Non-vital relays installed must pick up in 25 milliseconds or less with an applied voltage of 12 volts and drop in a maximum of 50 milliseconds with an applied voltage of 15 volts.

5. All non-vital relays installed must have a removable dust cover. The dust cover must be non-metallic and must withstand temperatures up to 71° C without becoming deformed.

6. Contractor must supply, install, and wire all plugboards for the non-vital relays.

7. Each relay must be securely fastened to its plugboards by means of a spring clip or other method authorized by the Engineer.

8. The non-vital relays installed must be identical by type and class or by the function for which they are used.

9. Contractor must provide means of mounting and installing relay identification tags for each relay. The tags must be legible from the front of the relay and be replaceable, but must be secure during normal maintenance.

10. Non-vital relays used for line circuits must have high enough impedance for proper operation.

K. Non-Vital Time Element Relay

Contractor must provide and install non-vital time element relays, as required by the design and as shown on the Plans. The non-vital time element relays must be AGASTAT, Part Number DPCXX012XSQAXAA or approved equal.

L. Non-Vital AC Relay

Contractor must provide and install non-vital 120 volt AC relays, as required by the design and as shown on the Plans for operation of the equipment case power off blue lights. The non-vital AC relays must be Potter Brumfield part number KRP11AG-120 or approved equal.

13-5.05 Electrical Grounding

Contractor must provide grounding systems for the Signal System.

A. Grounding System Functions
The functions of the grounding systems include the following:

1. To protect personnel and equipment from electrical hazards.
2. To reduce fixed potential for system neutrals.
3. To reduce or eliminate the effect of electromagnetic and electrostatic interference arising both within and outside of the systems.

B. Materials

Grounding materials must be copper or copper alloy, corrosion-resistant with high-conductivity. All grounding connection cables must be stranded copper conductors, softdrawn, Class B conforming to ASTM B with THW insulation except that where they are buried or concrete encased, the grounding connection must be bare. Fittings for splices, taps, and terminations must be made with high conductivity compression connectors that must be fully insulated, after compression, with tape that is compatible with the cable insulation.

C. Protective Grounding

Unless otherwise indicated in the Contract Documents, all exposed non-current carrying metallic parts of electrical equipment, raceway systems, pull boxes, terminal boxes, and metallic cable armor must be grounded. Contractor must ensure that a good electrical connection is provided between mechanical parts of the equipment and their metal equipment enclosures. Equipment that Contractor designs and provides must be arranged to ensure good electrical connections between enclosures and protective grounds during the operating life of the equipment.

1. Connections to the equipment must be with bolt connectors after the contact surfaces have been cleaned. Where grounding is not specifically indicated, but is required by the NEC or the National Fire Protection Association, suitable ground connections must be made by Contractor so that completed work must comply with that code in all respects.
2. Contractor must install grounding ferrules or bare copper wire jumpers where flexible conduit, one and 1-1/2 inches or smaller, is used to connect rigid conduit to equipment. Copper wire jumpers must be used where 2-inch conduit or larger is used. Contractor must not use ground cable smaller than AWG 8, or smaller than required by the NEC.
3. AC receptacles located within the equipment cases must be of the ground fault interrupter type 20 amp spec grade and must meet the requirements of the NEC.

D. System Grounding

Neutrals throughout the system must be solidly grounded, unless otherwise indicated in the Contract Documents. Contractor must follow the installation procedures specified in this Section. Grounding connection to the neutral must be made at one point only per service, and that ground point must be at the main
terminals of the panel first in line from the apparatus or system which supplies the service. For example, a transformer neutral, unless otherwise indicated in the Contract Documents, must be connected with a fully rated cable to the neutral in the first panel served. The grounding connection must be made from this point by grounding cable. Grounding wires must be sized for the service as required by the NEC.

E. Interstation Cables, Conduit, and Raceways

All interstation cables, conduits, and raceways must be grounded by Contractor to the associated system ground as indicated in this Section. All interstation cable shields must be grounded once only in each section. The ungrounded end of the cable shield must be connected individually to low-voltage protectors. The low-voltage protectors must discharge all voltages in excess of 350 volts dc, and 350 volts rms from zero to 1 MHz.

F. Shielding

The shields of interstation cables and other trackside cables must be sectionalized at cable termination points.

G. Grounding Cable

Cable must be copper, soft-drawn, bare, Class B conforming to ASTM B 8.

H. Ground Rods

Ground rods must be copper clad steel, Grade 40HS conforming to ASTM B 228. Unexposed ground rod connections must be exothermic welds.

13-5.06 Switch-And-Lock Movement Layouts

RT will furnish switch and lock movement layouts shown on the Plans. Contractor must provide all additional material necessary for a complete installation of a standard lock layout as shown on the Plans.

Dual movements will be US&S Style M23A 110 volt dc dual control, high speed.

Each switch and lock movement will be supplied with an internal wiring diagram of a plastic laminated or plastic encased type, which must be fastened to the underside of the contact compartment cover.

Installation and adjustment of switch and lock movements must conform to the requirements of the AREMA C&S Manual, Parts 12.2.1, 12.2.5, 12.2.15, and 12.2.16.
All front rods will be of the hinged type, insulated, and adjustable. Lock, detector, and front rods will be insulated. The point detector rod must be connected to the normally closed point.

Each switch and lock movement operating layout will include an elevated cast iron junction box suitable for terminating the interconnecting wire and cable.

A complete push-pull booster assembly layout, including all mounting hardware, crankstands, cranks, rollers, fittings, baskets, and rods will be provided by RT with each switch and lock movement for number 20 or longer turnouts as shown on the Plans. Contractor is fully responsible for the installation and adjustment of each switch and lock movement layout.

Installation of rods and mechanical connectors must conform with the applicable portions of AREMA C&S Manual Part 12.

13-5.07 Signals

Contractor must provide signals as shown on the Plans. Signals must conform to the requirements for color light signals of the AREMA C&S Manual, Section 7 unless otherwise specified herein in this Section. Signals must be complete with LEDs, lenses, terminal boards, visors, hoods, blanking plates, wiring and mounting hardware. Signals must be freestanding and be complete, with background, steel-mast, junction box, removable ladder and appropriate foundations. Low signals must not have backgrounds or ladders.

Signals must be of the LED color light signal type and must be certified by the microprocessor and signal manufacturer to be compatible with the solid-state equipment that provides power to the signal to provide a fail-safe aspect. Aspects not used on the 3 light units must be equipped with a blanking plate as shown on the Plans. LED color light signals must be GETSGS Part Numbers: 45879-02 (Green), 45880-02 (Yellow), 45881-02 (Red) and 45960-02 (Lunar White), manufactured by GELcore, or approved equal.

Signals must be located within 5 feet of the controlling insulated joint. The signal aspect must be distinct and unmistakable when viewed from a height of 7 to 12 feet above top-of-rail at a minimum distance of 1,000 feet.

13-5.08 Push Button Route Selector

Push button route selection stands for initiating route clearance requests and cancellations must be provided by Contractor at locations indicated on the Plans.

Push buttons must be in weather proof, locked enclosures mounted on or adjacent to the respective signal or mounted adjacent to the respective mini-high platform as shown in the Plans. Push buttons, door limit switches, push buttons with indicator light emitting diodes (LED), and LED indicators must be of the hermetically-sealed waterproof type.
13-5.09  AC Track Circuits

The Signal System must use double rail 100 Hz AC track circuits for wayside block signaling and highway-railroad grade crossing warning system train detection as shown in the Plans and as specified in these Technical Specifications.

Track circuit limits must be as defined by the insulated joints indicated on the Plans, and track circuit detection must extend to cover the clear point of tracks connected to the mainline.

Track circuits must function to provide continuous train detection throughout the length of the circuit whenever a shunt of 0.20 ohms is applied to the rails, including turnouts.

The track circuits must function over the distances as shown in the Plans with ballast resistance of 3 ohms or greater per 1,000 feet.

The track circuits must be capable of functioning properly and reliably under the EMI/RFI conditions that will be present. Track circuit design must take into consideration EMI/RFI conditions that exist in conjunction with 750 VDC propulsion systems, light rail vehicle systems, and utility company power distribution systems.

AC Track circuits must be immune from improper operation due to crossed or grounded wires or any other influences such as capacitive and inductive coupling or stray currents.

Selection and adjustment of track circuit components must be coordinated with the configuration of the 100Hz power distribution network to assure that the track circuits will operate properly when the 100Hz distribution line is energized from a single 100 Hz converter.

13-5.10  Audio Frequency Track Circuits

Contractor must provide audio frequency (AF) track circuits for train presence detection where required for grade crossing approaches, island circuits and electric lock release track circuit locations, as indicated on the Plans. The AF track circuits must provide vital fail-safe train detection. Contractor must be aware that the use of AF equipment in the Signal System specified in this Section requires the utmost care in design and application. AF track circuits must be Safetran Systems Phase Shift Overlay 4000 (PSO 4000) and Safetran Systems Intelligent Processor Island Track Circuit (IPITC) or approved equal. The AF track circuit equipment to be provided must meet or exceed the following criteria and characteristics:

A. The track circuits must function over the distances as shown in the Plans with ballast resistance of 3 ohms or greater per 1,000 feet.
B. The track circuits must be capable of functioning properly and reliably under the EMI/RFI conditions that will be present. Track circuit design must take into consideration EMI/RFI conditions that exist in conjunction with 750 VDC propulsion systems, light rail vehicle systems, and utility company power distribution systems.

C. Contractor must select operating frequencies that will not interfere with the proper operation of other systems or adjacent AF circuits and the design must ensure adequate protection against AF cross-talk, adjacent track interference, spillover under normal and broken down insulated joint conditions, and any other source that may cause AF interference problems. Contractor must examine the existing signaling As-Built Plans and follow the AF track circuit manufacturer’s recommendations in assigning frequencies. Contractor must use the highest AF frequencies possible to minimize pre-shunt and post-shunt and to ensure proper operation of the highway-railroad grade crossing stick logic.

D. AF track circuit frequencies must be coordinated with UPRR signal and communications equipment frequencies.

E. Track circuits must function to provide continuous train detection throughout the length of the circuit whenever a shunt of 0.20 ohms is applied to the rails, including turnouts.

F. The AF track circuits must be designed and constructed so that at any point in the circuit, the rail-to-rail train detection signal potential is not less than 250 millivolts peak-to-peak.

G. AF track circuits must be immune to improper operation due to crossed or grounded wires or any other influences such as capacitive and inductive coupling or stray currents.

H. No combination of frequencies and/or coding may produce a signal that may improperly energize a track relay.

I. The detection signal must be a coded carrier signal to distinguish the presence of a legitimate signal from any noise or a signal produced by an amplifier that goes into oscillation. The track circuit receiver must verify carrier and coding of the detection frequency in order to energize the track relay.

J. The AF track circuits must operate safely and reliably when superimposed on 100Hz double rail power frequency track circuits as shown in the Plans.

13-5.11 Impedance Bonds

Contractor must provide and install impedance bonds, as indicated on the Plans, complete with cables, rail connections, covers, mounting hardware and other necessary appurtenances.
Impedance bonds must have a 2-hour dc rating of 1500 amperes per rail (nominal 1500 amperes rating and 8000 amperes per rail for one minute.

Contractor must connect the substation negative return cables provided and installed under this Contract to the impedance bonds.

Impedance bonds must use either oil or petroleum as a cooling medium and must conform to the applicable requirements of the AREMA C&S Manual, Part 8.4.5.

Impedance bonds must be as manufactured by Power Engineering Industries, or accepted equal. Impedance bonds must be untuned unless otherwise authorized by the Engineer and must have an impedance of 0.85 ohms minimum at 100 Hz. Each Impedance Bond must have the field tunable circuit. The bonds must be so designed that audio frequency track circuits up to 20 kHz may be superimposed on 100 Hz power frequency track circuits.

13-5.12 Event Recorders/Analyzers and Laptop Computer

Contractor must provide and install event recorders/analyzers to monitor Signal System operation at each of the interlockings, intermediate signal, and highway-railroad grade crossings locations shown on the Plans. The recorders must be relay rack mounted in each of the instrument housings.

The event recorders installed by Contractor must be of the microprocessor type. The event recorder must have a service proven history of a minimum of 3 years on an operating rail passenger system with similar application. The Engineer will determine the acceptability of the event recorder proposed and that decision will be final.

Each event recorder/analyzer must be programmed by Contractor with the site-specific logic associated with the events to be monitored. Contractor must also supply the site-specific programming logic on CDROM. The site-specific logic must include assigning each input to a front panel indicator and assigning the name of each input to the associated data printout. The site-specific logic must be capable of being downloaded to the event recorder/analyzer as required for maintenance and repair. Contractor must supply a portable means of downloading the site-specific logic.

Contractor must provide, in addition to the field event recorders, a portable means of transferring memory and transferring it to a printer located at a central location. This portable means of obtaining the information must be via laptop computer. Contractor must supply the laptop computer complete with all necessary hardware and software including the operating system software. The laptop computer must be Panasonic semi-rugged-laptop-toughbook-53 or approved equal.

The event recorders installed by Contractor must have sufficient memory to store a minimum of 299,000 events before the first occurrence recorded is written over. When
an event occurs, the recorder must also store the time and the state of all other items being monitored.

Contractor must design and wire circuits to monitor interlocking and highway-railroad grade crossing events, as indicated on the Plans. Additional event recorder/analyzers are required when the number of monitored inputs at a location exceeds the number of event recorder/analysers available on the front of a single unit.

Event recorder/analyzers must be manufactured by Progress Rail, HAWK Event Recorder or approved equal. Event recorders must operate from the battery B14 bus.

13-5.13 **Wire and Cable**

A. **General**

Contractor must provide single and multiple conductor wire and cable as indicated on the Plans. Such wire and cable must be insulated and jacketed for continuous operation in wet and dry locations on AC and DC signal circuits operating between zero and 600 volts. Wire and cable must be shielded or non-shielded, twisted or not twisted, armored or non-armored, and must be used for installation in conduits above and below grade, aerial cables, and for signal case wiring as indicated on the Plans and as specified in these Technical Specifications. The manufacturer must have a minimum of 5 years reliable experience in supplying vital circuit signal cables of the type specified on at least five Class I railroads (as defined in ARR, AREMA, FRA), with a minimum of 1,000,000 cable feet installed.

B. **Conductors**

Conductors must be soft or annealed copper. All conductors 16AWG or smaller must be tinned conforming to ASTM B33 or ASTM B189. Bare conductors must conform to ASTM B3. All stranded conductors must conform to ASTM B 8, Class B, unless otherwise specified. Signal cables leaving instrument houses, relay cases, and junction boxes, must be AWG #14 minimum.

C. **Conductor Sizing**

Contractor must size all conductors as shown on the Plans and in accordance with NEC requirements.

D. **Power Supply Cable**

Cable must be multi-conductor, rated 600 volts, meeting ICEA S-68-516 and UL44, current editions. Insulation must be ethylene-propylene (EPR). Power cable used in conduit applications must have a polyethylene (PE) jacket. Power cable used in aerial applications must have a chlorosulfonated polyethylene (CSPE), neoprene, or PE jacket suitable for aerial applications, U.V. stabilized, and sunlight resistant. The 60 HZ power feeder cable must be twisted.
E. Power Bond Cable

Cable must be single-conductor, 500 MCM, extra flexible stranded, tinned or alloy-coated soft annealed copper rated 2KV with ethylene propylene rubber (EPR) insulation and an oil and sunlight resistant chlorosulfonated polyethylene (CSPE) jacket.

F. Signal Cable

Cable must be multi-conductor, rated 600 volts minimum, insulated, and jacketed, meeting ICEA S-68-516 and AREMA, current editions. Insulation must be ethylene-propylene (EPR) with a PE jacket extruded overall. Aerial signal cable must have a chlorosulfonated polyethylene (CSPE), neoprene, or PE jacket suitable for aerial applications, U.V. stabilized, and sunlight resistant.

TWC System cable from the loop distribution panel to the loop buffer must be two pair #10 AWG twisted shielded cable. This cable must meet all Signal Cable requirements.

G. Insulators

Strain insulators must meet the requirements of Section 11-4.10, “OCS Assembly Requirements,” of these Technical Specifications.

H. Identification

1. Single-Conductor Cable - Each length of cable must have either the manufacturer's identification printed on the surface of the jacket or the manufacturer's color threads placed under the insulation.

2. Multiple-Conductor Cable - Each length of cable must be permanently identified as to the manufacturer and year of manufacture, at intervals of not less than 30 inches, by a moisture-resistant marker tape under the jacket and parallel to the longitudinal axis of the cable. Aerial cable jacketing must be marked “Aerial Cable – Sunlight Resistant”.

I. Shipping and Marking

2. Shipping Lengths - Cable must be provided in lengths suited to the pulling calculations developed by Contractor. All cable must be shipped on reels, adequately protected from damage in shipment by heavy wrapping or wood lagging.

3. Reel Design - Each length of cable must be wound on a separate reel. Reels must be substantial to withstand reasonable handling and must be so designed that the inner end of the cable must be accessible but protected from injury. The diameter of the drum must be at least 14 times
the cable diameter to prevent damage to the cable during reeling. The arbor hole must admit a spindle 2½ inches in diameter without binding.

3. **Cable Winding on Reels** - Cable must be closely and tightly wound in each layer on reels. Both ends of the cable must be accessible and sealed to prevent the entrance of moisture and securely fastened so that they will not become loose while in transit.

4. **Reel and Cable Information** - Each reel must contain on the outside flange, plainly legible and weather resistant, information to show the manufacturer's name, purchase requisition number, lengths of each section of cable, number of conductors, gauge of conductors, and the name and address of the consignee. Reel Rolling Instruction - An arrow must be painted on one flange of each reel pointing the opposite direction from the outer end of cable with the words "Roll This Way."

### 13-5.14 Conduit

**A. Rigid Conduit**

Rigid conduit must be used by Contractor as shown on the Plans. Where conduit crosses under existing tracks, as shown on the Plans, it must be installed by jacking. No excavation of the track bed is permitted. The jacking method must be submitted to the Engineer for acceptance.

The types of conduit to be provided by Contractor for the various applications must be as follows:

1. Rigid steel conduit must be made of the best grade standard-weight steel pipe protected inside and outside by a coat of hot-dip galvanizing. Where elbows are used, they must be long radius type. Steel conduits must be protected in shipping and handling by approved thread protectors.

2. Thick-wall polyvinyl-chloride conduit, High Impact Schedule 80, referred to in this Section as PVC conduit, must be provided for installation where conduit is not in the trackway. Where elbows are used, they must be rigid PVC or steel of the long radius type.

3. PVC conduit that will be exposed to sunlight when it is installed must be rated as UV resistant.

4. Innerduct must be smooth wall polyethylene type SDR-11 as manufactured by TVC Communications or approved equal.

5. Split PVC conduit must be a length of PVC conduit split along its length specifically manufactured to encase a pre-installed cable. Split PVC must be either Schedule 40 or Schedule 80 as shown for specific applications on the Plans. The two halves of a section of split PVC conduit must be secured at a minimum spacing of 12 inches using stainless steel tie wraps or stainless steel band clamps. Sections of split PVC conduit must be joined together using manufactured couplings designed specifically for this purpose. Split PVC conduit may be used only for fiber optic cable system work.
6. Slit corrugated conduit must be a heavy duty polyethylene wrap used for encasement of a pre-installed cable when bends are required. Slit corrugated conduit must be Fiber-guard® HDPE conduit as manufactured by ARNCO or an approved equal. Sections of slit corrugated conduit must be joined to other sections of slit corrugated conduit or to sections of rigid conduit using connectors that are manufactured specifically for making these types of connections. Slit corrugated conduit must be used only where bends are required or for short (under 5’ in length) runs of straight conduit. Slit corrugated conduit must be used only for fiber optic cable system work.

B. Flexible Conduit and Hose

1. Where used, hose must be Braided Cordura Rayon, vari-purpose hose internal tube Hycar neoprene cover as made by the Acme Rubber Mfg. Co. or an approved equal.
2. Where the Engineer permits the use of metallic flexible conduit, it must be Type HC "Sealtite," American Brass Company, or an approved equal.

C. Fittings

1. Manufacturer-approved PVC fittings must be used for PVC conduit. All fittings for rigid steel conduit must be of cast malleable iron and must be protected by hot-dip galvanizing.
2. Expansion joints for PVC conduit, if required under the Contract Documents, must be as manufactured by Kraloy, Barrett Division of Allied Chemical, Triangle Conduit and Cable Co., or an approved equal.

D. Sealing Compound

Sealing compound for use in sealing interior cable entrances must be in accordance with the AREMA C&S Manual, Part 15.2.15. The sealing compound must be "Dux-seal" as manufactured by Johns-Manville Co. or an approved equal.

E. Weather Heads

Cast metallic weather heads are required on all vertical cable entrances to prevent the intrusion of water. The weather heads must be securely fastened by Contractor to the conduit riser. All unused cable entrance plugs must be sealed with a "plug" or equivalent device by Contractor. In existing locations where new cable is to be added to an existing conduit riser containing cables, installation of a weather head is not required. Sealing compounds and other preventative devices in lieu of weather heads is not allowed.
13-5.15  **Instrument Houses, Cases, and Junction Boxes**

Instrument houses, cases and junction boxes must be provided by Contractor as shown on the Plans and as specified in this Section.

A. Instrument houses and cases must be completely factory-wired with all necessary equipment. Wiring must conform to the requirements for wiring in weather-protected housings of the AREMA C&S Manual, Section 10 or NEMA Standard IS-70, as applicable.

B. Contractor is responsible for determining the size of the instrument houses, cases, and junction boxes required for each location based upon the final accepted equipment layouts and as specified in this Section.
   1. For houses, aisle ways between rows of equipment must have a minimum continuous horizontal clearance of 30 inches measured between floor level and height of 6 feet, 6 inches above floor level.
   2. For cases, the case must be oriented so that the relays and other signaling equipment are on the side facing the track being controlled. Cable must be brought into the floor of the case on the side facing away from the track.
   3. Relays and electronic components that require periodic test and adjustment must be mounted a minimum of 18 inches above floor level and no higher than 5 feet above floor height.
   4. Contractor must adapt the general house layouts shown in the Plans based upon site-specific requirements and its accepted circuit plans.

C. When calculating the quantity of equipment for houses and cases, Contractor must allow space for 20 percent additional equipment in each rack.

D. Prior to beginning manufacture of the instrument housing or junction box, Contractor must submit plans showing the size, type, and equipment layout for the various type of houses, cases, and junction boxes it intends to supply.

E. Each instrument house and case must have utility power connection, service meter fitting, circuit protection devices, and all appurtenances necessary to supply the power required at each site. Power service connection points must be as indicated on the Plans.

F. Houses and cases must be weather-tight and dust-tight in accordance with requirements of National Electrical Manufacturers Association (NEMA) for a 3R enclosure. Ventilation must be provided as specified in this Section. Housing must be of 12-gauge galvanneal steel for floors, walls and doors. Floors must be designed for a minimum of 250 lbs. per sq. ft loading. Roofs must be no less than 14-gauge galvanneal steel with a minimum of 50 lbs. per sq. ft loading. House panel seams must be continuously welded and ground smooth prior to Contractor applying finish. The entire structure must be powdercoated on the
outside with TGIC Polyester Powder with a nominal thickness of 4 mils, but no less than 3 mils at any point on the surface of the enclosure. The exterior color must be light gray, except for S1155IH and S1165IH, which must be painted a sand or tan color. RT will provide Contractor with a paint sample of the sand or tan color. The exterior of the new houses and cases must be coated with 2 coats of an RT accepted anti-graffiti coating. The interior surfaces must be finished with a primer and two coats of white latex enamel paint. Contractor must submit color samples for Engineer's review prior to painting. Contractor must submit manufacturer's coating/painting system procedure for reference, in case touch painting or surface coatings have to be restored. The procedure must include the type of coating products used, the required preparation, and the mil thickness of each application coat wet and dry, as well as any additional information needed to ensure restoration of the manufacturer's coating finish.

G. The houses and cases must be complete with powder coated steel equipment racks, moveable shelves, fixed overhead wire chase, wall mounted wire chases, and backboards. Entrance and instrument racks must be open-frame welded steel telecommunication type racks with 19-inch, 23-inch, or 30 inch wide panel spaces. Racks must be approximately 84-inches in height. Panel mounting holes must be 12-24 tapped on EIA universal spacing located on both front and rear flanges. Supports must be included for mounting AREMA wire terminals, relays, and rack mounted equipment. Additional cross supports must be included to support cable and wire at the backs of the racks. The racks must be electrically insulated from each other and from the supporting framework. Each rack must be equipped with a ground stud for use in attaching a ground wire.

Contractor must individually run ground wires from each rack’s ground stud to the house signal ground plate.

H. Each house and case must have a minimum 1-inch thick layer of Thermax insulation on the walls, doors, and ceiling. A minimum 2-inch thick layer of Thermax insulation must be applied by Contractor under the floor. The floor and the top surface of the equipment shelves must be covered with a layer of the housing manufacturer’s standard non-skid rubber matting.

I. Houses and cases must have hinged doors with a three-point catch and handle. The handle must be configured with a locking hasp to accept a standard signaling padlock. The door locking mechanism on houses must be configured so that the door can be opened from the inside, even if a padlock has been inserted in the exterior locking hasp. Each door must be fitted with a mechanism for holding the door open in both the 90° and 180° positions. Grease fittings must be included at each door hinge.

J. Each upper corner of the houses, and the top of each end wall of the cases, must have eyelets for the purpose of lifting the housing. The eyelets must either be permanently welded to the housing structure, or must be securely bolted to the structure. Contractor may submit an alternate method for lifting the housing.
K. All Contractor-provided, non-signaling-specific electrical distribution products must be U.L. listed and must be installed in accordance with the requirements of the NEC. Power circuits for housing lighting, ventilation, and convenience receptacles must be run by Contractor in electrical metallic tubing (EMT) that is secured to the housing structure with clips and brackets specifically designed for the securing of conduit. Conduit clips and brackets must be free from sharp or protruding edges that can contribute to snagging of clothing or to either personal injury or damage to house wiring.

L. House lighting, vent fan, and receptacle loads must be fed from a ground fault interrupt circuit breaker used exclusively for these loads. Signaling logic and appliance power loads must be fed from separate circuit breakers. Circuit breakers and wiring must be sized by Contractor.

M. Copper grounding plates must be provided by Contractor as shown on the Plans. Each corner of houses and one end of each case must have Type VS exterior welded grounding connections, similar to Erico No. SB01VS06.

N. Housing must be fitted by Contractor with backboards for the wall mounting of equipment. The backboards must be constructed of 3/4" AB marine exterior plywood, which must be primed and painted by Contractor on all surfaces, as specified above for interior surfaces. Backboards must be primed and painted after all mounting and wire access holes have been drilled in the backboard. Any wood that may afterward be exposed during fabrication must be re-primed and re-painted. The "A" side must be the exposed side.

O. Overhead cable chases must be steel and must be a minimum of 6" wide and be securely affixed to the house structure. The bottom of the cable chase must be no lower than 79" above top of floor and must have a minimum clearance above the chase of 6". The cable chase must be free of any sharp edges that could result in damage to wiring, or to personal injury.

P. Contractor must provide wire panduit for securing all wires and cables, except where wiring is otherwise secured in overhead cable chases in houses. Wire panduits must be sized by Contractor for the wiring required by the accepted circuit plans, plus an additional space allocation of 40% for future wiring in each panduit. Panduits must be complete with covers.

Q. Terminals and both ends of all wires must be tagged by Contractor with the circuit nomenclature and “to and from” terminal designation assigned by Contractor.

R. Houses must have switch-controlled fluorescent lighting fixtures located above each open aisleway. Each fixture must be a 3 bulb, 4-foot, 32 watt tube fixture (electronic ballast) with a high-quality prismatic lens and reflector. A three-way light control switch must be provided by Contractor at each personnel access door. Contractor must also provide grounded 20A duplex convenience...
receptacles. As a minimum, one receptacle must be located near each light switch and a receptacle must be located near the equipment shelf.

S. Two thermostatically-controlled vent fans must be located at the roof ridge or at the end walls of the house. A thermostatically-controlled vent fan must be located on the end wall of the case. The vent fans must be located relative to the fresh air inlets so as to draw air over the equipment. The fresh air inlets must be hooded, screened, and provided with replaceable dust filters. The thermostat must be adjustable between 20° C to 44° C.

T. Instrument houses and cases must be equipped with a blue light as manufactured by Austin Electronics, Model 2020BHA Blue Hi-Dome or approved equal, for indicating power off, as shown in the Plans.

U. Instrument houses and cases must be equipped with a ground detector light for indicating that a ground has been detected, as shown in the Plans.

V. A photocell and motion sensor activated light must be mounted over each of the personnel entrance doors. Light units must be a minimum 60 watt unit for exterior mounting. Bulb must have a lexan cover. A manual over-ride light switch must be mounted inside the house next to the door opening.

W. All 480-volt wiring and terminals must be protected by conduit or protective insulated covering. Exposed terminals or wiring are not allowed. The 480-volt equipment must be mounted on a sidewall of the house and in the rear of the equipment case. Access to 480-volt terminals and equipment must not be blocked by placement of other wiring or equipment.

X. Air Conditioning – Contractor must provide air conditioning at each Instrument House (IH) as shown on the Plans. Air Conditioner must operate at 208V, 1 phase input.

Y. The housing must have precast foundations as specified in Section 13-5.16.

Z. Junction boxes must be rain tight and dust tight, NEMA 3R, ventilated and have hinged doors with a single-point catch and handle. Contractor must provide hasp and padlock. Junction boxes must be made of either cast aluminum or cast iron with the appropriate interior cable supports and backboards. Ground mounted junction boxes must be provided complete with pedestal bases. Pole mounted junction boxes must be provided complete with mounting hardware.

13-5.16 Foundations

A. Precast concrete foundations must be made of 4,000 psi concrete, complete with anchor bolts, nuts, and washers, in accordance with the AREMA C&S Manual, Part 14.4.

C. Reinforcing bars and wire mesh for precast units must be in conformance with AREA requirements, as specified, and with the AREMA C&S Manual, Part 14.4.


13-5.17 Traction Power Bonding

Power bonds must be as manufactured by Erico Products, Inc., or an approved equal. Contractor must apply all required traction power bonding to make the traction power and signaling systems completely operational. Bonds must be applied to all bolted joints, frogs, special work, impedance bonds, and at all locations required to pass traction power. Bonds must be applied at all required locations regardless of the signal configuration. All bonding must be as shown on the typical drawings in the Plans.

13-5.18 Locks and Keys

Contractor must provide and install temporary locks for all equipment provided under this Contract having hinged or removable doors, and as otherwise required by these Specifications. Contractor must coordinate with RT for the type of temporary locks to be installed. These locks must be keyed in a manner that is accepted by the Engineer. RT will replace Contractor’s temporary locks with three different types of locks as follows, when Systems Integration testing is successfully completed:

A. A brass switch lock will be furnished by RT to secure the hand throw lever on switch mechanisms when in the normal position. The lock will be fastened to the switch tie by a length of bronze chain.

B. A flush mounted lock will be furnished by RT and installed in the door of the route selector enclosure. The locks must be Corbin Lock Company #15748 x C6L or accepted equal.

C. A heavy duty padlock will be furnished by RT and installed to secure the doors of all instrument houses, cases, junction boxes, cantilever ladders, crossing gate covers, electric locks and circuit controller covers. The lock will be fastened to the mechanism by a length of bronze chain.

In providing and installing the equipment, Contractor must account for and plan to accommodate locks of the types and in the locations specified above, to be installed by RT after Final Acceptance.
13-5.19 Utility Power

Contractor must install AC service connections, as shown on the Plans. Contractor must provide and install all conduit and conductors for the service as required. The service requirements must conform to NEC and SMUD requirements, whichever is more stringent. Service conductors must be sized to allow no more than 2.5% voltage drop under full load conditions.

13-5.20 Crossing Gates

Crossing gates conforming to C.P.U.C. G.O. 75-D must be provided and installed by Contractor as shown on the Plans and as specified in this Section.

A. Gates must include mechanisms, masts, foundations, arms, wind guards, counterweights, LED lights, bell, wiring, and all other appurtenances required for a complete operating system.

B. Gate mechanisms must be of the power-down/power-up electromechanical type. Gate mechanisms must be Safetran Model S-40 with maintainer switch for replacement of gate arm or approved equal.

C. Gate arms must be fiberglass with three red lensed gate arm incandescent lamps mounted on them. The arms must be striped with a red and white Type 1 reflecting material conforming to AREMA C&S Manual Part 15.2.20. Gate arms of 24’ or less must be of the self-restoring as specified in AREMA C&S Manual Part 3.2.23. Self-restoring gate arms must be General Signal’s Gate Keeper, or an approved equal.

13-5.21 Crossing Signal Lights and Crossing Indicators

Flashing light signals conforming to C.P.U.C. G.O. 75-D must be provided by Contractor as shown on the Plans, complete with LED lighting units, housing, backgrounds, visors, cross arms, junction box assemblies, mounting bracket, and all hardware required for installation. LED lighting unit must be as manufactured by Safetran Systems, GELcore Part Number RG6RTFB48B, or approved equal.

Crossing indicator signals must be provided by Contractor as shown on the Plans, complete with LED lighting units, housing, backgrounds, visors, cross arms, junction box assemblies, mounting bracket, and all hardware required for installation. Crossing indicators must be of the LED type and must be certified by the microprocessor and crossing indicator manufacturer to be compatible with the solid-state equipment that provides power to the crossing indicator to provide a fail safe aspect.

13-5.22 Crossing Warning Cantilever Structures
Each highway-railroad grade crossing warning cantilever structure must be provided by Contractor complete with all associated hardware consisting of mast, junction box, flashing light unit(s), bell, signs, ladder with ladder guard, and miscellaneous hardware as shown on the Plans and as specified in this Section.

A. The cantilever structure must conform to all applicable AREMA requirements for a railroad highway-railroad grade crossing flashing light cantilever structure with walkway.

B. Each cantilever structure must accommodate the flashing light configuration shown on the Plans (e.g., length, number, and spacing of flasher units).

C. The cantilever structure must be of aluminum construction.

D. The walkway must be constructed of expanded aluminum and must have an expanded metal non-slip-walking surface.

E. Each cantilever structure must be equipped with an aluminum ladder that is securely fastened to the main structure. A hinged flat plate ladder guard must be fitted to the ladder to prevent unauthorized access to the ladder. The ladder guard must be locked in place by a signal padlock and hasp arrangement intended for this purpose.

F. A junction box suitable for terminating the interconnection wires and cable must be provided by Contractor as a part of each cantilever structure. The junction box must be located either at the base of the cantilever support mast or on the support mast at a height of between 3 and 5 feet above the finished grade level at the base. The cover of the junction box must be gasketed to provide a weather tight housing and must be securely bolted in place.

G. Contractor must provide a method of routing control wires from the junction box to each flashing light unit mounted on the cantilever. The tubular members of the cantilever structures must be used for this purpose to the greatest extent possible. Galvanized rigid steel conduit must be used where wire is to be run external to the cantilever structural members, except that flexible armored conduit must be used to make the connection from conduit run pull boxes to the individual flashing light units. A conduit run pull box must be located a maximum of 5 feet from each flashing light unit.

H. All unused threaded holes must be plugged or capped by Contractor.

13.5.23 Signs

Contractor must provide and install signs as required by CPUC G.O. 75-D for the grade crossing protection devices and as called for in the Plans. The signs must be as shown on the AREMA C&S Manual, Drawing 17191, and in the Plans.
Contractor must provide and install all wayside signs for begin block, end block, approach end block, mile pole, speed restrictions, street name, and resume speed. Signs must be fabricated, located and mounted by Contractor as shown on the Plans.

A. Material

Sign material must be 5052-H38 (ALLOY), .080" thick. The aluminum sheet should be true, square and free from warping, bending, blemishes and scratches.

B. Sign Panel Fabrication

1. Shearing

All sign panel edges must be shear-trimmed or roll split to produce neat edges and square corners. Sign panel edges must be straight within 1/32" from a straight plane. Edge delamination or incomplete coverage of the base metal substrate up to and coincident with the cut edge of the sign panel is a sufficient basis for rejection of the entire sign panel.

2. Finish

The finished sign must be flat within a ratio of .04" per linear foot when measured across the plane of each panel. All finished signs must have a smooth flat surface without defects or objectionable marks of any kind on either the front or back faces. All letters must be clearly cut and sharply defined.

The appearance of the sign face must be uniform throughout and must be free of wrinkles, gel, hard spots, streaks, extrusion marks, air bubbles or other blemished that may impair the serviceability, detract from the general appearance or color-matching of the sign panel when viewed from a distance of 25 feet. The back of the finished sign panel must be free from objectionable blemishes.

The finished sign must be clean and free from all burrs, sharp edges, loose rivets and aluminum marks.

Signs with any defects or damage that would affect their appearance or serviceability are not acceptable. All metal parts must be fabricated in a uniform and workmanlike manner with all sign surfaces and edges free of defects. Contractor must not make any repairs to the face sheet without the Engineer's written authorization.

C. Reflective Sheeting

Sheeting must be Type III, High Intensity grade manufactured by 3M or approved equal; series 2200 (3M) with heat activated adhesive or series 3200 (3M) with
pressure sensitive adhesive; double faced. The colors must be as specified on the Plans.

D. Inks

All screen printing must be of the highest quality available to ensure uniform long lasting color (High Life expectancy is 20 – 30 years.).

E. Anti-Graffiti

Anti-graffiti film must be Nippon Carbide Industries, F-Cal coating or approved equal. Contractor must apply Anti-graffiti film to front of signs as indicated in the Plans.

F. Attachment

Contractor must attach speed limit signs, street name signs, block signs and mile post markers to the Overhead Catenary poles and to free standing poles as shown on the Plans. The signs must be center mounted at a height of 10’ from the bottom of the sign to the top base of the pole foundation.

G. Mounting Details

1. Fastener:

   Hawkins theft proof steel and Zinc Head Cap washer # M2G-BTP. Screw 5/16” - 18 x ½” with Nylon Washer 1/32” – 3/8” I.D. x ¾” O.D., (or approved equal).

2. Bracket:

   HAWKINS Electrolier Zinc Coated 12 Gage Steel Straight Leg Bracket # M2G-UB-TP, with M2G-BTP fasteners; BAND-IT, BREAK-IT D004, STAINLESS STEEL (or approved equal).

3. Banding Strap

   STA-BAND, BANDIT; HAWKINS TRAFFIC SAFETY SUPPLY; SIGNFIX BANDING AISI 201 Stainless, ¾” # M2G-34S (HD) with M2G-34B (HD) Buckle (or approved equal).

13.5.24 Battery

Contractor must provide and install batteries at the block signaling and highway-railroad grade crossing instrument houses and cases that meet the following requirements:
A. Batteries must be nickel-cadmium or lead-acid with clear cases, as manufactured by the NIFE Corporation or approved equal.

B. The batteries installed to supply the B12, B14 and B16 at block signaling and/or highway-railroad grade crossing locations must be sized as shown in the Plans.

13.5.25 Crossing Bell

Contractor must provide and install electronic highway-railroad grade crossing bells, conforming to CPUC G.O. 75-C, as shown on the Plans. Bells must be loud tone and operate when power is applied from 8 to 15 vdc. Bells must be General Signals, Inc. Model EB-3-360-5 or approved equal.

13-5.26 Ground Detector

Contractor must furnish provide and install DC ground detectors as shown on the Plans. Ground detectors must be Electro Pneumatic, Part Number GFD-5 or approved equal.

13-5.27 DC Power Systems

Contractor must provide and install battery chargers and rectifiers as shown on the Plans.

A. Battery Charger

The battery chargers must meet the following requirements:

1. The capacity of the charger must be 40 amps or 60 amps minimum and must support the loads as shown on the Plans. The chargers must be Cragg Railcharger Model 40EC-12V and 60EC-12V or approved equal.
2. The battery charger must be a fully automatic, constant voltage, taper charge type with a float-equalize switch.
3. The battery charger must be of the full-wave rectifier type. The charger must employ a transistor-controller magnetic amplifier circuit and must maintain rated output voltage within ±1 percent. The charger must be convection cooled in a ventilated steel enclosure.
4. The charger must have separate float and equalize potentiometers. Both the float and equalize settings must be adjustable ±5 percent by potentiometers located on the front panel.
5. The charger must have Automatic AC line compensation; Automatic current limiting protection; Automatic DC voltage regulation; Hermetically-sealed silicon diode rectifiers; Automatic surge suppressors; and DC ammeter and voltmeter with 50-millivolt movement and 2 percent accuracy.
6. Filtering to reduce the ripple to less than 100-millivolt rms.

B. Switch Rectifier
Switch rectifiers must be 110 volt DC, 35 amp. Switch rectifiers must be US&S, part number N435449 or approved equal.

13-5.28  **Transformers**

Contractor must provide and install transformers as required by the design and as shown on the Plans. Transformers must conform to the following requirements:

A.  Transformers must meet the requirements of the AREMA C&S Manual, Part 14.2.10.

B.  Transformers must have primary and secondary voltage taps to compensate for high or low line voltages.

C.  The primary and secondary taps must be brought to terminals mounted inside the transformer case, and a connection for each must be brought out of the transformer to suitable terminals or bushings.

D.  The track feed transformers required for the track circuits must be equipped with terminal boards containing AAR terminals for the primary and secondary leads. The track secondary windings must be arranged to provide for varying the voltage. The primary excitation must be a nominal 120 volts. Track feed transformers must have a volt-ampere rating to handle the operating load. Track transformers must not be susceptible to DC saturation by propulsion current.

E.  Signal transformers required for signal lamp compartments must be rated for a minimum of 60 watts with a nominal 120 volt 60 Hz primary winding, and must be equipped with taps to provide voltage adjustments for the secondary. Taps must be connected to AAR terminals.

F.  Isolation transformers must be connected between the 120-volt, 60 Hz bus and equipment as shown on the Plans. Transformers must have a sufficient number of secondary taps to obtain voltage adjustments to compensate for line voltage drops.

G.  Power distribution transformers must have a primary winding rated at 480 volts, 60 and 100 Hz and must have sufficient primary taps to compensate for a minimum of 10 percent voltage adjustment, 5 percent above and below the rated primary voltage. The secondary winding must be rated for a nominal 120 volts, 100 Hz. The transformer insulation temperature rise must be a maximum of 115° C.

H.  Each transformer must, as a minimum, be rated for continuous operation at 125 percent of the maximum load.
13-5.29 **Uninterruptible Power Supply**

Uninterruptible Power Supplies (UPSs) must be provided and installed by Contractor as required by the design and as shown on the Plans. The UPSs must conform to the following requirements:

A. The input power source must be 120 VAC 60 HZ. The environmental requirements are -20 degrees C to 40 degrees C and 0 to 95 percent humidity non-condensing. The output must be 125 VDC with plus/minus 1 percent regulation.

The output battery backup must provide 4 hours of RT rush hour operation of the switch machine(s) at their nominal rated running current. Each UPS must be RLW 100 Series as manufactured by C-CAN Power Systems, Inc. or approved equal. Maintenance-free batteries must not be less than 40AH. Contractor must submit calculations to the Engineer for acceptance.

B. The status and controls that must be provided are: UPS Output digital metering, AC fail, rectifier fail, high volts, low volts and low volts disconnect. Remote monitoring using form “C” contacts must be provided.

C. The UPS must be completely factory wired and mounted in a suitable NEMA enclosure capable of being wall- or floor- mounted in the instrument house.

13-5.30 **Electrical Components**

The various electrical components must be provided and installed by Contractor as required by the design and as shown on the Plans.

A. Resistors,Reactors, and Capacitors

Resistors, reactors, and capacitors must be as specified in the following:

1. Track circuit resistors must be of the wire-wound, multi-tap type. All resistors other than those required for electronic circuits must be in accordance with the AREMA C&S Manual, Part 14.2.15. Resistors for electronic equipment must be in accordance with the applicable requirements of the AREMA C&S Manual, Part 14.2.40.

2. Reactors other than those required for electronic circuits must be in accordance with the AREMA C&S Manual, Part 14.2.20. Reactors for electronic equipment must be in accordance with the applicable requirements of the AREMA C&S Manual, Part 14.2.40.

3. Capacitors for electronic circuits must be in accordance with the applicable requirements of the AREMA C&S Manual, Part 14.2.40.
B. Diodes

All diodes to be provided under the Contract must carry a Joint Electron Device Engineering Council (JEDEC) number or must be available from more than one manufacturer and must be used within the published specifications for such numbers. All diodes must be silicon type.

C. Terminal Blocks, Binding Posts, Insulators, and Test Links

Terminal blocks, binding posts, insulators, gold nut test links, and test links must be as specified in the following:

1. Terminal blocks must be in accordance with the applicable requirements of the AREMA C&S Manual, Part 14.1.5.
2. Terminal binding posts must be in accordance with the AREMA C&S Manual, Part 14.1.10.
3. All terminal posts located on terminal boards in the wayside housings or cases used to terminate 120-volt circuits must have a protective insulator. The type of insulator must be Type 023408-1X as manufactured by Safetran Systems Corporation or approved equal.
4. Insulated test links must be Type 024620 as manufactured by Safetran Systems Corporation or approved equal.

D. Circuit Breakers, Fuses, and Fuse Clips

Contractor must design fusing of all circuitry according to the following and as shown on the Plans:

1. Each power feed must be individually fused for each rack.
2. Fuses must be sized to protect the wire.
3. Fuses must be of the nonrenewable indicating type.
4. All branch feeds for a circuit must be from the same fuse to prevent fuse cascading due to branch fusing carrying loads for other circuits.
5. Loads must be divided so that no normal operating current is more than 75 percent of the fuse rating.
6. Fusing must be functionally oriented to minimize the equipment affected by a blown fuse.
7. Circuit breakers and fuses must be the correct size and rating for circuit current interruption and must protect the electrical equipment and circuit from short-term and long-term overloads.
8. Fuse clips must be constructed to retain their resilience under all installation and service conditions and to ensure a positive contact between the clips and the fuse.

13-5.31 Train-to-Wayside Communications
RT will furnish the wayside TWC equipment specified in this Section and as shown in the Plans. Contractor must install, test, and program the TWC equipment in accordance with the manufacturer's service manuals. TWC service manuals will be available in accordance with the schedule identified in Section 8 of the Technical Specifications. Contractor must take the TWC design/installation information and equipment delivery schedule into account when developing the Construction Staging Plan and design/installation schedule. Contractor must install the instrument house TWC equipment after the instrument house is installed in the field, if required by Contractor's CPM schedule.

RT will provide the wayside TWC transmitter/receiver unit, loop distribution panel, DC/DC converter, and loop transceiver for each TWC loop location as identified in the Plans.

Contractor must provide all mounting hardware, wire, cable, loop conduit, loop frame, and miscellaneous mounting hardware required to complete the installation.

Contractor must assume 150 watts per TWC loop location for his instrument house power calculations.

13-5.32 Vital and Non-Vital Microprocessor

A. General

Contractor must provide vital and non-vital microprocessors at the interlockings, intermediate signal, highway-railroad grade crossing, and other locations as shown on the Plans and as specified in this Section. The vital and non-vital microprocessors must be the latest proven designs as manufactured by GETSGS (Vital Harmon Logic Controller – VHLC) or approved equal. If Contractor's proposed microprocessor is not serially (vital and non-vital) compatible with the existing VHLC at Meadowview interlocking (235IH), interface relays must be added by Contractor to/from a new microprocessor that must be installed in 235IH and serially connected to the microprocessor at Meadowview Road (S744IH).

The vital and non-vital microprocessor must conform to the following general requirements.

1. The vital and non-vital microprocessor system provided must be based on solid-state microprocessor technology and must not require any off-line storage devices for operation or start-up. The vital and non-vital microprocessor system must from the same manufacturer. The vital and non-vital microprocessor system must provide serial communications between each other.
2. All software programs must be checked by Contractor after power-up and continuously during operation, up to the time of Final Acceptance, for alterations to ensure no modifications have taken place after being installed. The central processing unit must be continually tested by the processor hardware and software to ensure all instructions are being executed properly and that processor integrity is being maintained.

3. The vital and non-vital microprocessor must incorporate self-checking features and diagnostic tests to ensure that the equipment, and program where applicable, are functioning properly. These check must be integral parts of both the hardware and software to provide for a secure system. Vital microprocessor systems must eliminate the possibility of false information being transmitted to external devices. Transmission of false information from a non-vital to a vital subsystem must in no way affect the safety of the vital system. Non-vital visual indications, such as LED lamps, must demonstrate that the system is functioning properly; similarly, failure and diagnostic indications must be provided. Indications must isolate a failure to a particular function, or to the interface between two functions.

4. PROMs, EPROMs, and EEPROMs used must be checked by the processor hardware and software to ensure they have been unaltered during microprocessor execution. Benchmarks must be established in the software and hardware for blocks of memory to facilitate these checks.

5. Inputs for the equipment must be buffered and must be immune to contact bouncing and must be electrically and physically isolated from one another. A visual indication, such as an LED lamp, must be provided on the input board for each input to indicate when the input is activated. The effects of contact or input bouncing may be mitigated by the application logic, subject to acceptance by the Engineer.

6. Outputs for the equipment must be electrically and physically isolated from one another. A visual indication, such as an LED lamp, must be provided on the output board for each output to indicate when the output is activated.

7. Operating programs and database definition must be stored in nonvolatile memory so that automatic power fail/restart can be provided.

8. The non-vital microprocessor system must include the controls shown in the Plans. The controls must be provided on a serial port using Genisys protocol for future remote controls from a central office. The serial port must be capable of being operated over the interface defined in Technical Specification Section 14 and Plans.

Contractor must design, install and test these controls. The test must be performed using simulation software (developed by Contractor) on a laptop computer. Contractor’s proposed design must be submitted for acceptance by the Engineer.

9. The non-vital microprocessor system must include the indications shown in the Plans. The indications must be provided on a serial port using Genisys protocol for remote indications to a central office.
Contractor must design, install and test these indications. The test must be performed using simulation software (developed by Contractor) on a laptop computer. Contractor's proposed design must be submitted for acceptance by the Engineer.

10. The source application for the system must be provided by Contractor in a readable hardcopy and in a word processor text file. The format may be Microsoft Word or other accepted word processor.

11. The application logic programming for the field vital and non-vital microprocessor system must be modular in format. Common pieces of logic must be represented by variable names. All networks, such as the Route relay networks, should be modular in format and be minimized to the greatest extent possible. The application logic must be expressed in the form of ladder logic, relay equivalents or approved equal. Relay logic circuit equivalents must be provided by Contractor with the As-Built Plans for each vital and non-vital microprocessor location. The format of the relay logic equivalents must be submitted to the Engineer for acceptance. In addition to the relay logic equivalents, Contractor must produce circuit plans similar to the Contract Typical Plans (e.g., show relay equivalent logic, not ladder logic) on the hardware plans. The Engineer will provide Contractor with the format to be used for Contractor's circuit plans that must show the combined hardware and application logic relay equivalents on the same plan. The application logic and relay equivalents logic must show the state of the relay contacts in their quiescent state, e.g., the XR is normally energized and the GDPR is normally de-energized.

12. The vital and non-vital microprocessor system must provide vital serial communications between adjacent microprocessor locations at the locations shown in the Plans. This vital serial communications must use separate transmit and receive lines unless otherwise authorized in writing by the Engineer. The vital serial communications must be capable of sending and receiving 128 data bits in each direction (128 input data bits and 128 output data bits). Contractor must provide all equipment necessary to provide the vital serial communications.

B. Vital and Non-Vital Microprocessor Software and Application Logic

1. Diagnostic checks must act on current (fresh) data only. Memory locations used to determine the proper states of inputs and outputs must be cleared or destroyed prior to being reused during each cycle to ensure the integrity of the data. The diagnostic checks must be independent of the user application logic for the system. The diagnostic checks must be incorporated in the executive systems software and must operate independent of the user application software for the system.

2. Background diagnostic tasks must run during application software wait states and must serve to monitor and verify the integrity of the software execution. Synchronized tasks must execute properly and a synchronized
task must execute in the proper order. Checks must be included to shut down the system in the event of an executive microprocessor overload.

3. Compiler software must be supplied by Contractor to maintain and upgrade the Vital and Non-vital application software. The compiler software must be licensed to RT for unrestricted use. Software technical support and revisions must be provided for a minimum of 10 years by Contractor without further cost to RT.

4. The system software must recognize a secure distinction between the executive software and the application software such that it must be impossible through the implementation of the application software to overwrite or otherwise modify the executive software.

5. The executive software must not contain any data that will limit or prevent the microprocessor system from being reconfigured for alternative site configurations by modification of application software.

6. Executive software must be maintained in non-volatile memory that cannot be altered by any operation of any component of the microprocessor system. The executive software data storage must include a check sum or CRC to provide a method of determining data validity. Diagnostic checks must be incorporated that verify the integrity of the executive software during operation.

7. Application software must be maintained in non-volatile memory that cannot be altered by any operation of any component of the microprocessor system. The application software data storage must include a check sum or CRC to provide a method of determining data validity and verification of the software in use. Diagnostic checks must be incorporated that verify the integrity of the application software during operation.

8. The Vital and Non-vital application logic implemented in accordance with the Contract Document requirements must not exceed 50 percent of the Vital and Non-vital microprocessor system’s application logic capacity at each location.

9. All Vital and Non-vital application logic timers must be adjustable from front panel controls on the Vital and Non-vital microprocessor system or through the use of a laptop computer. Adjustment of the application logic timers must be password protected and must not require re-verification of the application logic, except for testing the timer setting. Also, adjustment of the application logic timers must not require replacement of the application logic PROMs, EPROMs, and/or EEPROMs. Contractor may propose external vital and non-vital time relays in lieu of this requirement, subject to written authorization by the Engineer.

10. Vital and non-vital application logic must be electrically keyed to the location for which it is intended. No two locations or applications may have the same keying. Contractor must provide a keying chart for all locations and this chart must be included in the As-Built Plans for each location.

11. Vital and non-vital microprocessor systems must provide internal event recording of the vital and non-vital application logic. The vital and non-vital microprocessor system must event record the following as a minimum
in its internal event recorder: parallel inputs, parallel outputs, serial inputs, serial outputs, all internal variables and all internal timers. Contractor must provide the tools and equipment necessary to extract and view/print the internal microprocessor data. Also, Contractor must provide the tools and equipment necessary to view the internal microprocessor data in real time.

12. Contractor must provide means by which Vital Functions implemented in the Vital application logic can be completely tested without interference or masking by any intervening Non-vital logic. For example, if Non-vital interlocking application logic prohibits requests from being made to the Vital application logic, means must be provided to circumvent the intervening Non-vital application logic during testing of the Vital logic functions such that the vitality of the Vital application logic can be challenged.

13. Contractor must provide vital assurance that the Vital application logic stored and processed by the Vital microprocessor system is the intended logic. In addition, Contractor must provide vital assurance that no application logic in excess of that intended is stored and/or processed by the vital microprocessor. To provide this assurance, Contractor must reconstruct the vital application logic and regenerate all necessary vital parameters and logical constructions, directly from the programmable read only memory based data. The reconstructed data must be in a form that can be easily confirmed and/or compared to the original application logic requirements. Contractor may submit a plan for alternative methods for providing vital assurance that the Vital application logic stored and processed are the intended functions, and that no additional functions exist, to the Engineer for acceptance. However, such methods must provide the same degree of assurance as the method specified.

C. Vital and Non-Vital Microprocessor Hardware

1. Diagnostic indications must isolate a failure to a particular function or the interface between the failing function.
2. Contractor must provide labels and annotation for each input and output indication that clearly denote the respective function for ease of troubleshooting and maintenance.
3. All components must be in accordance with the environmental parameters described in these Technical Specifications.
4. The microprocessor equipment must be mounted complete with all necessary accessories on standard 19-inch racks.
5. All power for the vital and non-vital microprocessor system must be properly isolated from the effects of electromagnetic interference, lightning, noise, humidity, current fluctuations, and grounds.
6. All major assemblies, subassemblies, circuit cards and devices must be permanently marked with the manufacturer's part identification number.
7. The local control panel must be tied directly to the input and output boards of the vital and non-vital microprocessor system. A separate non-vital
microprocessor system may be provided to interface to the local control panel, subject to written authorization by the Engineer.

8. Ten percent spare inputs and outputs must be provided per cardfile.
9. Contractor must supply input and output circuit boards that provide ports in multiples of 8 minimum. Output and input functions must be provided on different circuit boards unless otherwise authorized in writing by the Engineer.

10. Contractor must provide isolation to ground of a minimum of 2500 VDC.

11. Each input and output circuit must have surge and lightning protection.

D. Chassis/Cabinets

1. Any unused chassis slots must be fully covered by blank removable plates made of the same material as used in the working circuit boards. The blank slots have no gaps greater than 1/8 inch. All chassis must have a solid covered door on the front to protect the circuit boards and any switches or pushbuttons from accidental operation. The door must be removable and secured by screws or other accepted fasteners. The screws or fasteners must remain attached to the door when it is removed.

2. The chassis or cabinet material must be aluminum or other non-corroding material as accepted. Chassis must have rear panels that permit easy access to rear edge connectors.

3. All backplane wiring methods and material must be submitted for acceptance. This must include, but not be limited to, wiring, connectors or motherboards. All wiring must be twisted pairs to provide maximum isolation to EMI noise. All support devices and internal chassis or cabinet elements must be protected with an accepted material to prevent wires from being cut or damaged.

4. The power for each chassis/cabinet must be routed through a toggle switch with an indicated LED, and must break both the DC power and neutral path. The switch must be recessed to prevent accidental operation.

5. All wiring from each chassis or cabinet to other chassis, cabinets or other devices or sources must be through plug-connected cables or plug-connected wiring. Each connector must be AMP M-series or approved equal device. Each connector must be keyed in a unique manner. Each connector must be mounted on the rear of the chassis or cabinet as required. Each connector must have a unique labeling method. All connectors, tooling, attachment methods and fittings must be submitted for acceptance.

6. All chassis must be lockable with a key lock. Each chassis must be keyed alike.

7. Any ventilation screens must be easily removable for cleaning.

8. All chassis or cabinets must be completely covered or enclosed to prevent the entry of a rodent.

9. Each chassis must be grounded to the rack with a #10 AWG stranded green wire. No ground loops or series ground wires are permitted.
10. All chassis must be flush mounted to the face of the rack unless otherwise authorized in writing.

E. Circuit Boards

1. All circuit boards must have a unique serial number clearly marked on each board. The board manufacturer’s part number must also be clearly marked on each board. All markings must be of a permanent type.

2. Each circuit board must have all components clearly identified by a silk screening process. All markings must be clear and easily readable. The markings must include, but not to be limited to, polarity, switch position numbers, resistor identifications or integrated circuit identifications.

3. Each circuit board must be secured in the chassis by a secure manner such as captive screws or latching ejector tabs. Both the top and bottom of each board must be secured.

4. Each circuit board must be coated with a moisture sealant after manufacture and testing. Any further work done to the board must be re-coated.

5. Contractor must supply a minimum of 2 each of any extender card required to match each type of circuit board.

6. The circuit boards must be removable and be mounted on guide-ways or channels for ease of removal or insertion. The removal of any wire must not be required to replace a circuit board.

7. The edge connector finger contacts of each circuit board must provide a firm wiping action to prevent oxidation in the railroad environment. A gas tight connection must be maintained.

8. All circuit boards must have plated through holes.

9. All circuit boards using any indicator LED must have the LEDs mounted on the front edge of the board. The colors of the LEDs must be accepted by the Engineer. Each LED must be labeled on the circuit board in a permanent method.

10. Each circuit board of the same type must be uniquely keyed. The chassis slots for circuit boards of the same type must be keyed to match the board and reject others. The keying methods must be modifiable and submitted for acceptance.

11. Circuit boards requiring an address setting, word count or slot number must make use of dual in-line circuit board switches or approved equal with a proven record of performance within the railroad environment.

12. Each circuit board and chassis slot must withstand a minimum arc-over potential of 600 volts between conductor and ground.

13. All circuit board copper traces must be 2 ounce minimum.

14. All circuit boards must have internal surge and polarity protection for power, data, control and indication inputs and outputs.

15. All circuit boards and components must be new. The use of refurbished material is not permitted.

F. Spare Application Logic Circuit Boards
Contractor must provide a spare of each circuit board containing vital and/or non-vital application logic at each vital and non-vital microprocessor location. Each spare circuit board must be subjected to the same pre-service testing as the primary circuit board unless otherwise authorized in writing by the Engineer. Spare application logic circuit boards must be stored in a housing provided by Contractor in each instrument house. These circuit boards must be supplied in addition to the spare parts requirements specified elsewhere in this Section. Full compensation for providing, installing, and testing these spare application logic circuit boards complete with As-Built application logic is considered as included in the Contract lump sum price paid for the instrument house and no additional compensation will be allowed therefor.

13-5.33 Local Control Panel

A. General

Contractor must provide an etched aluminum local control panel mounted in a sheet metal enclosure within each interlocking instrument house as shown on the Plans and as specified in this Section.

B. Panel Enclosure

1. The enclosure must be constructed of 16 gauge galvanized steel. The frame must be reinforced to provide rigidity required to maintain alignment. The enclosure must have accurately machined surfaces to assure proper positioning. Steel must be accurately rolled and have a smooth finish. Joints must be formed to a tight fit with abutting edges flush and securely welded. Joints must be welded their full length and dressed flush on exposed surfaces. Spot welding must be used when practicable in preference to screws or rivet fasteners. Holes for screws or bolts must be drilled and countersunk. All bolts, nuts, washers and screws must be chromate zinc plated. The finished work must be strong and rigid and neat in appearance. Surfaces must be smooth and free from warp and buckles.

2. The local control panel must be attached to the enclosure by a piano hinge to provide free and ready access to all parts of the interior. The faceplate must be secured by a key lock(s) when it is in the closed position.

3. The panel frame must be equipped with a terminal lug for the purposes of grounding.

4. The panel enclosure must be mounted on a hinged bracket as shown on the Plans so that the panel can be accessed from either inside or outside of the Instrument House.

C. Local Control Panel Details
1. The local control panel must consist of an aluminum etched panel that has a brushed aluminum background with black lettering and track model. The track diagram, signal and switch symbols, lettering, and identification numbering must be configured on the panels generally as shown on the Plans. The panel must be equipped with key switches, pushbuttons and indicators described in this Section. Pushbuttons may be wired directly to a Non-vital microprocessor input circuits. Local control panel indicators may be lit directly from a Non-vital microprocessor output circuits.

2. The panel must be mounted on the enclosure with a continuous hinge and wired in a manner that allows it to be opened to access the interior. The panel must be locked in place with a locking mechanism and key.

D. Local Control Panel Components

1. Pushbuttons
   a. To facilitate quick replacement of pushbuttons, all contacts on each pushbutton assembly must be connected to the plug portion of a locked, quick detachable keyed connector so that all like units are interchangeable. Only the required wires must be provided in the wiring tree and connected to the other side of the connector. The plug portion of the connector must be an integral part of the pushbutton assembly. Each pushbutton assembly must be hermetically sealed.
   b. Pushbuttons must be of the unit type. The term "unit type" must be understood to mean that each of the units may be completely and easily removed from the control panel without interfering with the operation of any other unit.
   c. Pushbuttons must have a built-in LED indicator and the LED colors must be as shown on the Plans.
   d. Pushbuttons must be provided by Contractor for the following functions and as shown on the Plans:
      (1) Route Request Pushbuttons
      (2) Route Cancellation Pushbuttons
      (3) Switch Request Pushbuttons.
   e. Pushbuttons must have normally open and normally closed contacts that change states when the pushbutton is depressed.

2. Rotary Switches
   a. Rotary switches must be of the unit type. The term "unit type" must be understood to mean that each of the units may be completely and easily removed from the control panel without interfering with the operation of any other unit. Each rotary switch assembly must be hermetically sealed.
   b. Rotary switches must be provided by Contractor for the following functions and as shown on the Plans:
      (1) Terminal Mode Request
      (2) Lamp Test.

3. Key Switches
a. Key switches must be of the unit type. The term "unit type" must be understood to mean that each of the units may be completely and easily removed from the control panel without interfering with the operation of any other unit. Each key switch assembly must be hermetically sealed.

b. Key switches must be provided by Contractor for the following functions and as shown on the Plans:
   (1) Local Control – key removable in off position only
   (2) Auto Switch Key – key removable in either position.

c. All local control panel key switches must be keyed alike. The keys must be of the “Do Not Duplicate” type.

4. LED Indicators

a. LED indicators must be of the unit type. The term "unit type" must be understood to mean that each of the units may be completely and easily removed from the control panel without interfering with the operation of any other unit. Each LED indicator assembly must be hermetically sealed.

b. LED indicators must be provided by Contractor for the following functions and as shown on the Plans. The LED colors must be as shown on the Plans.
   (1) Signal Aspect Indications
   (2) Track and Block Occupancy Indications
   (3) Traffic Direction Indications
   (4) Terminal Mode Indications
   (5) Local/Display Indications
   (6) Switch Lock Indications and Switch Auto Indications.

5. Local Control Panel Wiring

The control panel must be wired with single conductor, not smaller than No. 20 AWG, 19 strand wire, insulated for 600 volt service and insulated per the AREMA C&S Manual Part 10.3.14 requirements for ETFE insulation. The wiring harness must allow clear access to all components.

6. Plug Connector Receptacles

a. The control panel must be equipped with plug connector receptacles to receive the cable plugs interconnecting the control panel to the non-vital microprocessor rack.

b. Plug connector receptacles must be mounted in the control panel in such a manner that both the front and rear of the receptacles are readily accessible.

13-5.34 Bridge Lighting System

Contractor must provide and install bridge lighting systems as shown on the Plans.

13-5.35 Bridge Warning System
Contractor must provide and install bridge warning systems as shown on the Plans.

**13-6 INSTALLATION OF MATERIALS AND EQUIPMENT**

13-6.01 Power Switch-and Lock Movements

A. General

1. Contractor must make a preliminary adjustment of the track switch layout at the time of installation. The final adjustment must be made at the time of the functional test. Final adjustments must be made in conformance with requirements of the AREMA C&S Manual, Part 12.2.1 and 2.4.1.

2. Cables terminating in the switch junction box must be dressed and sealed. The individual conductors must be fanned in a neat, workmanlike manner, terminated, and tagged. Wire must terminate in the switch-and-lock movement in a neat, workmanlike manner. This wire must also be tagged and terminated by Contractor. The wires between the switch junction box and the switch-and-lock movement must be installed in an appropriate length of weatherproof flexible metal conduit. The flexible conduit must be fastened to the switch junction box and switch and lock movement with appropriate connectors.

3. During storage and after installation, switch layouts must be lubricated and maintained by Contractor on a regular schedule until accepted by the Engineer. The Engineer may monitor Contractor's compliance with the maintenance requirement, from time to time, as deemed necessary.

4. Contractor must exercise care that the switch-and-lock movements are thoroughly lubricated, that machined surfaces susceptible to rusting (both external and internal) are thoroughly coated with NO-OX-IDE grease (or its equivalent), and that threaded portions of switch rods and nuts are coated and protected.

5. The switch tie plates must be lubricated by Contractor with an accepted graphite lubricant. The plates must be steam cleaned by Contractor to remove oil and grease prior to applying graphite. Contractor must maintain the protective coatings until Final Acceptance.

B. Tie-Mounted Switch Layouts

Contractor must install tie-mounted switch layouts according to the Plans, AREMA Specifications, and the procedures listed in this Section. Contractor must provide a complete and functional installation. The major installation tasks that must be completed by Contractor as part of the switch installations include:

1. Contractor must remove stone ballast necessary for the installation of switch operating layouts and must replace and tamp the ballast after the installation has been completed. Excess ballast must be spread evenly between ties in the vicinity of the track switch-operating layout.
2. Contractor must properly align the switch movement ties, as shown on the accepted switch installation drawings. Contractor must perform drilling of ties to meet the requirements of this Technical Specification Section. Where it is necessary for Contractor to cut treated ties, the cut surfaces must be thoroughly saturated with hot creosote oil. The limit of cut or dapping must not exceed two inches.

3. Contractor must restore track alignment and surface displacements if made necessary by Contractor’s work on track switches.

4. Contractor must check that the switch circuit controller contacts are not made when the switch point is 1/4 inch or more from being closed and are made when the switch point is 1/8 inch from being closed. Measurement must be made over the No. 1 switch rod.

5. Contractor must install tie straps and the identification name as indicated on the Plans and as indicated on the accepted Shop Drawings. The identification name must be as shown in parenthesis next to the switch on the Shop Drawings.

C. Painting

Except as otherwise specified in these Technical Specifications, all components of switch-and-lock movements must be finished in accordance with the AREMA C&S Manual requirements. The finish color must be black.

13-6.02 Wayside Signals

A. Installation

1. Signal layouts must be installed by Contractor in accordance with accepted drawings and as indicated on the Plans.

2. Contractor must align and focus signals both horizontally and vertically for maximum brightness and in such a manner that the aspects displayed, when viewed from a position 7 feet above the top of the left-hand running rail are distinct, unmistakable, and continuously visible over a range of 15 to 1000 feet under the most adverse environmental conditions prevailing on the transit system. Contractor must perform final alignment using a LRT operator and a LRV that will be furnished by RT.

3. The signal number plate must be placed by Contractor under the lowest signal lens in the assembly, bracket-mounted to the signal housing, and must be fastened by four brass screws with lead and brass washers under the screw heads and under the enameled plate. The lead washers must be installed adjacent to the enamel.

B. Painting

1. Except as otherwise specified in these Technical Specifications, all components of the signal must be finished prior to shipment in accordance with the AREMA C&S Manual. The finish color of the signal head,
background, and hood must be flat black. The color of the mast and base must be aluminum.

2. After installation and prior to Contract completion and Final Acceptance, the exterior of each signal head, background, and hood must have a final coat of dull black paint applied by Contractor of the same quality and texture as the manufacturer's finish coat.

C. Shipping and Handling

1. Each signal, complete with the associated mounting hardware, mast, and base, must be clearly marked on the shipping crate(s) with the appropriate signal number as indicated on the Plans.
2. If precast signal foundations are used, then each precast signal foundation must be clearly marked with the appropriate signal number as shown on the Plans.
3. Signals and their component parts must be protected against damage or loss during handling and shipment.
4. Signal ladders must be provided, installed, and fitted with a lockable guard.

13-6.03 Push Button Route Selectors

Contractor must install push button route selector control stands at the locations indicated on the Plans and in accordance with accepted installation details.

The push button enclosure must be painted light gray by Contractor. Stenciling must be applied by Contractor using black lettering.

13-6.04 Impedance Bonds

Contractor must install impedance bonds at the locations indicated on the Plans and in accordance with accepted installation details.

Impedance Bonds must be painted flat black by Contractor.

13-6.05 Installation of Wire and Cable

A. General

Cables must be inspected by Contractor at time of delivery to ensure that no damage was done in shipping and that the specified cable was received.

Contractor must comply with the following during cable installation:

1. Cable ends must be resealed promptly when a length is cut from the reel.
2. Contractor must verify that the installation design is correct and adequate for the cables to be installed. Contractor must ensure that conduit size, conduit fill, conduit bend radii, raceways, ducts, and associated hardware are proper for the intended installation.

3. Wires and cables must be continuous, unless otherwise specifically noted on the plans, without splices between junction boxes, equipment cases, pull boxes, and hand holes.

4. Contractor must install wires and cables in accordance with cable handling and pulling practice as defined by the AREMA C&S Manual, Part 10.4.1 (Wiring and Cable), and the cable manufacturers' recommendations.

5. Pulling winches and associated equipment must be of adequate capacity to assure a steady continuous pull on the cable. A dynamometer must be used on all cable pulls. Records must be kept on the actual tensions encountered in each pull.

B. Wires and Cables in Conduit

Contractor must install the conduits as shown in the Plans. Contractor must provide and install additional conduit, junction boxes, and associated materials as required to complete the installation. Conduits and pull boxes must be installed by Contractor in accordance with the Plans, these Technical Specifications, and the Standard Specifications.

Contractor-provided conduit must have a clean, smooth concentric interior surface. Contractor must have all signal conduits inspected by Engineer prior to cable installation.

Contractor must establish the maximum allowable length of cable that may be safely pulled into each conduit after obtaining the wire and cable manufacturer's recommendations regarding pulling limits for the cables. Consideration must be given to fill, friction, clearance, configuration, jam ratio of the cables and conduit, weight correction factor, bend radii, training of the cables on entering and exiting the conduits, maximum allowable tension, sidewall load, and weight of the cables. These factors must be calculated for each pull as required, and Contractor must not exceed the maximum allowable values of sidewall pressure, pulling strain on conductors or sheath, limits of pulling device, and pulling tension.

Contractor must use only the wire and cable manufacturer's approved pulling compound or lubricant compatible with the cable. The lubricant must be used in ample quantity to reduce friction and must be applied in such a manner that the cable is lubricated throughout the entire length being pulled through the conduit. The lubricant must be non-hygroscopic and vermin proof.

C. Aerial Wire and Cables

Signal cable must be carried on a single messenger supported and routed on catenary poles as shown on the Plans. The maximum diameter of a single signal
cable, or bundle of signal cables, suspended from the single messenger supported by catenary poles must not exceed 3 inches. If the cabling requirements result in a bundle that would otherwise be greater in diameter than 3 inches, Contractor must provide a second cable and messenger installation directly above or below the original cable run and redistribute the cable bundles as necessary to conform with this requirement. Contractor may, in lieu of providing the second messenger run, submit calculations that demonstrate that a cable bundle of greater than 3 inches will not adversely impact the integrity of the OCS pole line system. All calculations must be prepared and certified by a registered structural engineer. RT may, at its option, either accept or reject the calculations and require the second messenger run. The decision of RT will be final. Cabling in excess of this limitation must be installed in raceways as indicated in these Technical Specifications. Splices are not permitted in the signal or messenger cable.

Messenger and guy strand must be installed in accordance with the requirements of Section 11 of these Technical Specifications and as shown on the Plans.

D. Termination

Contractor must comply with the following requirements for terminations:

1. Cables must be trained into final position while observing minimum bending radii.
2. Slack must be provided at all terminals in an amount sufficient for two re-terminations.
3. Where connected directly to signal equipment, wire and cable must be of sufficient length to allow access for removal and inspection of equipment.
4. Local wire and cables must be continuous, without splices, between terminals within a housing and enclosure or the individual piece of equipment.
5. Termination work must be conducted under clean and dry conditions.
6. For stranded wire, Contractor must use compression type insulated terminals in accordance with the AREMA C&S Manual, Part 14.1.1 (Requisites for Solderless Type Wire Terminals for Use in Wiring Signal Apparatus), and the wire and cable manufacturers' recommendations. The terminals must be installed by Contractor only with tools and techniques recommended by the terminal manufacturer. Solid wire must be terminated by wire eyes.
7. Vital wires and cables must be terminated at an AREMA terminal block.
8. Compression type insulated terminal connections to terminal blocks must use a single washer on top of the terminal. Wire eyes require two washers for one eye, three washers for two eyes. Connections must be completed with double nuts torqued to the rated value of the nut.
9. All wires and cables, including spares, must be terminated at both ends and properly identified during the termination process.
10. Splicing of signaling cable will only be permitted as a part of an interim cut-over and then, only with the written authorization of the Engineer on a
site-specific basis. Splicing of signaling cables is not allowed as a part of a permanent installation. Splicing of signaling cable must only be done in designated pull boxes. Splicing of signal cable must only be performed under the direct supervision of Contractor’s Signal Engineer. The individuals making cable splices must be experienced and competent in making splices to signal cabling. Splicing of cabling must conform to the recommendations in AREMA C&S Manual Part 10.4.1.H.

E. Identifying

Contractor must comply with the following requirements for identifying:

1. All single-conductor and multiple-conductor wires and cables must be identified whenever they enter or leave a junction box, manhole, housing, or enclosure, and at all terminals.
2. Permanent non-conducting marking tags fastened securely to the wires and cables must be used for identification.
3. Wire designations must consistently conform to the existing RT scheme.
4. Wiring in modified equipment locations must be tagged with temporary color coded string tags to facilitate a quick transition to the new Signal System. The colored tags must convey the following:

GREEN Wire or equipment to be connected.
RED Wire or equipment to be disconnected.
YELLOW Wire or equipment to be moved and/or retagged.

13-6.06 Instrument Houses, Cases, and Junction Boxes

A. Installation

1. Contractor must set and level instrument houses and cases on Contractor-provided foundations.
2. The base of the excavation for instrument house and case foundations must be level and flat and have been tamped to 95% of the maximum compression prior to setting the shelter or case foundation. After the shelter has been set and leveled, the footing excavations must be backfilled and tamped by Contractor.
3. Unless otherwise noted on the Plans for a site-specific location, an area extending a minimum of 6 feet from housing walls with access doors and 3 feet from walls without doors must be covered by Contractor with a minimum layer of 6" of clean ballast. The ballast must be leveled and compressed by Contractor to provide a good walking surface. The sub-grading beneath the ballast must be configured to divert water from the shelter.
4. Where an instrument house or case is shown on the Plans to be installed in a paved area, the area under the house must be paved by Contractor.
prior to setting of the house. Drainage must be provided by Contractor to prevent accumulation of standing water under the house.

5. Each instrument house and case must be installed level and plumb. Contractor must assure that all doors operate freely without binding in its opening.

6. Spreader bars conforming to the housing manufacturer’s recommendations must be used by Contractor when lifting the houses and cases by eyelets that are an integral part of the housing structure. The spreader bar must be adjusted for the spacing between eyelets to ensure a vertical lifting moment on each eyelet.

7. All cable entrances must be sealed upon completion of installation at a given location.

B. Instrument House, Case, and Junction Box Layout

1. Spare space and facilities for the Signal System, unless otherwise specified in this Section or noted on the Plans, must be as follows:
   a. Ten percent spare terminals must be provided by Contractor.
   b. Cable termination arrangements must be laid out by Contractor to locate spare wire conductors of a cable on a dedicated terminal post in line with and grouped with the working conductors of that cable.
   c. Ten percent spare space for future mounting of equipment must be provided by Contractor.

2. Contractor’s layout of equipment mounted on the backboard must provide sufficient space between units and housing and other units above, below, and on either side for making wire connections and performing any normal equipment maintenance action with reasonable ease.

3. Wire-wound resistors mounted on the terminal board must be spaced with ½-inch minimum between adjacent resistors or other units.

4. In designing the detail layout of the equipment within wayside cases, Contractor must group together similar types of equipment or functions.

5. Contractor must provide and install a reinforced concrete skirt around the entire perimeter of each equipment case. The skirt must extend 3 feet beyond the boundary of the case and be a minimum of four inches thick.

C. Identification of Equipment

1. There must be an identifying nameplate for each relay, transformer, resistor, and related individual components, and for each relay rack or terminal board. The nameplate must display the nomenclature as well as the case location number.

2. The back of the plugboards must be equipped with a tag, or other accepted means of identification, to indicate the nomenclature of the relay for which it is wired.

3. The contact numbering system must be uniform for each type of relay used.
4. The wiring to each removable contact must carry an accepted tag identifying the nomenclature, termination location and location of the opposite end of the wire.

5. Wire and cable conductor identification tags must be as specified in this Section and provided with each case.

D. Painting

The interior of instrument houses, cases, and junction boxes cases must be painted by Contractor according to the manufacturer's standards and as specified in this Section. The terminal board must be painted gray, ANSI-61, or an approved equal.

E. Shipping and Handling

1. Contractor must ensure that wayside instrument houses, cases, and junction boxes and their component parts are protected against damage or loss during handling and shipment. All exterior openings must be covered during shipment. Contractor must protect this equipment from damage or theft and store inside until installation and acceptance.

2. Contractor must ensure that vital relays are packed and shipped separately from the racks in which they are to be used. Relays must be stored in a protected indoor area until they are installed in the racks.

3. All wayside cases must be shipped complete with relay plugboards, identification tags, terminals, resistors, and associated apparatus. Relays for wayside cases where required, must be shipped at the same time as shipment of the case.

13-6.07 Foundations

A. Installation

1. Prior to placing precast foundations or constructing cast-in-place foundations, Contractor must complete the excavation and installation of crushed stone bases to the lines and grades required and in accordance with the requirements specified in the Contract Documents.

2. Precast foundations must be installed to the lines, grades, and dimensions required as determined by Contractor and accepted by the Engineer.

3. When placing these foundations, Contractor must ensure that anchor bolts are not bent or threads damaged. Anchor bolt thread, washers, and nuts must be protected by applying friction tape, or other method accepted by the Engineer, until such time as the wayside equipment is installed.

4. Exposed foundations must be rubbed to obtain a uniformly smooth, clean surface of even texture and appearance.

5. Non-conductive material must be provided by Contractor between the foundations and the mounted apparatus to prevent direct contact between the concrete and metal surfaces.
6. Backfill, compaction, and clean-up operations by Contractor must be as specified in Contract Documents.

B. Shipping and Handling

Contractor must ensure that precast concrete foundation units are handled to avoid damage in transit and at storage locations. They must be supported, cushioned, and stacked to protect the edges of the units. Chipped, cracked, or damaged units must be replaced by Contractor at no additional cost.

13-6.08 Traction Power Bonding

Frog assemblies, switch point, all special trackwork, joints and insulated joints must be bonded, as indicated on the typical drawings on the Plans. Cable must be as specified and as indicated on the Plans. Traction power negative return cables must be installed and connected to the impedance bonds, as shown on the Plans.

A heavy coating of grease must be applied by Contractor to all bond cables immediately after Engineer’s acceptance. All bond wires must be securely fastened to prevent uplift or movement.

13-6.09 Highway-Railroad Grade Crossing Warning Equipment

A. Installation

Grade crossing warning equipment must be installed by Contractor in conformance with CPUC G.O. 75-D, and as shown on the Plans. Contractor must make preliminary adjustment and alignment of the grade crossing warning layout of the time of installation. The final adjustment and alignment must be made by Contractor at the time of the functional test. Final adjustments and alignments must be made in conformance with the requirements of the AREMA C&S Manual, Parts 2.4.1, 3.3.1 and 3.3.5.

B. Painting

1. Except as otherwise specified, all components of the crossing warning layout must be finished prior to shipment in accordance with the AREMA C&S Manual, Part 2.4.30. The finish color of the crossing signal hoods and backgrounds must be flat black. The color of the gate mechanism housings, masts, bases, bells, signal cross arms and housing, and mounting hardware must be aluminum.

2. After installation and prior to Contract completion and Final Acceptance, the exterior of each crossing signal hood and background must be given a final coat of flat black paint by Contractor, of the same quality and texture as the manufacturer's finish coat.
C. Shipping and Handling

1. Each gate mechanism and crossing signal complete with associated mounting hardware, gate arm, counter-weights, cross arms, signs, mast, and base must be clearly marked on the shipping crate(s) with the appropriate highway-railroad crossing number as indicated on the Plans.

2. If precast foundations are used, then each foundation must be clearly marked with the appropriate crossing number as indicated on the Plans.

3. Contractor must ensure that gate mechanisms, crossing signals, and their components are protected against damage or loss during handling and shipment.

4. Contractor must provide and install padlocks with gate mechanisms.

13-6.10 Train-to-Wayside Communications

Contractor must install TWC equipment in accordance with the manufacturer's installation and service manuals, per accepted installation drawings developed by Contractor, and as indicated on the Plans.

13-6.11 Re-adjustment of Existing Track Circuits

Contractor must re-adjust each track circuit that is modified at the Meadowview interlocking. Adjustments must be made in accordance with RT’s standard adjustment and test procedures and as accepted by the Engineer.

13-6.12 Bridge Lighting System

Contractor must install the bridge lighting system equipment in accordance with the manufacturer's recommendations, per accepted installation drawings developed by Contractor, and as indicated on the Plans.

13-6.13 Bridge Warning System

Contractor must install the bridge warning system equipment in accordance with the manufacturer's recommendations, per accepted installation drawings developed by Contractor, and as indicated on the Plans.
13-7 PERFORMANCE

13-7.01 General

Contractor must perform work in a manner that will not cause disruption of traffic, loss of utility services, or train delays.

13-7.02 Equipment and Modifications

When work under this Contract requires that modifications or additions be made to existing RT or UPRR operating equipment, Contractor must submit to the Engineer a request to schedule such work at least 21 days prior to the date that the work is to be performed. Work done in operating equipment locations that is not to be placed in service immediately must be done only to the extent that it does not connect to, or interfere with, operating circuits.

13-7.03 Work Affecting the UPRR Railroad

The UPRR railroad is in use and will be in continuous operation during the performance of this Contract. Contractor must not perform work that affects UPRR operations until Contractor has secured permission from the Engineer. In addition, Contractor must comply with the requirements set out in the Special Conditions with respect to work affecting UPRR.

13-7.04 Placing of Equipment in Service

Final connections of modified equipment and the placing in service of new equipment, including breakdown and operating tests of all equipment, must be done by Contractor during non-revenue service hours of RT and UPRR, if the connections affect existing operating RT or UPRR circuits.

13-8 COMMISSIONING

13-8.01 General

Contractor must prepare and submit for acceptance of the Engineer a Test Plan and Procedures 180 days before the planned start of testing. The Test Plan and Procedures must, at a minimum, include: (1) a listing of each type of test to be conducted, complete with a brief description of each of the tests; (2) a matrix showing the sequence of tests and which tests must be completed prior to the start of the next test in a sequence; and (3) a matrix identifying which tests will be performed at each signaling location and/or for each interim and final signaling configuration to be placed into service.
Contractor must prepare and submit for acceptance of the Engineer a detailed Test Plan and Procedure for each type of test to be performed in preparing and placing the signaling system into service. Each Test Procedure must, at a minimum, include the following elements: (1) a description of the component or system being tested and the objective of conducting the test; (2) a description of the physical inspection to be conducted to assure that the component or system under test is installed in a workmanlike fashion; (3) the status of the component or system being tested (i.e. power on, power off, final configuration, etc.); (4) a description or list of design documents to be used to verify that the component or system is properly configured; (5) a pass/fail criteria against which the component or system will be measured in determining if it has successfully passed the test; (6) listing of test equipment to be used in taking measurements; (7) a description of the sequence of steps to be taken in conducting the test; (8) a description of how test results will be recorded; and (8) sample test forms for recording test results. When test forms are used to record tests of a group of items or activities, such as all available routes at an interlocking, Contractor must fill in the specific items being tested on the test form prior to beginning the test and the test form must be independently checked and verified to assure that all items are included. Either the interim item listing entry or the independent check must be done by an individual that has been involved in the detailed circuit design to assure that design intent is recognized.

Contractor must include all tests specified in this Section, as specified in the appropriate sections of the AREMA C&S Manual, and the FRA Rules, Standards, and Instructions for Railroad Signal Systems, CFR 49, Parts 234 and 236.

Contractor must only use personnel who are completely qualified and experienced in the adjustment and testing of the type of equipment or system being tested.

Contractor must perform pretests on all procedures in advance of actual testing.

Actual testing must be witnessed by the Engineer.

All applicable tests must be performed at each interim stage of the Signal System, if any, before placing in service.

A test report must be prepared by Contractor and submitted to the Engineer, and must include details of test results and correction or adjustments performed to the signaling system or which remain to be completed.

13-8.02 Relay and Plugboards

Each DC vital relay must be tested by Contractor in accordance with AREMA Manual, Part 6.4.1. Each AC vital relay must be tested by Contractor in accordance with AREMA Manual, Part 6.4.5. Each non-vital relay must be tested by Contractor to verify proper operation. Contractor must complete and certify the specified record form. The original form must be delivered to the Engineer prior to delivery of the materials.
13-8.03 Factory Testing Requirements

A. General

1. Contractor or its subcontractors must perform factory tests of systems, subsystems, assemblies, subassemblies, and components supplied under the Contract to verify design and nameplate ratings for adequate and proper performance.

2. All Vital Systems, and each subsystem or piece of equipment related to Vital Systems, must be inspected and tested. One hundred percent of the components in Vital Systems must be fully tested.

3. Components other than those related to Vital Systems may be tested on a sampling basis. The submitted Test Plan and Procedures must propose a number of randomly selected components or units from the manufacturing process to be tested. RT will review the number(s) as part of the submittal review and may reject the Test Plan and Procedures if RT determines the proposed number(s) is(are) too low. Contractor must test the number of randomly selected components identified in the accepted test Plan to ensure the adequacy and acceptability of all components and units produced.

4. Components related to fail-safe circuits must be tested 100 percent. Testing must be performed by Contractor or a qualified supplier to the levels required to assure the characteristics demanded by the CLASS I hardware failure mode and effects analysis.

5. When test results are not recorded on a test data plate affixed to the equipment or unit, Contractor must provide certified test reports for items at the time of delivery.

6. The test report must contain a final description sheet on which Contractor must record discrepancies found and action taken. This documentation must be provided to the Engineer.

7. Test reports must be dated and signed by the responsible employee of Contractor or subcontractor on the day the test is performed. Space must be provided for the signature of the Engineer’s witnessing inspector.

8. Contractor’s report must identify the specific test instruments used on tests by name, type, and serial number as well as calibration due date.

9. If, during factory testing, Contractor discovers errors due to circuit detailing, factory wiring, and connections that do not agree with the accepted circuit plans, then Contractor may correct such errors without prior authorization of the Engineer, but must record the correction and submit the correction to the Engineer.

10. Contractor must not make changes that affect the operation of an approved circuit, as designed, without prior written authorization of the Engineer.

11. The Engineer makes final determination as to whether a test must be repeated in whole or in part when a specific factory test does not meet the requirements specified for the test.
B. First Article Inspection Testing

A first article inspection test is required for the following:

1. Test of first interlocking instrument house.
2. Test of first highway-railroad grade crossing warning system house.

These tests are required even for service-proven equipment. Each FAI must be a comprehensive test, conducted at Contractor’s facility and must include all interfaces to assure the complete and proper operation of the equipment. This test must be accepted by the Engineer and is a prerequisite to the manufacture of additional systems.

C. Instrument House Testing

The entire complement of equipment for each instrument house must be set up at the point of assembly with equipment installed and tested as a system. Interfaces to other systems and adjacent instrument houses must be simulated. These tests must be performed in accordance with accepted test procedures. The instrument house must be physically inspected to assure that workmanship is in conformance with industry standards, that wiring is complete, and all components are in place and of the correct size, type, and rating. If the physical inspection has passing results, the following test must be performed by Contractor at a minimum:

1. Resistance Verification Test

   The resistance verification test must ensure that all wiring is complete, that point-to-point wire resistance does not exceed the maximum approved value, termination points are correct, no extraneous wiring exists, and all tagging information conforms to the accepted circuit plans.

2. Power Distribution and Failure Alarm Checks

   The power distribution and failure alarm tests must be performed to ensure that the power distribution for the instrument house or relay case under test is complete and functioning as intended. Testing must verify that each energy bus: is fed from its discrete power supply; is free of grounds (if applicable), shorts, and opens; and is wired in a closed-loop configuration. Tests must also verify that each power supply is free of internal grounds, operates properly, and is effectively fused, and that all racks and equipment are supplied energy that is correct both in polarity and magnitude. Power failure alarms and power transfer must be simulated as part of this test.

3. Track Circuit System Test
This test must prove that the track circuit equipment functions as a system. The track circuits must be connected as shown on the accepted drawings. Running rails and impedance bonds must be simulated. All track circuits must be energized. A test of track circuit polarity must be conducted by simulating the effects of broken down insulated joints (IJJs) where applicable. This test must be performed for audio frequency (AF) and alternating current (AC) track circuits.

4. Operating Test

The operating test must ensure the proper operation of all instrument house or case equipment as a system. All relays and equipment must be installed and energized. The local control panel must be used to verify that conflicting routes cannot be established. All interfaces must be simulated, including adjacent instrument houses, line circuits, TWC System, wayside pushbuttons, traffic signals, etc. Test must include simulation of various abnormal operation and failure modes to verify that the system does not display unsafe conditions.

13-8.04 Field Testing Requirements

A. Switch-and-Lock Movement Layouts

Each switch-and-lock movement must be tested by Contractor to verify wiring, mechanical connections, point obstruction, point detection, locking, running voltage and current, and clutch overloading.

B. Electric Lock Layouts

Each electric lock layout must be tested by Contractor to verify wiring, mechanical connections, point obstruction, point detection, emergency release, time release, and approach release via release AF track circuit and/or block clear.

C. Track Circuits

Each track circuit must be tested by Contractor for shunting sensitivity and polarity in accordance with AREMA Manual, Part 8.6.1, except that track shunting tests must be done using a 0.2 ohm shunt in lieu of the 0.06 ohm shunt specified in the AREMA Manual. Each new track circuit must be adjusted by Contractor in accordance with Contractor’s accepted procedures. Each existing track circuit that requires re-adjustment must be adjusted by Contractor in accordance with RT’s standard procedures. Contractor will be provided with a copy of RT’s track circuit adjustment and test procedures.

D. Impedance Bonds
Each impedance bond must be tested by Contractor in accordance with the AREMA Manual, Part 8.4.5.

E. Insulated Joints

Each installed insulated joint must be tested by Contractor with an insulated joint tester, either the Harmon 1501A IJC or an approved equal, and must measure no less than 40 ohms across the joint.

F. Event Recorders/Analyzers

Each event recorder/analyzer must be tested by Contractor in accordance with the manufacturer-recommended procedure.

G. TWC System Equipment

Each TWC System must be tested by Contractor in accordance with the manufacturers recommended procedures.

H. Wire and Cable

All associated signal equipment not under test must be disconnected and grounded by Contractor. All electronic devices or signal equipment must be disconnected or unplugged by Contractor prior to any testing.

Contractor must follow the test equipment manufacturer's instructions as to operation and electrical connections.

A continuity test must be made by Contractor of all conductors and shields.

A 1,000-volt megger must be used by Contractor to determine insulation resistance to ground. A minimum of 5 megohms, between each conductor and ground and between conductors, is required.

Test data and results must be provided by Contractor for the Engineer's information and acceptance. The data must be provided in a form that complies with the FRA Rules, Standards and Instructions for Railroad Signal Systems, 49 C.F.R. Part 236.

I. Instrument Houses, Cases, and Junction Boxes

Contractor must inspect and test the completed instrument house, case, and junction box in accordance with the accepted Test Procedures. The Test Procedures must detail the step-by-step process of conducting each test. The tests conducted by Contractor must include the following, at a minimum:

1. Resistance Verification Test
The resistance verification test ensures that all wiring is complete, that termination points are correct, that no extraneous wiring exists, and that all tagging information conforms to the accepted circuit plans.

2. Breakdown Test of Vital Circuitry

The objective of the breakdown test is to verify that the Vital and Non-vital circuits are assembled, as intended by Contractor's Signal Engineer, and verify that the wiring of these circuits is in accordance with the Contract Plans and accepted Shop Drawings.

The fundamental procedure of the breakdown test is to test one circuit at a time, by opening the circuit at each contact in the control line of the relay (or other device) operated by the circuit. This action verifies that the contact on the controlling relay (or other device) is in the circuit under test. This test must be performed without power, relays not installed, and using jumpers to simulate contacts unless otherwise authorized in writing by the Engineer.

3. Power Distribution Checks

The power distribution tests must be performed to ensure that the power distribution for the equipment case under test is complete and functioning as intended. Testing must verify that each energy bus is fed from its discrete power supply; is free of ground (if applicable), shorts, and opens; and is wired in an enclosed-loop configuration. Tests must also verify that each power supply, battery charger, UPS and automatic transfer switch is free of internal grounds, operates properly, and is effectively used and that all racks and equipment are supplied energy that is correct both in polarity and magnitude.

Test must also include verification that the Approach Stick Relays will not inadvertently re-pick due to a low 100Hz power condition.

4. Track Circuit System Test

The track circuit system test must ensure that the track circuit components will function as a unit. Insulated joint breakdown detection must also be tested.

5. Operating Test

The operating test will be performed to ensure the proper operation of the equipment as a system including verification that interconnections to adjacent locations and systems function correctly. All relays and equipment must be installed and energized. Tests must be conducted to verify that conflicting routes cannot be established. Routes must be tested from the LCP, route selectors and TWC. Test must include simulation of
various abnormal operation and failure modes to verify that the system does not display unsafe conditions. Contractor must also test for abnormal conditions by systematically failing various component devices and systems to assure that no unsafe conditions exist. The operating test must test all LCP functions (controls and indications) specified in these Technical Specifications and shown in the Plans. The operating test must also test all instrument house equipment, including but not limited to, the ground detector light and blue light.

J. Foundations

Contractor must certify that the following tests and procedures have been adhered to:

1. The precast fabricator kept a record of the date and conditions under which the units are cast.
2. Representative test specimens of the concrete during the fabrication of the precast units were tested to determine the compressive strength of the concrete by an "accredited authoritative structural testing laboratory" at no cost to RT.
3. Cement, aggregates, mixing water, and reinforcement used for precast units and cast-in-place structures conform to the requirements specified in the current edition of the AREMA Manual for Railway Engineering.
4. Water-cement ratio, vibration frequency, and protection and curing processes were monitored to provide the strength of concrete specified in this section.

K. Traction Power Bonding

All final rail connections, impedance bond connections, and substation negative return connections must be tested by Contractor for electrical continuity and mechanical integrity.

L. Traffic Signal Interface

Contractor must coordinate with the appropriate City or County traffic engineer in conducting wire continuity and circuit functionality tests of the traffic signal interconnections.

M. Highway-railroad Grade Crossing Warning

Contractor must test each grade crossing warning installation in accordance with AREMA C&S Manual Parts, 2.4.1, 3.3.1 and 3.3.5 and in accordance with 49 C.F.R. Part 234 - Grade Crossing System Safety.

13-8.05 Dynamic Testing
Contractor must perform Signal System dynamic testing to ensure that the Signal System and interfaces function as intended. Contractor must perform these tests after all other applicable testing is complete. Contractor must use various types of LRVs to perform applicable tests. All functions of the Signal System must be tested under normal and abnormal operating conditions. The following dynamic testing must be performed:

A. Routing Test

All routes must be tested for proper automatic, manual, and default operation by circulating an LRV.

B. TWC System Test

Each wayside TWC loop location must be tested for proper operation using an LRV with a vehicle-borne TWC System.

C. Highway-railroad Grade Crossing Warning System Test

Each highway-railroad grade crossing warning system must be tested with an LRV operating at maximum authorized speed. Contractor must verify that the prescribed warning time is provided. Contractor must measure and record train speeds at crossing entry and station entry points and must record relative timing of critical activities such as: entry into detection zone, activation of crossing warning, gate down, clearance of station leaving signals, arrival of train at the crossing, clearance of the train through the crossing, crossing warning de-activation, and gates to their full vertical position. A minimum of 2 timed runs must be made at each crossing approach.

Contractor must verify crossing activation in reverse direction running by occupancy of the island circuit and must verify proper clearance of the crossing when the train leaves the approach circuit.

Contractor must verify the proper adjustment of island and AFO track circuits by verifying that a maximum length train will clear the island circuit and release the crossing warning when making a normal station stop beyond the crossing.

Contractor must verify proper operation of the grade crossing indicators.

Where fixed distance approaches are used at bi-directional crossings, Contractor must verify the proper operation of directional stick circuits, including interconnections to the wayside block signal system.

Contractor must also test for abnormal conditions by systematically failing various crossing warning devices and systems to assure that no unsafe conditions exist.
13-8.06 Electromagnetic Compatibility Control Program Plan

Contractor must submit an EMC control program plan no later than 180 days before the planned start of Signal System testing describing the approach Contractor will use to ensure that the Signal System and related equipment will operate as intended within the electromagnetic environment of the RT light rail transit system.

The EMC control program must describe Contractor's approach to ensuring that the Signal System will not generate emissions which could interfere with the operation of other systems internal or external to the RT light rail transit system.

The EMC control program must, as a minimum, comply the following:

A. Determine the existing electromagnetic environment emanating from fixed and mobile facilities external to the RT light rail transit system that may interfere with the operation of the Signal System.

B. Contractor must develop any additional emissions and susceptibility data needed to meet the requirements for the Signal System EMC.

C. The program must include an analysis of the electromagnetic environment developed under Paragraphs A and B above. The analysis must include recommendations for train detection, and other Signal System frequencies, a frequency management plan, and a receiver sensitivity plan. The receiver sensitivity plan must provide the envelope of susceptibility (frequency versus amplitude) for all power and signal receiving devices utilized in the Signal System. These analyses must clearly demonstrate that the Signal System will perform the intended functions without degradation. The control plan must include the EMC management and control, frequency management, analysis, environment, design, and implementation considerations to realize the required systems EMC.

D. The techniques proposed to prevent the electromagnetic interference (EMI) with the low power control circuits, including analog circuits and microprocessors, must be presented.

E. Results of the EMC testing of electronic equipment on other similar rail transit systems may be presented, along with a description of how microprocessor logic will react and recover in the event of momentary malfunctions caused by the EMI.

13-8.07 Electromagnetic Compatibility Tests

A. Electromagnetic Compatibility Test Plan, Procedures, and Reports

1. During Signal System Equipment selection phase and no later than 180 days before Contractor intends to begin Signal System testing, Contractor
must submit, for the Engineer’s acceptance, a EMC test plan that outlines the proposed test efforts. The purpose of the EMC test plan is to establish the requirements necessary to demonstrate Signal System compliance with the EMC specifications.

2. Upon acceptance of the EMC test plan, Contractor must submit detailed Test Procedures for concurrence and acceptance. The detailed Test Procedures must include, but not be limited to, test requirements, test scenarios, instrumentation requirements and selection, test personnel, site selection, logistics, coordination, support requirements, and test scheduling.

3. Contractor must submit certified test reports to verify and document that EMC requirements as set forth in these Technical Specifications have been incorporated into the Signal System and all specified EMC performance standards have been met.

B. Tests

Contractor must perform tests, either separately or as part of other testing, to ensure proper operation of the Signal System equipment in the projected electromagnetic environment.

Tests, data reduction, analysis, and reporting must be in accordance with the appropriate Urban Mass Transportation Administration (UMTA) (now Federal Transit Administration (FTA)) Suggested Test Procedures. Where UMTA Suggested Test Procedures do not meet the needs of a specific test requirement, Contractor must recommend other standard (e.g., military standard) procedures that may be applied.

Tests must include determination of the following:

1. Susceptibility of the Signal System equipment and systems to electrical energy appearing on AC and DC power leads.
2. Susceptibility of equipment and systems to intermodulation and rejection of unwanted signals appearing at the input terminals.
3. Susceptibility of equipment and systems to transient interference on AC and DC power leads.
4. Magnetic field emissions from equipment, power cables, and interconnecting wiring.
5. Electric field emissions from equipment, power cables, and interconnecting wiring.
6. Susceptibility of equipment and systems to short duration magnetic fields or transient interference appearing on the input and output cabling.
7. Susceptibility of equipment and systems to magnetic and electric fields.

13-9 TRAINING

Training is not required for Owner-furnished material.
13-9.01 General Requirements

Contractor must train RT personnel in the operation and maintenance of the Signal System. The training courses must be oriented toward providing various levels of the RT personnel with a thorough understanding of the Signal System capabilities and comprehensive instruction in the operation and maintenance of the Signal System. Training must also include engineering and maintenance level training for maintaining and making changes to the Signal System application software and relay logic.

Students entering the training program will have the basic skills pertinent to their job classification, but they will not have knowledge of the equipment provided under this Contract.

Training may be conducted by Contractor, Contractor’s subcontractors, and/or equipment manufacturers. The training must be conducted in Sacramento and it must be both classroom and hands-on training.

13-9.02 Signal System Operations Training

The Signal System operations training must train the RT Operator’s Instructors in the operating procedures necessary to operate the Signal System. This course must include, but not be limited to, the following training:

A. Classroom courses must give course participants an understanding of the overall Signal System operation and must include:

1. Operations overview of all Signal System functions of the wayside block signal and highway-railroad grade crossing warning systems.
2. Interactions between the wayside and vehicle TWC Systems.
3. Interactions between the automatic TWC routing, local control panel routing, and route selector pushbutton routing.
4. Interactions between the wayside block signal, highway-railroad grade crossing warning, traffic signal, and UPRR railroad highway-railroad grade crossing warning systems.
5. Detailed instructions on the operation of each interlocking local control panel. These instructions must include descriptions of the interlocking operation and interactions with the highway-railroad grade crossing warning system.
6. Detailed instructions on the use of each route selector.
7. Detailed instructions on the use of each highway-railroad grade crossing cancellation pushbutton. These instructions must include descriptions of the highway-railroad grade crossing warning system operation and interactions with the wayside block signal system, vehicle-borne TWC System, traffic signal system, and UPRR railroad highway-railroad grade crossing warning system.
13-9.03 **Signal System Maintenance and Engineering Training**

The Signal System maintenance and Engineering training must train the RT personnel with system and equipment operation and maintenance procedures necessary to troubleshoot and maintain the Signal System. These courses must include, but not be limited to, the following training:

A. **Overall System Maintenance Training**

The overall Signal System maintenance training must provide RT personnel with an overview of and hands-on experience with the Signal System functional capabilities and overall system operation in order to properly troubleshoot and maintain the Signal System. This course must provide course participants with a working knowledge of the Signal System equipment and its operation, interfaces, and use of test equipment for diagnosing troubles. This course must provide sufficient theoretical background and hands-on experience in troubleshooting and repair procedures to permit participants to locate and repair system faults in a timely manner. This course must use the Signal System circuits and operations and maintenance manuals as applicable. This course must cover all troubleshooting and debugging techniques available for use in the Signal System.

B. **Equipment Operations and Maintenance Training**

Contractor must provide training in the operation and maintenance of all Signal System equipment. The training must provide RT personnel with a thorough knowledge of the equipment and its operation, its interface with other equipment, and the capabilities and use of test equipment and self-diagnostics. These courses must provide course participants with a theoretical background and hands-on experience in troubleshooting, repair procedures, and preventative maintenance procedures. Courses must include board level troubleshooting and repair. Courses must also include component-level repair where appropriate. Course participants must operate actual in place equipment, and learn how to use test equipment and fixtures to troubleshoot problems and repair failures.

These courses must first be given in the classroom and then RT personnel must be given hands-on instruction where they will be able to put the theoretical classroom training to practical use. The training must cover the following subjects, but are not limited to these subjects, if Contractor requires additional subjects for the RT personnel to be self-sufficient:

1. Equipment operation
2. Troubleshooting procedures, including self-diagnostics and test equipment
3. Interface with other equipment
4. Preventative maintenance procedures
5. Theory of operation
6. Application logic revision/replacement.

C. Signal System Software Training

Contractor must provide software courses for all application software provided. These courses must be designed in a manner that enables the RT personnel to maintain and make modifications to the software. These courses must be given first in the classroom and then using the various software development tools. The software training courses must cover the following subjects, but are not limited to these subjects, if Contractor requires additional subjects for the RT personnel to be self-sufficient:

1. Vital and Non-vital application implementation software, including interlocking control, highway-railroad grade crossing warning system controls, and interface with the wayside TWC System.
2. Event recorder/analyzer programming.

13-9.05 Class Sizes

Contractor must provide Signal System operations training, maintenance training, and engineering training for the following number of course participants:

A. RT must be able to send 5 participants to the Signal System operations training courses.
B. RT must be able to send 10 participants to the Signal System maintenance and engineering training courses.

13-9.06 Training Schedule

RT will develop a complete detailed training schedule in consultation with Contractor after review of Contractor recommendations.

Each training course for operators, maintenance personnel and engineers must be conducted during RT’s normal business hours Monday through Friday.

13-9.07 Training Location and Classroom

All training courses must be conducted in Sacramento, California. Classroom training must be conducted in RT’s training room.

13-9.08 Instructors

The principal instructors provided by Contractor, subcontractors, and/or equipment manufacturers must have previous formal classroom instruction training and relevant experience with the Signal System equipment in an operating environment.
Instructors must demonstrate a complete and thorough technical knowledge of the material being covered in the course. These instructors must be thoroughly familiar with handbooks, guides, tools, test equipment, and other aides used in troubleshooting, repair, preventive maintenance, and Signal System design and operations. Contractor’s instructors must be submitted to the Engineer for acceptance. The submittal must include resumes and training references. Oral interviews may also be required. The Engineer’s decision concerning the qualifications of the various candidate instructors will be final. The Engineer may conduct quality audits of the training courses during classroom and/or hands-on training courses.

All training material must be presented in person at RT by a qualified instructor. If prerecorded lectures are used to supplement training, the instructor or a qualified substitute must be present to supplement the recorded material and answer questions.

13-9.09 Training Reports

Prior to completion of a class curriculum, the instructor must test the knowledge learned by each class participant by administering written and oral tests of the material covered in the class.

All instructors must submit to the Engineer confidential evaluation reports and technical performance of the RT personnel attending each course.

13-9.10 Training Manuals and Equipment

Contractor, Contractor’s subcontractors, and/or equipment manufacturers must prepare training manuals and submit them to the Engineer at least 6 months prior to the planned start of classroom instruction. The training manuals must be prepared specifically for use as training aids. Reference manuals, maintenance manuals, and user’s manuals may be used as supplementary training material, but not as the primary training manual. Principal documents used for training must be tailored to reflect all the RT equipment and specific user requirements.

Contractor must provide one accepted training manual copy and other pertinent material for each course participant. The manuals and other pertinent material must also be supplied in electronic form (CD-ROM or USB flash drive) to the Engineer so that additional copies may be generated by RT personnel as required.

Contractor must provide a complete set of instructor’s manuals and training aids to the Engineer.

Upon completion of each course, the instructor’s manuals, training manuals, and training aids become the property of RT. Throughout the Contract period, Contractor must supply RT with all changes and revisions to the training manuals and other documentation.
RT reserves the right to copy all training materials and aids for use in future RT-conducted training courses.

Contractor must provide all special tools, equipment, training aids, and any other materials required to train course participants. The number of special tools and other training equipment must be adequate for the number of participants attending the course.

13-9.11 Training Program Development Plan

Contractor must prepare a training program development plan and submit it to the Engineer for acceptance. The training program development plan must contain, as a minimum, the following:

A. A flow diagram indicating the logical progression of training to be conducted.
B. Lesson plans for the proposed courses of instruction and a course outline of each course, including the proposed course duration.
C. Resumes and references of the proposed instructors for each course.
D. A proposed training schedule. Minimum duration of the training course for operator instructors must be no less than 1 working day of actual training. The minimum duration of the training course for maintenance personnel and engineers must be no less than 4 working days of actual training.
D. A list of prerequisites for each course.

13-10 TEST EQUIPMENT

Contractor must supply all special test equipment, special test fixtures, patch cords, adapters, extender boards, and any other special devices and software necessary to troubleshoot, maintain, and perform design and application logic software changes. Special equipment and software is defined as equipment and software not commercially available as a stock or general production item from more than one manufacturer. Contractor must provide 2 of each type of special equipment and software.

Contractor must also provide the Engineer with a list of all proposed standard test equipment, software, and apparatus required.

Contractor must provide special test equipment that calibrates and verifies the functional operation of the Signal System equipment. As a minimum, the special test equipment must include the following:

A. Test equipment and software required to modify and/or replace application logic in the wayside microprocessors.
B. Test equipment and software required to program the event recorder/ analyzer.

13-11 MAINTENANCE DURING CONSTRUCTION

RT will perform Signal System maintenance during construction for existing equipment that requires modification from Meadowview interlocking to 47TH Avenue Station.

Contractor must perform Signal System maintenance during construction for all new equipment from Meadowview interlocking south. Contractor’s maintenance responsibilities include preventive maintenance, troubleshooting and repair, and regulatory agency testing requirements during the interim highway-railroad grade crossing warning systems configurations required to support the UPRR and/or RT railroad operations.

Contractor’s maintenance during construction responsibilities include, but are not limited to the following:

A. Contractor is responsible for all interim system testing and all cutover testing.

B. Contractor is responsible for lubrication of switches.

C. Contractor must supply all requirements necessary for RT to perform maintenance of newly-installed or modified signaling equipment from 47th Avenue to Meadowview prior to Final Acceptance. These requirements include, but are not limited to providing spare parts, training, As-Built Plans or interim As-Built Plans, test equipment, and FRA testing, reporting and record keeping requirements.

13-12 MEASUREMENT AND PAYMENT

13-12.01 Engineering Design Submittals

A. Measurement

Contractor's engineering design submittal and drawing schedule effort will be measured and paid as a lump sum for all design submittals and the drawing schedule as described in these Technical Specifications and will be paid after the acceptance of the drawing schedule and design submittals by the Engineer. Bid Item Number WS-01 Engineering Design and Submittals.

B. Payment

The lump sum price paid for engineering design submittals includes full compensation for the engineering design effort, for producing all necessary documents, for preliminary designs, for all submittals and the labor, shipping and incidentals required in the preparation of each submittal, and for the revision of
any document and the re-submittal as required by the Contract Documents and as directed by the Engineer for the wayside signaling and highway grade crossing warning systems.

Until all As-Built documentation required by the Contract Documents for the Signal System has been submitted, Contractor will be entitled to, and may request payment for, only 70% of the lump sum price for engineering design submittals. The remaining 30% of the Contract price for engineering design submittals will not become due, and Contractor may not request payment for such engineering design submittals, until as-built documentation as required in the Contract Documents has been submitted and accepted.

13-12.02 Install Electric Switch-and-Lock Movements

A. Measurement

Install Electric Switch-and-Lock Movements will be measured as units, determined by actual count of electric switch-and-lock movements, of each type and configuration installed. Bid Item Numbers WS-11 Supply Misc. Hardware & Install Power Switch & Lock Movement and WS-12 Supply Misc. Hardware & Install Power Switch & Lock Movement W/Helper Assembly.

B. Payment

The unit price paid for each electric switch-and-lock movement includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing miscellaneous mounting hardware and providing all other required hardware as identified in the Plans, installing and testing the switch-and-lock movement, complete and in place, including the switch machine, circuit controller, hand throw lever stands, front rods, throw rods, lock rods, point lugs, head rods, rollers, adjustment baskets, junction boxes, point detector rods, mounting, controlling equipment, wiring, wire tags, cable to the control location, push-pull helper assemblies, gage plate extensions, switch mounting plates, pipe helpers, conduit, locks, keys, labor, tools, hardware and appurtenances, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.03 Provide and Install Signals

A. Measurement

Provide and Install Signals will be measured as a unit determined by actual count of signals, of each type and configuration, provided and installed. Bid Item Numbers WS-02 Supply & Install 3-Aspect High Signals, WS-03 Supply & Install 3-Aspect High Signals W/Route Selector on Mast, WS-05 Supply & Install 3-Aspect Medium Signals and WS-06 Supply & Install 3-Aspect Low Signals.
B. Payment

The unit price paid for each signal type and configuration includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing each signal type and configuration, complete and in place, including number plates, ladders, signal heads with LED units, lens, offset arms, route selectors, foundations, controlling equipment, wiring, wire tags, locks, keys, labor, tools, hardware, and appurtenances, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.04 Provide and Install Route Selector Control Stands

A. Measurement

Provide and Install Route Selector Control Stands will be measured as unit, determined by actual count of route selector control stands provided and installed. Bid Item Number WS-08 Supply & Install Route Selector Control Stands.

B. Payment

The unit price paid for each route selector control stand includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing of the route selector stand, complete and in place, including foundation, mast, mast cap, route selector control stand enclosure, LED indicators, push buttons with LED indicator, controlling equipment, wiring, wire tags, locks, keys, labor, tools, hardware, and appurtenances, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.05 Provide and Install Impedance Bonds

A. Measurement

Provide and install Impedance Bonds will be measured as a unit, determined by actual count of impedance bonds provided and installed. Bid Item Number WS-14 Supply & Install 1500 Amp Impedance Bonds.

B. Payment

The unit price paid for each impedance bond includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing and testing of the impedance bond, termination plates, cables, connectors, bolted rail connections, wood mounting ties, cable guards, plywood security covers with mounting timbers, re-spacing
ties, complete and in place, including labor, tools, hardware, and appurtenances, rail connections, welds and bond strand, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.06 Provide and Install Power and Signal Bonding

A. Measurement

Provide and install power and signal bonding will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-15 Supply & Install Power & Signal Bonding.

B. Payment

The lump sum price paid for power and signal bonding includes full compensation for providing all labor, materials, tools, equipment, and incidental, and for doing all work involved in providing, installing, and testing of the bonding, complete and in place, including labor, tools, hardware, conduit and appurtenances, wire clips and conduit clips, rail connections, welds, cables, connectors, jumpers, exothermic welds, bolted rail connections, and bondstrand, provided, installed and tested, as necessary to complete a working component of the Signal System and traction power system, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.07 Provide and Install Instrument House at an Interlocking or Future Station

A. Measurement

Provide and install instrument house at an interlocking or future station location will be measured as a unit, determined by lump sum for each instrument house at an interlocking or future station provided and installed. Bid Item Numbers WS-26 Supply & Install Instrument House S849IH at Future Morrison Creek Station, WS-27 Supply & Install Instrument House S945IH at Franklin (S945) Interlocking and WS-28 Supply & Install Instrument House S1155IH at CRC Terminal (S1155) Interlocking.

B. Payment

The lump sum price paid for each instrument house at an interlocking or future station includes full compensation for providing all labor, materials, tools, equipment, and incidental, and for doing all work involved in providing, installing, and testing of the instrument house, complete and in place, including labor, tools, hardware, and appurtenances, foundations, circuit breakers, cable entrances, transformers, power supplies, battery chargers, batteries, wiring, wire tags, relays, vital and non-vital microprocessors, spare vital and non-vital microprocessor application logic circuit board and associated storage housing, event recorder/analyzers, TWC control unit, uninterruptible power supplies, local...
control panel, ground detector, ground detector light, busses, fuses, lighting, fans, thermostats, air conditioner, track circuit equipment, racks, trays, shelves, backboards, terminal boards, steps, shoring, identification, junction boxes, track transformer cases, utility connections, utility meter and housing, local cabling to wayside devices, locks, and keys, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

SMUD direct charges for providing AC power service connections will be paid by RT and will not be a Contract cost.

13-12.08 Modify Existing RT Instrument Houses and Relay Cases

A. Measurement

Modify Existing RT Instrument Houses and Relay Cases will be measured as a lump sum for each instrument house and relay case, modified, as shown on the Plans and as specified in this Section. Bid Item Numbers WS-30 Modify Instrument House S235IH at Meadowview (S235) Interlocking, WS-31 Modify Instrument House S643H at Florin Station and WS-32 Modify Instrument House S541H at 47th Street Station.

B. Payment

The lump sum price paid for modifying each instrument house and relay case includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in modifying, installing, and testing of the Signal System equipment, complete and in place, including labor, tools, hardware, and appurtenances, cable, conduits, cable entrances, transformers, power supplies, battery charger, batteries, wiring, wire tags, relays, track circuit equipment, vital and non-vital microprocessor equipment and programming, TWC control equipment, local control panel, busses, fuses, circuit breakers, backboards, terminal boards, identification, signals, route selectors, and junction boxes, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.09 Provide and Install Relay Case at Intermediate Signals and Ends of Track Circuits

A. Measurement

Provide and Install Relay Case at intermediate signals and ends of track circuits will be measured as a lump sum for each relay case at intermediate signals and ends of track circuits, provided and installed. Bid Item Numbers WS-17 Supply & Install Tk RC and Conduit/Cabling for S802/S803 Signals, WS-18 Supply &

B. Payment

The lump sum price paid for each relay case at intermediate signals and ends of track circuits includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing of the relay case, including labor, tools, hardware, appurtenances, foundation, cable entrances, local solar power system, transformers, wiring, wire tags, relays, track circuit equipment, busses, fuses, circuit breakers, lighting, fans, thermostats, racks, trays, shelves, backboards, terminal boards, steps, shoring, identification, junction boxes, track transformer cases, cabling from the controlling instrument house, local cabling to wayside devices and track circuit connections, locks, and keys, provided, installed and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.10 Provide and Install Express Signal Cable System

A. Measurement

Provide and Install Express Signal Cable System will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-34 Supply & Install Express Signal Cable System (for Messenger see OCS) – 245+65 to 559+66.

B. Payment

The lump sum price paid for Express Signal Cable System includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing all aerial and in-conduit cable, including all power cable, 100 Hz distribution cable, express signaling circuit cable, track transformer cases, temporary cabling for interim conditions and miscellaneous interconnection cabling, complete and in place, including labor, tools, conduit, conduit fittings, weatherheads, pull boxes, pull line, aerial signal cable strapping and attachment hardware, fill, excavation and backfilling, mounting hardware, cable ties, drops, hardware, cable tags, wire tags, junction boxes, and terminals, provided, installed, relocated and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.
13-12.11 Provide and Install Systems Conduit and Pull Box System

A. Measurement

Provide and Install Systems Conduit and Pull Box System will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-35 Supply & Install Systems Conduit System – 245+65 to 579+00.

B. Payment

The lump sum price paid for signaling and communications conduit and pull box system includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing all conduits and pull boxes, complete and in place, including labor, tools, conduit, conduit fittings, pull boxes, pull box tamperproof covers, pull line, fill, excavation and backfilling, marker tape mounting hardware, provided, installed, and tested, as necessary to complete a working component of the Signal System and communications system, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.12 Provide and Install Highway Grade Crossing Warning System

A. Measurement

Provide and Install Highway Grade Crossing Warning System will be measured as a lump sum, per each highway grade crossing warning system location provided and installed. Bid Item Numbers WS-36 Supply & Install Meadowview Road Hwy Crossing Warning Sys W/ S744IH, WS-37 Supply & Install Franklin Blvd. Crossing Warning Sys W/ S975IH, WS-38 Supply & Install Center Parkway Hwy-Rail Crossing Warning Sys W/ S1078IH and WS-39 Supply & Install CRC Hwy-Rail Crossing Warning Sys W/ S1165IH.

B. Payment

The Contract lump sum price paid per each highway grade crossing warning system includes full compensation for providing materials and installing all materials, and all incidentals, and for doing all the work involved in installing each highway grade crossing warning system, complete in place, including signs, miscellaneous iron and steel, instrument house, case, ground detector light, power off light, gates, flashers, crossing indicators, pedestrian-activated warning signs, queue activated warning signs, cantilevers, local cabling to wayside devices and track circuit connections, track circuit equipment, event recorder/analyzers, vital and non-vital microprocessors, spare vital and non-vital microprocessor application logic circuit boards and associated storage housing,
TWC control unit, power supply, battery charger, batteries, air conditioner, wiring, wire tags, utility connections, utility meter and housing, traffic signal interface connection and conduit, UPRR railroad interface connection conduit and cabling, relays, relay logic, ABS system control equipment, pushbuttons, nearside pushbutton cancellation selector at mini-high platforms, foundations, track transformer cases, locks, keys, and associated materials as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

Full compensation for all additional materials not shown on the Plans, or specified in this Section that are necessary to complete the installation of the various grade crossing warning systems are considered as included in the Contract unit price paid per each for the various grade crossing warning systems, and no additional compensation will be allowed therefor.

SMUD direct charges for providing AC power service connections will be paid by RT and will not be a contract cost.

13-12.13 Wayside Signal Construction Staging

A. Measurement

Wayside Signal Construction Staging will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-46 Construction Staging.

B. Payment

The lump sum price paid for Wayside Signal Construction Staging includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, modifying, relocating, testing and removing wayside block signaling and highway grade crossing warning system equipment, hardware, and appurtenances, in order to maintain the operation of the RT Signal System and the RT and UPRR railroad highway grade crossing warning systems as required for each stage of the construction sequence, as specified in these Technical Specifications, as shown on the Plans, and as directed by the Engineer. Retagging equipment and wiring are included in the Construction Staging payment item. Initial and final system testing cutover to revenue service are also included in the construction staging payment item. The construction staging plan(s) and cutover plans are included in the construction staging payment item.

13-12.14 Removal and Salvage of Equipment

A. Measurement
Removal and Salvage of Equipment will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-47 Removal and Salvage of Equipment.

B. Payment

The lump sum price paid for removal and salvage of equipment includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in removing and salvaging the Signal System equipment, including signals, equipment cases, route selectors, gates, flashers, signs, instrument house and case equipment, foundations, cable, and conduit, as necessary to complete the work as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.15 Wayside Signal System Spare Parts

A. Measurement

Spare Parts will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-48 Spare Parts.

B. Payment

The lump sum price paid for spare parts includes full compensation for providing and delivering spare parts as specified in these Technical Specifications for the Signal System.

13-12.16 Supply Laptop Computer

A. Measurement

Supply Laptop Computer will be measured by unit price as described in these Technical Specifications. Bid Item Number WS-49 Supply Laptop Computer.

B. Payment

The unit price paid for laptop computer includes full compensation for providing all labor, materials, equipment, and incidentals, and for doing all work involved in providing and testing the laptop computer, complete and in place, including labor, and software, as necessary to complete a working component of the Signal System, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.17 Supply Test Equipment

A. Measurement
Supply Test Equipment will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-50 Supply Test Equipment.

B. Payment

The lump sum price paid for test equipment includes full compensation for providing all labor, materials, equipment, and incidentals, and for doing all work involved in providing and testing the test equipment, complete and in place, including labor, and software, as necessary to complete a working component of the Signal System, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.18 Training

A. Measurement

Training will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-51 Training.

B. Payment

The lump sum price paid for training includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing the training including, preparing training plans, providing training manuals, conducting training sessions, conducting and grading tests, and evaluating training participant performance, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.19 Dynamic Testing

A. Measurement

Dynamic Testing will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-52 Dynamic Testing.

B. Payment

The lump sum price paid for dynamic testing includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing the testing including, preparing test plans, test reports, and conducting testing, as specified in these Technical Specifications, and as directed by the Engineer. EMI/EMC testing is included in the dynamic testing payment item.

13-12.20 Provide and Install Signs

A. Measurement
Provide and Install Signs will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Number WS-53 Supply & Install Signs.

B. Payment

The lump sum price paid for Supply and Install Signs includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing and installing the signs complete and in place, including mile pole signs, begin block signs, end block signs, approach end block signs, speed signs, street name signs, resume speed reflectors, poles, mounting hardware, and foundations, provided and installed, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.21 Signal Engineer

A. Measurement

Cost of Signal Engineer will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-54 Signal Engineer.

B. Payment

The lump sum price paid for Signal Engineer(s) includes full compensation for providing all labor, materials, tools, equipment, travel and living expenses, and all other incidentals, and for doing all work involved in providing the signal engineer(s) as necessary to complete the Signal System work, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.22 Provide and Install Bridge Lighting System

A. Measurement

Provide and Install Bridge Lighting System will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Numbers WS-41 Supply & Install Bridge Lighting System for Morrison Creek Bridge and WS-42 Supply & Install Bridge Lighting System for CRB Bridge.

B. Payment

The lump sum price paid for each Bridge Lighting System includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing the bridge lighting system, complete and in place, including labor, tools, lighting fixtures,
lamps, lighting contactors, photo-electric controls, control wiring, fuseholders, fuses, cable, fill, conduit, conduit fittings, cable messenger, hardware, cable to the controlling instrument house, cable ties, drops, cable tags, junction boxes, pull boxes, and terminals, provided, installed, and tested, as necessary to complete a working component of the bridge lighting system, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.23 Provide and Install Bridge Warning System

A. Measurement

Provide and Install Bridge Warning System will be measured by lump sum as described in these Technical Specifications and as shown on the Plans. Bid Item Numbers WS-43 Supply & Install Bridge Warning System for Morrison Creek Bridge and WS-44 Supply & Install Bridge Warning System for CRB Bridge.

B. Payment

The lump sum price paid for each Bridge Warning System includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in providing, installing, and testing the bridge warning system, complete and in place, including labor, tools, lighting fixtures, lamps, control housings, switches, control wiring, fuseholders, fuses, cable, fill, GRS conduit, conduit fittings, cable messenger, hardware, cable ties, drops, cable tags, junction boxes, cabling to controlling instrument house, and terminals, provided, installed, and tested, as necessary to complete a working component of the bridge warning system, as shown on the Plans, as specified in these Technical Specifications, and as directed by the Engineer.

13-12.24 Re-adjustment of Existing RT 100 Hz Track Circuit

A. Measurement

Re-adjustment of Existing RT 100 Hz Track Circuits will be measured by lump sum as described in these Technical Specifications. Bid Item Number WS-25 Re-adjustment of Existing 100Hz Track Circuits.

B. Payment

The lump sum price paid for Re-adjustment of Existing RT 100 Hz track circuits, within the limits shown on the Plans and as specified in this Section, includes full compensation for providing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in testing and re-adjusting (if necessary) existing RT 100 Hz double rail track circuits complete and in place, including labor, tools, and wire tags provided, installed, and tested, as necessary to complete a working component of the Signal System, as shown on the Plans, as specified in these
Technical Specifications, and as directed by the Engineer. The 100 HZ Power Line Analysis is included in the re-adjustment of existing RT 100 Hz track circuits payment item.