3. Design calculations, installation detail and component shop drawings.

4. Contact and messenger wire stringing procedure and attachment to and adjustment of balance weight anchors.

E. Thirty (30) days following installation: Submit the following within 30 calendar days following acceptance

1. OCS Stringing Records including: wire run number, anchor structure locations, reel number, length of conductor installed, weather conditions at time of installation, installation tension, location of factory splices (if applicable).

1.07 GENERAL DESIGN REQUIREMENTS

A. Safety Design. As a minimum, incorporate the following requirements in system design and operational procedures:

1. Avoid, eliminate, or reduce hazards identified by analysis, design selection, redesign, material selection, or substitution.

2. Control and minimize any risks to personnel, public, equipment and materials from those hazards that cannot be avoided or eliminated.

3. Incorporate fail-safe principles where failures would disable the system, injure human beings, damage equipment, or cause inadvertent operation of critical equipment.

4. Locate equipment components so access to them by the required personnel during operation, maintenance, repair, or adjustment minimizes exposure to hazards such as entrapment, chemical burns, electrical shock, cutting edges, sharp points, or toxic atmospheres.

5. Provide necessary warning and caution notes in operations, assembly, maintenance, and repair instructions, and distinctive markings on hazardous components and equipment for personnel and public protection.

B. Operating Environment: Make OCS inclusive of all its equipment, devices, and materials, capable of being operated and maintained at the performance levels indicated, without impairment resulting from the impact of the environment, over the ranges and values indicated in the Contract Documents.

1. Ambient Outdoor Temperature: 25°F to +130°F.
2. Relative Humidity: 8 to 100 percent.


3. Operating wind Velocity: 70 mph

4. Rainfall: Maximum rainfall in 24 hours – 1.2 inches.

5. Ice Buildup: None

6. Snowfall: None.

7. Freezing Rain: None.


1.08 APPEARANCE OF COMPLETED INSTALLATION

A. Ensure that the completed OCS has a neat and attractive appearance, with minimum adverse impact on fixed facilities and surrounding areas, after all components, equipment, and hardware are installed in place and final adjustments made. The new OCS system is to have the same appearance as the existing Metro OCS system, insofar as possible. To ensure this, submit to the Authority, prior to starting on-site work, information on his proposed components and installation methods, accompanied by photographs of existing OCS constructed similarly.

PART 2 PRODUCTS

2.01 GENERAL

A. All materials to be new products of manufacturers having five years proven experience designing and manufacturing materials and equipment for electrified light rail transit systems.

2.02 SPARE PARTS LIST

A. Contractor to submit all complete ordering information on all assemblies and subassemblies. Group-lists by system and subsystem and include component name, description, current price, manufacturer's name, part number, and material reference number. The agency may request that spare parts be purchased.

2.03 SPARE PARTS TO BE FURNISHED
A. Delivery: Deliver spare parts to the Agency’s maintenance storage facility at a time mutually agreed upon between the Agency and Contractor. All costs of loading, shipping and unloading at the Agency’s facility to be included in the lump sum price for spare parts.

2.04 SPECIAL TOOLS FOR OCS INSTALLATION

A. Provide special tools required for the work, including height/stagger gauges, superelevation/step gauges, telescopic measuring stick, and measuring wheel.

B. Height/stagger gauges, and superelevation/step gauges shall be special designs fabricated by the contractor in accordance with the performance requirements specified herein. All other equipment items shall be standard manufactured items, as hereinafter specified, unless otherwise noted.

C. All special tools specified herein shall be used by the Contractor, and shall remain his property, throughout the construction period of the OCS, and during its subsequent testing and commissioning as specified in Section 34 23 90, Overhead Contact System Acceptance. Following acceptance of all segments of the complete system, all gauges and special tools shall become the property of the Agency, and shall be delivered to the Agency, in good working condition, as directed by the Authority.

PART 3 EXECUTION

3.01 LOCATION OF STRUCTURES

A. Reference points for location of OCS structures and facilities are indicated in the Contract Documents. All permanent structures are indicated in the Contract Documents.

B. Actual location of the OCS support structures may vary from those indicated in the Contract Documents.

C. Identify clearly all structures and objects that might interfere with OCS installation in terms of location and elevation, referenced to the adjacent track, and advise the Authority of any obstructions that could interfere with the OCS installation if not corrected. The Authority will advise the Contractor of remedial action to be taken.

D. Prior to installing supports on poles and buildings, verify the pole foundation and building support locations and attachment provisions, and advise the Authority of any deficiencies that could result in an
unacceptable OCS installation if not corrected. The Authority will advise the Contractor of remedial action to be taken.

E. Prior to installation of poles, cantilevers, and other OCS structures and assemblies, measure and record the actual location of each OCS foundation with respect to the adjacent track, the superelevation, magnitude and direction from track. This ensures that in all locations the structures are installed with the correct geometrical relationship to track alignment as indicated in the Contract Documents.

F. Reference point for locating structure with respect to the track to be the design position as indicated in the Contract Documents. Refer any deviations in the actual position of the track from the design position indicated to the Authority.

G. Submit the setting dimensions of each structure with respect to the reference point in the layout schedule to the Authority. Structure offsets generally to be at right angles to the track centerline.

H. Contractor is responsible for final location and accuracy of all OCS elements and their proper operation.

3.02 STRUCTURE NUMBERING

A. Number all structures clearly and permanently as indicated in Section 34 23 80, Pole Identification and Warning Signs, and as indicated in the Contract Documents.

3.03 INSTALLATION TOLERANCES

A. Conform to the following installation tolerances:

Pole and Foundation Deflection:
- Pole Deflection: 2½” at contact wire
- Foundation Rotation: 2.5% of pole height
- Total Deflection: 4” at Contact Wire height, including pole bending and foundation rotation

Structure Locations:
- Along Track Spotting Tolerance ± 1'-0"
- Special Trackwork Locations: ± 6'-0"
- All other locations ± 5'-0"
- Cross Track Spotting Tolerance Restricted location ± 3/4" track spacing

All other locations ± 1 ½"

Contact Wire Locations:

<table>
<thead>
<tr>
<th></th>
<th>Lateral</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railroad Crossings:</td>
<td>± 2&quot;</td>
<td>+2&quot; / -0&quot;</td>
</tr>
<tr>
<td>Overlap Locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Between parallel wires):</td>
<td>± 1/2&quot;</td>
<td>± 1/2&quot;</td>
</tr>
<tr>
<td>All others</td>
<td>± 2&quot;</td>
<td>± 2&quot;</td>
</tr>
</tbody>
</table>

Support and Setting:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Cantilever along Track Offset:</td>
<td>± 3 inches</td>
<td></td>
</tr>
<tr>
<td>Hanger Length:</td>
<td>± 1/2 inches</td>
<td></td>
</tr>
<tr>
<td>Hanger Spacing:</td>
<td>± 6 inches</td>
<td></td>
</tr>
<tr>
<td>Cantilever Heel Setting</td>
<td>+1/2&quot;, -0&quot;</td>
<td></td>
</tr>
</tbody>
</table>

3.04 INSULATORS

A. Provide double insulation as indicated in the Contract Documents. Insulator placement relative to poles and supports shall conform to the requirements of CPUC GO-95.

B. Clean all insulators before installation. Use only clean rags, free from any abrasive material for cleaning insulators. Wire brushes not to be used for cleaning any parts, metal or otherwise. In the completed line, clean all insulator assemblies and hardware, bright and free from nicks, chips or other marks.

C. After installation of the OCS Support System, megger all insulators. Replace insulators that are found to be defective.

D. Repair insulators with slight damage as recommended by the manufacturer. If the damage is excessive as appraised by the Authority, replace the insulator. Replace cracked insulators.

3.05 HARDWARE

A. Install all hardware in accordance with the manufacturer’s accepted Shop Drawings. Tighten bolts and nuts in accordance with the manufacturer’s recommendations. All bolts to be of required length for a full thread beyond the nut and locknuts, but not protrude beyond the nut and locknut to exceed one and one-half inches. Bolt ends shall not to be cut off. All parts shall be standard measurements and thread sizes.
B. Install all locknuts according to manufacturer’s instructions.

C. Install hardware with tools and methods specified by the manufacturer and accepted by the Authority.

D. Bend all cotter pins to form a minimum of 90° on ends.

E. Inspect hardware for cleanliness and any damage. Any item that does not fit, creates scraping of galvanizing during or after installation, or is found defective, will be rejected.

F. Aluminum paint shall not be used on any OCS parts or equipment. Only accepted galvanized paste shall be applied to repair minor deficiencies of OCS parts. Rusting, globbing and overrun of the galvanizing on hardware shall be grounds for rejection of the entire shipment.

G. All cuts and drilled holes on catenary structures must be cold galvanized prior to installation.

3.06 INSTALLATION OF DOWN GUYS

A. Install downguys of the sizes and types as indicated in the Contract Documents.

B. Install downguys before the catenary wires are strung and prior to installing and balance weight anchors. Pull taut and secure in place with provisions for future adjustment as required to hold the structure in proper alignment after wires are pulled up.

C. Install downguy attachments as recommended by the manufacturer.

D. Provide an eight feet guy guard for each guy to an anchor installed as indicated in the Contract Documents.

3.07 INSTALLATION OF GALVANIZED STEEL AND STAINLESS STEEL WIRE AND WIRE ROPE

A. Use galvanized steel and stainless steel wire and wire rope as indicated in the Contract Documents.

B. Cut and install galvanized steel and stainless steel wire and wire rope using tools and methods specified by the manufacturer.

C. Splicing of the galvanized steel and stainless steel wire and wire rope will not be permitted.
3.08 INSTALLATION OF CATENARY SUPPORT AND REGISTRATION ASSEMBLIES

A. Tighten all connections, bolts, and nuts properly in accordance with the manufacturer’s recommendations.

B. Inspect all items for improper fit, damaged coating and bent/kinked members. Replace any piece found to be defective.

C. Install supporting devices as indicated in the Contract Documents and, where applicable, in accordance with the manufacturer’s instructions. Take field measurements prior to fabrication of the supporting device to determine the as-built dimension from centerline of track to face-of-pole at either contact wire height or messenger wire height. Where applicable, make allowance, during fabrication of the respective supporting devices, for dead load deflection of the supporting pole.

D. The wire height and stagger indicated in the Contract Documents are related to the high rail level and the centerline of track normal to the plane of the rails of the individual tracks.

E. For stability during stringing, restrain the cantilevers and supports temporarily to prevent from collapse due to swinging. Submit the details of the restraint to the Authority for acceptance.

F. Position cotter pins and nuts on the same side of the structure on each assembly to assure uniformity along the line.

G. Orient assemblies fitted with pins, cotters, bolts and nuts where possible in such manner as to lock these components together by gravity if the pins or nuts should become detached under service conditions.

H. Grease components employing a hinge or swivel with an accepted grease before assembly of the rubbing surfaces.

I. After installation of supporting devices and stringing of conductors, adjust stagger, heel setting, contact wire height and cantilever inclination as required to bring the installation within the specified design tolerance.

J. Coat conductor interfaces of all clamps for feeder terminations, equalizing jumpers and continuity jumpers with conductive grease.

K. Install all cantilever assemblies perpendicular to track at medium temperature of 75°F. Adjust all supports to compensate for the amount of wire movement with the setting or adjustment temperature.
L. Contractor is responsible for all adjustments and making all corrections until accepted by Authority.

M. Install disconnect taps and clamps to top span wire, leaving some wire loose to compensate for along track movement and wire relocations during construction staging.

3.09 INSTALLATION OF CROSS SPAN AND HEADSPAN ASSEMBLIES

A. Prior to installation of the cross-span and head-span assemblies, record the following field details along the axis of the span for review by the Authority:

1. Pole-to-pole, track-to-track, and track-to-pole centerline dimensions.

2. Relative cross track elevations of foundations and tracks.

3. Track superelevations and directions of foundations and tracks.

B. Submit any proposed design changes to be implemented in the field to the Authority for approval. Record all accepted field changes.

C. Types of cross-span and head-span assemblies as indicated in the Contract Documents are diagrammatic in nature. Contractor is responsible for the detailed design and installation.

D. Provide double insulation as indicated in the Contract Documents.

E. Install cross-spans and head-spans to clear the pantograph dynamic envelope.

F. Perform minor field adjustments of hangers and contact and messenger heights as required.

G. Adjust the stagger, wire height, and heel settings in accordance with the requirements indicated in the Contract Documents.

H. Tensions and attachment heights to be set by Contractor to obtain required contact wire heights as indicated in the Contract Documents.

3.10 HANGERS
A. Hanger types, size, spacing and locations to be as indicated in the Contract Documents.

B. Check and calculate hanger lengths prior to their fabrication but after the final weights of all components in span have been determined by the supplier.

C. Perform hangers by the use of jigs and tools accepted by the Authority.

D. Securely fit hanger saddles to the conductors as indicated in the Contract Documents to avoid excessive wear or damage.

E. Uniformly install hangers along the line with the top and bottom tail of each hanger facing the same rail when looking in the direction of increasing station. Remove hanger identification and temporary tie wires from the completed installation.

F. Hangers to be plumb within ± ½ inch.

3.11 MESSENGER AND CONTACT WIRE STRINGING

A. Install all conductors in accordance with the manufacturer's recommendations and the requirements indicated in the Contract Documents with special attention to conductor creep. If prestressing is used, submit prestressing method to the Authority for acceptance. Remove the initial stretch and the ten-year creep at the time of installation.

B. Conductor tension, cantilever settings, and counterweight settings are temperature related. During stringing, use actual conductor temperatures as measured by contact thermometers in conjunction with the stringing charts to ascertain the various stringing parameters. Check the stringing charts as indicated in the Contract Documents for conformity to the actual wire data before messenger and contact wire stringing is started.

C. Ensure that the installation complies with the acceptance requirements for the OCS as indicated in the Contract Documents and in Section 34 23 90, Overhead Contact System Acceptance.

D. Splices in fixed termination single contact wires are prohibited, unless directed otherwise by Authority.

E. Use of splices on catenary conductors in auto-tensioned sections shall not be permitted, unless directed otherwise by Authority.
F. Avoid kinks in the wires. Destranding (birdcaging) of stranded conductor is unacceptable. Kinks in the contact wire will not be accepted.

G. Ensure contact wire is free of twists from anchor clamp to anchor clamp.

H. Equip in-running contact wires crossed by another in-running contact wire fitted with a contact bridge.

Main line contact wire shall be run below crossover contact wire. Free contact wire movement shall be provided over the range of operating temperatures. The “through” contact wire of auto-tensioned catenary shall be adjusted to “float” through the contact bridge. All converging in-running contact wires shall be adjusted to permit free and smooth operation by pantographs without risk of hook-up at any conductor temperature.

I. Install equalizing and overlap jumpers as indicated in the Contract Documents.

J. Orient all termination fittings in accordance with the manufacturer’s recommendations.

K. Ground both messenger and contact wire during and after the stringing process prior to energization.

3.12 INSTALLATION OF SECTION INSULATORS

A. Install section insulator of the types at the locations indicated in the Contract Documents.

B. Install section insulators as recommended by the manufacturer and as required by the design requirements specified in Section 34 23 44, Section Insulators.

C. Adjust as required, after installation to ensure proper operation.

3.13 INSTALLATION OF BALANCE WEIGHT ASSEMBLIES

A. Install balance weight assemblies at locations indicated in the Contract Documents.

B. Ensure that the balance weight assemblies are free to move between conductor temperatures of 20°F and 130°F.
C. Exercise with special care during installation of balance weight assemblies to obtain adequate wire temperature and travel clearance for the balance weight and pulley assemblies. Complete preliminary tensioning of the OCS to remove ten-year creep prior to finalization of the counterweight settings.

B. Apply accepted lubricating grease to pulley bearings, swivels, guideways, guide rods, and wire ropes as required.

3.14 JUMPERS

A. Configurations of all types of jumpers to be as indicated in the Contract Documents.

B. Cut and tie ends of jumper wires projecting not more than ½ inch through open clamps.

C. Use continuity jumpers in auto-tensioned catenary, of length and configuration required for the anticipated differential movement of the conductors. Determine the formula used to establish lengths of jumpers, based on actual field measurements.

D. Install and train all jumpers so as to avoid conflicts with the pantographs, adjacent cantilevers, and droppers.

E. Clean each cable end with an accepted decontaminant immediately prior to making connections.

F. Install connectors as indicated in the Contract Documents and in accordance with the manufacturer’s recommendation.

G. Lubricate bolts in bolt-type connectors with conductive grease as recommended by the manufacturer, and torqued to the bolt manufacturer’s recommendations, using a calibrated torque wrench.

3.15 INSTALLATION OF GROUNDING

A. Install grounding as indicated in the Contract Documents.

B. Install bonding between poles and pole foundations as indicated in the Contract Documents.

3.16 INTERFACE WITH EXPOSITION PHASE II MAINLINE
A. OCS poles, supports and terminations on the east and west approach tracks shall be installed by the Expo Phase II mainline contractor, as indicated in the Contract Documents. Installation of catenary along the approach tracks and bypass track shall be performed by the Expo Phase II mainline contractor, as indicated in the Contract Documents.

B. Coordinate access and schedule for installation of OCS poles and foundations adjacent to the Expo mainline with mainline contractor as required.

C. Clean and restore site as indicated in the Contract Documents.

END OF SECTION 34 23 00
SECTION 34 23 01
CATENARY FITTINGS AND HARDWARE

PART 1 GENERAL

1.01 DESCRIPTION

A. This Section covers the requirements for catenary fittings and hardware for cantilevers, registration arms, pull offs/push offs, and other components required as part of the Overhead Contact System (OCS) hardware as indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Metal Characteristics
E. Manufacture and Performance
F. Sampling and Testing
G. Workmanship, Finish, and Appearance
H. Marking and Shipping
I. Installation Requirements

1.03 RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 02 - Catenary Support and Registration Assemblies
D. Section 34 23 00 - Overhead Contact System
F. Section 34 23 10 – OCS Wire and Wire Rope Assemblies
G. Section 34 23 11 – OCS Uninsulated Conductors
1.04 QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements for general requirements and procedures.

B. The Authority reserves right to first article inspection of all catenary fittings and hardware.

1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit certified copies of the test reports containing the physical and mechanical properties of all components showing compliance to the requirements indicated in the Contract Documents. (CDRL)

1.06 STANDARDS

A. American Society for Testing and Materials (ASTM)
   - A27 Mild to Medium-Strength Carbon-Steel Castings
   - A47 Malleable Iron Castings
   - A153 Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   - A518 Corrosion-Resistant High Silicon Cast Iron
   - A536 Ductile Iron Castings
   - A668 Steel Forgings, Carbon and Alloy, for General Industrial Use
   - A711 Steel Forging Stock
   - B29 Refined Lead
   - B148 Aluminum-Bronze Sand Castings
   - B179 Aluminum Alloys in Ingot Form for Castings from All Casting Processes
   - B248 General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip and Rolled Bar
   - B249 General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes, and Forgings
PART 2 PRODUCTS

2.01 METAL CHARACTERISTICS

A. Malleable Iron. Fittings or components made of malleable iron to be Grade 32510 or better, and conform to ASTM A47. Galvanize all components and fittings in accordance with ASTM A153.

B. Forged Steel. Material for forged steel to comply with AISI Types C-1035 to C-1045 SBQ and ASTM A711 or A668. Galvanize all components and fittings in accordance with ASTM A153.

C. Cast Iron. Cast iron weights and counterweights to be of corrosion-resistant, high-silicon cast iron in accordance with ASTM A518.

D. Ductile Iron. Fittings or components requiring higher yield strength to be of ductile iron, grade 60.40.18 or better and conform to ASTM A536. Galvanize all fittings and components in accordance with ASTM A153.

E. Stainless Steel. Stainless steel hardware to be AISI Type 302 or 304.

F. Non-Ferrous Metals. Copper alloy for fittings and components to comply with ASTM B584 and B148.

G. Copper. All copper components to conform with ASTM B248 or B249.

H. Copper-Clad. Grounding components to be the manufacturer’s standard items and conform to the IEEE definition of copper-clad materials.

2.02 MANUFACTURE AND PERFORMANCE

A. Produce the designated metals by an accepted method that will meet the requirements of the ASTM standards and as indicated in the Contract Documents.
B. Castings to be of uniform quality and made in such a manner that the material of the casting conforms to the chemical and mechanical properties prescribed in the applicable ASTM standards.

2.03 SAMPLING AND TESTING

A. For tension tests, pour a minimum of three test bars from each lot of metal.

B. For chemical analysis, analyze each lot of castings for conformance with the chemical composition specified in the ASTM standards.

C. A lot consists of all castings produced from one furnace melt.

2.04 WORKMANSHIP, FINISH, AND APPEARANCE

A. Castings to be free of adhering stain, visual cracks, surface porosity and shrinkage.

B. Contractor is responsible for the dimensional accuracy of castings and forgings.

C. Casting repairs will be permitted only to the extent allowed by ASTM standards. If welding or repair of a greater magnitude is required, obtain the Authority’s acceptance prior to proceeding. (CDRL)

2.05 MARKING AND SHIPPING

A. Cast the identification mark of the foundry and the pattern numbers assigned by the supplier into all castings, of size and position that they will not interfere with the further processing and serviceability of the casting.

B. Package castings in accordance with the best commercial practice to ensure acceptance and safe delivery.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Installation of assemblies, fittings and hardware is covered under Section 34 23 00, Overhead Contact System.

END OF SECTION 34 23 01
SECTION 34 23 02

CATENARY SUPPORT AND REGISTRATION ASSEMBLIES

PART 1 GENERAL

1.01 DESCRIPTION

A. This Section covers the requirements for design, manufacture, delivery, installation, and testing of various types of catenary support and registration assemblies and other components required for the Overhead Contact System (OCS) Support System as indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Requirements
B. Submittal Procedures
C. Standards
D. Delivery, Storage and Handling
E. Products - Description
F. Metal Characteristics
G. Installation Requirements

1.03 RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 00 - Overhead Contact System

1.04 QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.
1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit Drawings for the design fabrication, and erection of assemblies of metal work that are not completely indicated by manufacturer’s data sheets. Include plan and elevations at scale not less than one inch to one foot, and include details of sections and connections as well. Show anchorage and accessory items.

D. Submit manufacturer’s catalog cuts, load tables, dimension diagrams, design detail, and anchor details indicating compliance with the requirements indicated in the Contract Documents, and installation instructions for products to be used in the fabrication of OCS assemblies.

E. Submit welder certifications and qualifications as required by AWS, W1 CH12.

1.06 STANDARDS

A. American Society for Testing and Materials (ASTM)

A6 General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A36 Carbon Structural Steel

A47 Malleable Iron Castings

A53 Pipe, Steel, Black and Hot-Dip Galvanized, Zinc-Coated, Welded and Seamless

A123 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

A153 Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A484 General Requirements for Stainless Steel Bars, Billers and Forgings

A572 Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

B150 Aluminum Bronze Rod, Bar and Shaper

B. American Iron and Steel Institute (AISI)
C1035 to C1045 SBQ - Forged Steel
Types 302 and 304 - Stainless Steel

1.07 DELIVERY, STORAGE AND HANDLING

A. Protect all support and registration assemblies, components and materials against damage during handling and shipping, storage and installation.

B. Deliver the assemblies to the site at intervals to ensure uninterrupted progress of the Work.

C. Store material to permit easy access for inspection and identification. Protect steel members and packaged materials from corrosion and deterioration.

D. Provide a heavy-duty waterproof tag securely fastened to the package of all components and assemblies showing the assembly or component name, number, or identification code.

E. Submit packaging and/or packing methods of all assemblies or components for the owner's acceptance. (CDRL)

PART 2 PRODUCTS

2.01 DESCRIPTION

A. Provide all materials used in the catenary support and registration assemblies and associated components of strength and durability to withstand the loads as indicated in the Contract Documents with a minimum safety factor of 2.0.

B. Provide all materials light in weight and reliable to ensure a 30 years life period.

C. Provide component and assemblies of a proven and tested design.

D. Furnish all labor, tool, equipment, apparatus and facilities as required to perform all installation Work as indicated in the Contract Documents.

E. Utilize the following pipe sizes: Strut Pipe - 2” diameter schedule 40; top tube - 1-1/4” diameter and 2” diameter schedule 40; Registration tube – 1” diameter schedule 40; Heavy strut applications - 2 ½” diameter reinforced schedule 40 pipe and 4” diameter schedule 40 pipe.
Contractor is encouraged to utilize these sizes; however other pipe sizes may be substituted per manufacturer standards, with Owner approval.

2.02 METAL CHARACTERISTICS

A. Provide structural steel for twin cantilever brackets, shop supports, and miscellaneous other supporting devices conforming to ASTM A36 or A572. Galvanize components in accordance with ASTM A123.

B. Provide fittings or components made of malleable iron of grade 32510 or better material conforming to ASTM A47. Galvanize all components and fittings in accordance with ASTM A153.

C. Provide materials for structural steel conforming to ASTM A36 or A572. Galvanize materials in accordance with ASTM A123.

D. Provide stainless steel material conforming to ASTM A484.

E. Provide aluminum components conforming to ASTM B150.

F. Use cotter pins made of stainless steel.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Install all supporting devices including steady arms, messenger supports and cross-spans or wire pull-offs registration assemblies as indicated in the Contract Documents and in Section 34 23 00, Overhead Contact System.

END OF SECTION 34 23 02
SECTION 34 23 04

OVERHEAD CONTACT SYSTEM BALANCE WEIGHT AND MIDPOINT ANCHOR ASSEMBLIES

PART 1 GENERAL

1.01 DESCRIPTION

A. This section covers the requirements for design, manufacture, furnishing, installation and testing of the balance weight anchor assemblies and midpoint anchors for the Overhead Contact System (OCS) as indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Delivery, Storage and Handling
E. Performance Requirements
F. Testing
G. Installation Requirements

1.03 RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 10 – OCS Wire and Wire Rope Assemblies
D. Section 34 23 11 – OCS Uninsulated Conductors
E. Section 34 23 00 - Overhead Contact System
1.04 QUALITY CONTROL
A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.

1.05 SUBMITTALS
A. Refer to Section 01 33 00, Submittal Procedures.
B. Submit a complete set of assembly, component, and shop drawings giving dimensions and weights and related design calculations, demonstrating the suitability of the Balance Weight Assembly (BWA) for this Contract.
D. Installation, Operations and Maintenance Manuals.
E. List of special tools required for assembly and installation of single BWA.
F. List of recommended spare parts for maintenance.
G. Supplier’s certificate of compliance to accompany each shipment certificate as a minimum, to contain the following:
   1. Product Name.
   2. Drawing Number(s) and revision or date.
   3. Serial Numbers (if required).
   4. Quantity
   5. Purchase Order Number.
   6. List of specifications to which the product was produced.
   7. Suppliers name and address.
   8. Signature and title of recognized quality authority.

1.06 STANDARDS
A. American Society for Testing and Materials (ASTM)
   A27 Mild to Medium-Strength Carbon Steel Castings
   A36 Structural Steel
A47 Malleable Iron Castings
A123 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A153 Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A167 Stainless and Heat-Resisting Chromium Nickel Steel Plate, Sheet, and Strip
A307 Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength
A518 Corrosion-Resistant High-Silicon Cast Iron
A536 Ductile Iron Castings
A668 Steel Forging, Carbon, and Alloy, for General Industrial Use
A711 Steel Forging Stock

1.07 DELIVERY, STORAGE AND HANDLING

A. Package the balance weight anchor assemblies in a manner to allow safe stacking and outdoor storage until installation to prevent damage to components.

PART 2 PRODUCTS

2.01 PERFORMANCE REQUIREMENTS

A. Balance Weight Assembly (BWA) to maintain constant tension in the conductors not withstanding changes in ambient, solar or electric current heating temperatures. Compensate changes in the lengths of conductors by an equivalent change in stroke length of the unit.

B. BWA to operate at a nominal pulley ratio of 3:1.

C. BWA to have pulleys which permit routine maintenance and lubrication of the bearings. Seal the bearings to prevent the ingress of moisture or other contaminants.

D. BWA to operate freely in the complete vertical axis throughout the design temperature range under all climate conditions and function freely when a weight differential of plus/minus 25 lbs. is applied to the balance weight stack.
E. BWA to incorporate a safety feature to prevent collapse of the weight stack and fall to the ground in the event of a failure of the tensioned wires.

F. Fabricate balance weights from cast iron.

G. Weight sets to be one casting.

H. Tolerance on the balance weight stack to be -0 lbs. +50 lbs.

I. Weight stacks to be cylindrical in shape and compact allowing for the required vertical movements.

J. Balance Weight Assembly to have a minimum design life of 30 years and not require maintenance or inspection at intervals of less than twelve months.

K. Assemblies and component parts to be designed for ease of maintenance, replacement, assembly, and disassembly which may be accomplished with a minimum of special tools. Identify component parts that require special tools. Provide 15 sets of special tools.

L. Incorporate provisions for adjustment due to wire elongation in the assembly. It shall be the Contractor’s responsibility to ensure that the installation complies with the acceptance requirements at the time of Agency acceptance. Any adjustments of wires, hardware and fittings due to wire creep or elongation shall be made by the Contractor at no additional cost to the Agency.

M. All materials and design to have been proven by the manufacturer's experience to be suitable for the purpose for which they are intended, loads and climatic conditions existing in the project.

N. All external ferrous parts to be stainless steel or hot-dip galvanized in accordance with the appropriate ASTM specification. Paint any ferrous parts which are not stainless steel or cannot be galvanized with an epoxy coating with color to match ANSI #61, light gray.

O. Main components of the tensioning device to bear the manufacturer’s name or trademark and year of manufacture clearly and permanently imprinted.

P. Contractor may offer other alternatives for consideration. Such alternatives may include a differential pulley arrangement.
Q. Provide hardware for midpoint anchors as indicated in the Contract Documents

2.02 TESTING

A. Inspect and test each balance weight assembly and midpoint anchor to ensure it satisfies the requirements indicated in the Contract Documents, including dimensional accuracy and compatibility with match components.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Install the assemblies as indicated in the Contract Documents and in Section 34 23 00, Overhead Contact System.

B. Adjustment and testing of the device to be in conformance with the manufacturer’s instruction manuals.

END OF SECTION 34 23 04
SECTION 34 23 10

OCS WIRE AND WIRE ROPE ASSEMBLIES

PART 1  GENERAL

1.01  DESCRIPTION

A. This Section covers the requirements for all grades of galvanizing steel wire, preforms, and wire ropes for use as support wires cross and head spans, and guys for the Overhead Contact System (OCS) as indicated in the Contract Documents.

1.02  SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Products - Description
E. Types
F. Delivery and Marking
G. Installation Requirements

1.03  RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 00 - Overhead Contact System

1.04  QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.
1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit certified copies of test reports containing the physical and mechanical properties of all components showing compliance to the requirements indicated in the Contract Documents. (CDRL)

1.06 STANDARDS

A. American Society for Testing and Materials (ASTM)

   A475 Zinc-Coated Steel Wire Strand

B. Federal, State and Local Jurisdictions:
   All Applicable Codes, Ordinances and Regulations.

PART 2 PRODUCTS

2.01 DESCRIPTION

A. Components: Manufacture and test zinc-coated stranded wire in accordance with ASTM A475.

B. Performance: Physical properties of the zinc-coated stranded wire to conform to the description in Table 1 of ASTM A475.

C. Zinc Coating: The weight of coating for zinc-coating steel wire not to be less than that specified in Table 4, under Class C of ASTM A475.

2.02 TYPES

A. Galvanized steel wire and wire rope to be of the following types:


   2. Deadends: One-half inch diameter, high strength grade.

   3. Head and Down Guys: One-half inch diameter, extra high strength grade.
PART 3 EXECUTION

3.01 DELIVERY AND MARKING

A. Protect materials against damage in ordinary handling and shipping. Each reel to have a strong, weatherproof tag securely fastened to it showing the physical and mechanical properties as well as the steel type designation ASTM designation and the name and mark of the manufacturer.

3.02 INSTALLATION REQUIREMENTS

A. Galvanized steel wire and rope installation is covered in Section 34 23 00, Overhead Contact System.

END OF SECTION 34 23 10
PART 1 GENERAL

1.01 DESCRIPTION

A. This Section covers the requirements for uninsulated conductors which include messenger wire, contact wire, jumpers, bare feeders, ground wire, and associated splice as indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Materials
E. Packaging and Marking
F. Inspection and Testing
G. Installation Requirements

1.03 RELATED SECTIONS

A. Section 01 33 00 - Submittals
B. Section 01 40 00 - Quality Control
C. Section 34 23 00 - Overhead Contact System

1.04 QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Control, for general requirements and procedures.
1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittals.

B. Submit all shop drawings for acceptance prior to fabrication. Submit catalog cuts showing physical and electrical characteristics and other characteristics necessary to substantiate compliance to the requirements indicated in the Contract Documents. (CDRL)

C. Submit samples of conductors from each manufacturing batch in lengths and quantities requested by the owner or specified in the applicable standard. (CDRL)

D. Submit certifications verifying that the conductors have been designed, manufactured, inspected and tested in accordance with applicable portions of referenced standards and these Contract Documents. (CDRL)

E. Submit certified copies of manufacturer’s test reports for the specific conductors furnished. Submit a certified copy of the test report for each reel to the owner prior to shipment, with a copy of the test report packed with each reel. (CDRL)

F. Submit creep data verification tests and creep data for not less than 1,000 hours for all conductors. (CDRL)

1.06 STANDARDS

A. American Society for Testing and Materials (ASTM)

B1 Hard-Drawn Copper Wire

B3 Soft or Annealed Copper Wire

B8 Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B47 Copper Trolley Wire

B173 Rope-Lay Stranded Copper Conductors Having Concentric-Stranded Members for Electrical Conductors
PART 2  PRODUCTS

2.01 MATERIALS

A. Provide conductors conforming to the following requirements:

1. Contact Wire: 350 kcmil, hard-drawn copper wire, solid grooved, conforming to ASTM B47.

2. Messenger Wire: 500 kcmil, 19 strand, hard-drawn copper with a minimum breaking strength of 21,950 pounds, coefficient of expansion of $9.4 \times 10^{-6}$ per degree Fahrenheit, modulus of elasticity (final) of $17.0 \times 10^6$ psi, and conforming to ASTM B8, Class AA.

3. Potential Equalizing Jumper: 350 kcmil, bare, annealed copper cable, stranded, conforming to ASTM B3 and B8, Class C.

4. Continuity Jumper: 350 kcmil, bare, annealed copper cable, stranded, conforming to ASTM B3 and B8, Class C.

5. Feeding Jumper: 350 kcmil, bare, annealed copper cable, stranded, conforming to ASTM B3 and B8, Class C.

6. In-Span Jumper: 350 kcmil, bare, annealed copper cable, stranded, conforming to ASTM B3 and B8, Class C.

7. Ground Wire:
   a. Annealed copper conductor, bare, Class B, stranded, conforming to ASTM B3 and B8, as indicated in the Contract Documents.
   b. Copperweld, solid, bare and 40% conductivity.

8. Bonding Wire: 1/0 Copperweld, 40 percent conductivity, solid, bare.

B. Catenary Splice

1. Catenary splices are prohibited except where directed by owner. When directed by owner, contractor shall furnish the following splices.

2. Use full-tension copper compression sleeves as manufactured by WABCO, or accepted equal for messenger wire splice.
3. Use catenary trolley wire splice as manufactured by Arthur Flury AG, or accepted equal for contact wire splice.

2.02 PACKAGING AND MARKING

A. Ensure packaging and marking to conform to the manufacturers' recommendations unless otherwise indicated in the Contract Documents.

B. Contact wire reels shall be of steel, sized in accordance with ASTM B47, with heavy wood lagging. The drum diameter of contact wire reels shall be not less than 30 inches so as to minimize difficulty with waves or kinks when the wire is strung.

C. Contact wire shall be reeled in accordance with ASTM B47. The vertical axis of the grooved wire, as finally strung, shall be radial to the axis of the reel. Side wound contact wire may be acceptable if accepted by the owner. (CDRL)

D. Provide each reel with a heavy-duty weatherproof tag securely fastened to it showing the physical, mechanical, and electrical properties as well as type designation, ASTM designation, the name and mark of the manufacturer, the purchase order number, and the component number.

E. Provide a strip of paint across the outside layer of strands to indicate if the wire has moved during shipment.

F. Factory splices shall be avoided unless absolutely necessary. Spliced wire reels may not be supplied without prior owner approval. Where approved, wire splice location shall be marked with paint and recorded on tag per part D above.

2.03 INSPECTION AND TESTING

A. Owner reserves the right to witness the manufacture, testing and packing of all conductors. Notify the owner not less than 30 days in advance of manufacturing and testing operations. (CDRL)

B. All conductors shall be subject to factory quality control tests as required in the applicable standards. Perform tests on each reel and submit to owner prior to shipment.

C. Grooved contact wire supplied in accordance with ASTM B47 shall be subject to the ASTM B47 twist test in addition to other required tests. Perform the twist test as indicated in the Contract Documents for round
wire, except that 6 twists shall be required. Contact wire not meeting this test will be rejected.

D. Where approved per 2.02(F) above, ensure that the contact wire factory splices shall be free of any kinks and shall be marked with a bright paint for visual check and identification.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Conductor installation is covered in Section 34 23 00, Overhead Contact System.

END OF SECTION 34 23 11
SECTION 34 23 40  
DC DISCONNECT SWITCHES  

PART 1 GENERAL  

1.01 DESCRIPTION  

A. This section covers the requirements for design, manufacture, delivery, installation, and testing of dc disconnect switches complete with enclosure, ready for mounting and connection into service. The switches will be used to connect and disconnect dc traction power between the dc feeder breaker and overhead contact system, also to tie or sectionalize two adjacent power sections at crossovers, in the yard or yard leads.  

1.02 SECTION INCLUDES  

A. Related Sections  
B. Quality Control  
C. Submittals  
D. Standards  
E. Design and Construction  
F. Testing  
G. Execution - General  

1.03 RELATED SECTIONS  

A. Section 01 33 00 – Submittal Procedures  
B. Section 01 40 00 - Quality Requirements  
C. Section 31 23 02 – Excavation Backfilling and Compacting for Structures  
D. Section 03 10 00 - Concrete Formwork  
E. Section 03 20 00 - Concrete Reinforcement
F. Section 05 12 05 - Metal Poles

H. Section 34 23 10 - OCS Wires, Cables and Terminations

I. Section 34 23 00 - Overhead Contact System

K. Section 34 30 40 – Traction Electrification Testing and Commissioning

1.04 QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Control, for general requirements and procedures.

1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittals.

B. Submit a detailed description and drawings of all equipment to be furnished, including a composite drawing of the switch in its enclosure showing all clearances.

D. Provide all drawings showing all details including dimensions of switches and enclosures for the owner's review for Contract compliance prior to manufacturing. Shop drawings to be to scale and show all details of construction and materials including manufacturers' electrical components and complete mounting details.

E. Submit one complete 3 pole switch and a single pole switch with enclosure to owner for review and turn over to Agency for final acceptance.

1.06 STANDARDS

A. American National Standard Institute (ANSI)/IEEE

   C37.30     IEEE standard Requirements for High Voltage Switches

   C37.34     IEEE Standard Test Code for High Voltage Air Switches

B. American Society for Testing and Materials (ASTM)

   B152       Specification for Copper Sheet, Strip, Plate and Rolled Bar

C. National Electrical Manufacturers Association (NEMA)

   Pub. CC 250   Enclosures for Electrical Equipment (1,000 volts
PART 2 PRODUCTS

2.01 DESIGN AND CONSTRUCTION

A. Switches

1. Provide disconnect switches of front-connected, no-load break, vertically mounted type equipped with bolted-type connectors for copper cables. Provide terminal lugs as indicated in the Contract Documents for securing lug to terminal pad of the switch.

2. Provide copper switch blades and buses with straight smooth surfaces, free from defects, uniform in shape, width and thickness, which have machined smooth finish on the mating surfaces to provide an even contact on all contact surfaces. Use hard-drawn extruded bus bar in accordance with ASTM Specifications B152, Alloy 110 for the switch blade assemblies.

3. Other current carrying components may be made of composition in accordance with ASTM Specifications B152 unless otherwise indicated in Contract Documents.

4. Facing switch, locate the hinge end terminal lugs on lower left of switch. Locate terminal lugs for contact end on the upper right of switch unless otherwise indicated. Mount terminal lugs so that cables entering top or bottom can be positioned and attached vertically without any bends in order to facilitate disconnection and connection of individual cables, with lug attached for maintenance and testing purposes, without disturbing other cables. Use silver-plated terminal plates with threaded bronzed inserts. Tap inserts to accept bronze hex head ½ inch diameter cap screw to secure terminal lugs.

5. Form contact surfaces so that contact spots or areas can carry the rated current and are raised above the surrounding surface at both jaw and hinge. Contacts to be low-resistance, self-cleaning. Provide pressure adjustment bolts and nuts at jaw and hinge with bronze cotter keys, or other suitable means, to prevent nuts from backing off.

6. Silver plate bus bar contact surfaces for cable lugs.

7. Secure switches solidly to a base the same width as switch and terminal pads to prevent weight of the cables from imparting twisting strains on jaw or hinged ends. Switches may not be on standoff insulators for mounting to base.
8. Use all bolts, nuts and washers of high-tensile strength, silicon-manganese bronze. Base material to be NEMA Grade GPO-3 glass filled polyester with a thickness not subject to distortion under weight, alignment, or installation of multiple point switches.

9. Equip switch with pivot mounted, permanently attached, eyehooks that swing away from switch. When switch is in open position, eyehooks parallel to the blade so enclosure door may be closed. Eyehook arrangement to be capable of withstanding stresses of multiple openings and closings.

10. Provide copper connectors conforming to the requirements indicated in NEMA Publication CC-1972 (or latest) for Power Connectors.

11. Provide auxiliary contact rated at 20A, 240 VAC that with the switch in the closed position, the contact will open during drive shaft rotation while the switch blade is still in the closed position.

12. Provide grounding stud that will ground the load side of the switch in the fully open position.

B. Enclosures

1. Provide disconnect switch arrangements with a vented weatherproof fiberglass enclosure NEMA Type 3RX vented, conforming to requirements indicated, including a screened driphole. The driphole and vents should allow air into enclosure without allowing precipitation or insects to nest in driphole or louvers.

2. Fabricate each enclosure with a flanged lip, 1-inch minimum height at the top and bottom with mating overlapping doors to facilitate a tamperproof and weatherproof design. Provide overlapping two-door design for multiple switch enclosures, and one door for single switch enclosures. Fasten doors to main box with a continuous stainless steel of 16 gauge minimum, hinged full length of door. Design enclosure in such a manner that hinges are all concealed when doors are closed. Design doors capable of opening a minimum of 180° with a catch to keep it firmly in open position. Provide latch to secure the handle from falling and striking switch operator when doors are in open or closed position.

3. Fabricate enclosure using a hand lay up technique, polyester reinforced fiberglass, minimum ¼ inch thick on all sides. Laminate
with 40 percent glass fiber utilizing alternate layers of 1-½ ounce mat, 18 ounces woven roving, and 60 percent resin. Use fire-retardant polyglass 101fr resin or approved equal.

4. Provide enclosures with vents of required size to insure disconnect switch remain functional within allowable temperature rises in accordance with ANSI/IEEE C37.30 (1997). Design all vents to be tamperproof with stainless steel screening such that a person could not stick an object through vents and have contact with energized components inside.

5. Vent designs featuring an internal trough capable of retaining casual water will not be acceptable.

6. Fabricate doors and bottom of enclosure with fiberglass reinforced, ¼ inch thick for strength and rigidity.

7. Equip back of enclosure with glass-to-resin ratio of 40/60 for additional strength.

8. Provide latching mechanism of three-point lock design with handle on right-hand door. Provide handle with provisions for padlock with a 7/16 inches diameter clasp. Conceal all mounting hardware, latch mechanism, and handle. Use stainless steel for concealed latch mechanism inside by a non-conducting fiberglass cover with provision to be removable for latch repairs, and latch rods extending beyond the cover insulated the full exposed length.

9. Stanchion or pole mounted enclosures to be furnished with a solid fiberglass backboard a minimum of ½” thick. Backboard should be an integral part of enclosure, and not a subsequent addition. Insulate all exposed internal metallic hardware and surfaces to 1,000 Vdc minimum.

10. Exterior finish ISO-Gel coat to be polyglass PG-10105, (color as approved by the owner).

11. Insulate all switch and enclosure mounting hardware that protrudes into or out of the enclosure thoroughly against ground and energization to a minimum of 1,000 Vdc.

12. Anti-graffiti coating to be applied to all exterior surfaces per manufacturer's recommendation.

13. Provide approved weatherproof nameplates with approved lettering for each switch enclosure mounted on exterior portion of right-hand
door using nylon screws for insulating purposes. Provide nameplates of the weatherproof, fade-resistant, legible type designed to last for the lifetime of the enclosure. Provide another nameplate containing manufacturer’s name, voltage and ampere rating, mounted on inside of switch.

14. Equip all switch enclosures with key operated padlock with all locks keyed alike. Locks and keys shall be per LACMTA standards. Submit key and lock to Owner for approval. (CDRL)

C. Ratings

1. Switches to be of open-knife type, unfused, no-load break, number of poles and configuration as indicated in the Contract Documents, single-throw front-connected, front-operated, mounted on an insulated base of NEMA Grade GPO-3 glass filled polyester having following ratings:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>1,000 Vdc</td>
</tr>
<tr>
<td>Rated continuous current</td>
<td>2,000A</td>
</tr>
<tr>
<td>Dielectric withstand</td>
<td>4,800 Vac, rms.</td>
</tr>
<tr>
<td>Emergency 30 minute rating</td>
<td>5,000A</td>
</tr>
</tbody>
</table>

2.02 TESTING

A. All switch tests shall be in a manner acceptable to the owner. A complete set of design tests will be required on one switch of each type and standard factory tests on the other switches. The owner reserves the option to waive the requirement of design testing one switch of each type in lieu of a notarized certified test report of a complete set of tests on switch of the same design and ratings. Contractor to furnish four copies of design test certificates for each type of switch and four copies of routine certificates for each switch.

B. Allowable maximum temperature rise of switch parts during continuous operation at rated current not to exceed those specified in ANSI/IEEE C37.30 (1997) when ambient temperature outside enclosure is 40°C. For determining the overload capability, the switch is assumed to operate at specified emergency overload current for 15 seconds every 90 seconds over a two hours period. After two hours operation at specified cycle emergency exceed overload, maximum temperatures of switch parts not to exceed those specified in ANSI/IEEE C37.30 (1997) by more than 20°C (36°F) when external ambient temperature is 40°C (104°F).

C. Capabilities of switches when operating at specified continuous current at emergency overload to be demonstrated by temperature rise tests.
conducted according to the applicable paragraph of Section 4 of ANSI C37.34 (1971). Incoming and outgoing conductors to be connected to switch terminals and have same continuous and emergency current capability and allowable maximum temperature at the switch terminals.

D. Tests to be performed with switch (or switches) in enclosure assembled in closed, final operational configuration.

E. Switches to be tested and certified suitable for use on dc circuits with prospective fault current capabilities of 201 kA.

F. A sample switch is to be subjected to a maximum number of openings and closings to establish a life cycle capability. Continuous and overload current-temperature tests before and after is to be acceptance criteria in addition to visual and mechanical performance.

G. All switch assemblies to be factory assembled and precision aligned on base material and not be susceptible to nor subjected to distortion, during box or field inspection. Mechanical inspection, via feeler gauge (or other approved method) of each contact and assembly point to be made at this time and certified. Gaps at contact or assembly points to be grounds for rejection.

H. All tests to be successfully completed to show that switches meet specification requirements before final acceptance by owner.

I. Tests and checkouts to be conducted in accordance with the National Electrical Code, State Electric Code, and applicable standards and specifications of ANSI, NEMA, ICEA, AEIC, ASTM.

**PART 3 EXECUTION**

3.01 GENERAL

A. Locate and install all switches as indicated in Contract Documents so that they are readily accessible for operation and maintenance.

B. Brace all switches by securely fastening in place as indicated in the Contract Documents.

C. Provide cable clamps on all cables entering and exiting switch boxes to prevent stress on connectors and switch jaws.

**END OF SECTION 34 23 40**
SECTION 34 23 42

OVERHEAD CONTACT SYSTEM INSULATORS

PART 1 GENERAL

1.01 DESCRIPTION

A. This Section covers the requirements for design, manufacture, furnishing, installation and testing of suspension, strain, and standoff insulators for the Overhead Contact System (OCS), as indicated in the Contract Documents.

B. Use synthetic insulators, unless otherwise indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Synthetic Insulators
E. Metal Parts
F. Cementing
G. Painting
H. Performance and Testing
I. Marking
J. Electrical Ratings
K. Guarantee
L. Installation Requirements

1.03 RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements

C. Section 34 23 44 – Overhead Contact System Section Insulators

D. Section 34 23 01 - Catenary Fittings and Hardware

E. Section 34 23 00 - Overhead Contact System

1.04 QUALITY CONTROL

A. Refer to Section 01400, Quality Requirements, for general requirements and procedures.

1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit manufacturers' catalog cuts of all insulators showing their electrical and physical characteristics.

C. Submit manufacturer’s certification and test data showing compliance with the applicable requirements of the Standards and as indicated in the Contract Documents.

D. Submit samples of each insulator type to the Owner for final acceptance.

1.06 STANDARDS

A. American National Standard Institute (ANSI)

   C29.1 Test Methods for Electrical Power Insulators including Addenda C29.1a and C29.2a.

   C29.2 Wet Process Porcelain Insulators (Suspension Type)

   C29.7 Wet Process Porcelain Insulators (High-Voltage Line-Post Type), including Supplement C29.7a.

   C29.8 Wet Process Porcelain Insulators (Apparatus, Cap and Pin Type)

   C29.11 Composite Insulators – Test Methods

   C29.12 Insulators – Composites – Suspension Type
C29.13 Insulators – Composite Distribution Deadend Type
C29.17 Insulators – Composite Line Post Type
C29.18 Insulators – Composite Distribution Line Post Type
C76.1 Outdoor Apparatus Bushings, Requirements and Test Code for
Z55.1 Gray Finishes for Industrial Apparatus and Equipment

B. American Society for Testing and Materials (ASTM)
   A47 Ferritic Malleable Iron Castings
   A153 Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   C150 Portland Cement
   C151 Autoclave Expansion of Portland Cement, Test for
   D116 Vitrified Ceramic Materials for Electrical Applications, Testing

C. National Electrical Manufacturers Association (NEMA)
   HV-1 Insulators, High-Voltage

D. Federal, State and Local Jurisdictions
   All Applicable Codes, Ordinances and Regulations.

PART 2 PRODUCTS

2.01 SYNTHETIC INSULATORS

A. Synthetic insulators may be fabricated from any of the following materials or combination thereof, depending on type or application:

1. Molded ethylene propylene copolymer with hydrated alumina filler.

2. Fiberglass-reinforced epoxy solid rod.

3. Composite type, with molded ethylene propylene copolymer jackets or skirts formed over a fiberglass-reinforced epoxy core.
B. Treat insulators to withstand ultraviolet light.

C. Furnish insulators complete with integral galvanized or stainless steel hardware for connection to supports or catenary hardware.

D. Specific types and applications of synthetic insulators for use with cantilevers, cross-spans or structural ceilings, or for use as strain insulators, as indicated in the Contract Documents.

E. Metal inserts for spool type insulators to be stainless steel.

2.02 METAL PARTS

A. Fabricate the metal parts of the insulators from malleable iron, Grade 35018, conforming to ASTM A47 or open-hearth or electric furnace steel. Galvanize all ferrous metal parts in accordance with ASTM A153. Insulator fittings to provide for connections as indicated in the Contract Documents, and fully compatible with insulating materials.

2.03 BONDING

A. Bonding agent for synthetic insulators to be of the types recommended by the insulator manufacturer.

2.04 PAINTING

A. Protect the galvanizing from harmful chemical action of the bonding agent as recommended by the insulator manufacturer.

2.05 PERFORMANCE AND TESTING

A. Insulators shall be tested in accordance with all applicable ANSI standards.

B. The mechanical strength of suspension and strain insulators to meet or exceed the strength indicated in the Contract Documents. Where the strength is not indicated, insulators to exceed the ultimate strength of the conductor, wire or crossspan guy to which it is attached.

C. Insulators for various uses to have ratings not lower than the classes indicated in the Contract Documents.

D. Provide a certification of compliance with the applicable portions of the ANSI Standards and as indicated in the Contract Documents.

2.06 MARKING
A. Manufacturer’s name or trademark and year of manufacture shall be clearly and permanently imprinted, without affecting the appearance or the function of each item.

2.07 ELECTRICAL RATINGS

A. All insulators to have the following minimum ratings:

- Nominal System Voltage: 750 V dc
- Insulation Level: 4.8 kV ac, rms
- Creepage Distance: 1.88 inch (min.)
- 60 Hz Withstand Voltage, Dry: 30 kV
- 60 Hz Withstand Voltage, Wet: 15 kV

B. Synthetic spool insulators to withstand a 25 kV flashover across 2-1/2 inch leakage distance.

2.08 GUARANTEE

A. All insulators furnished under this Contract to have a minimum in service life expectancy of thirty (30) years operating in a light rail electrified rapid transit environment.

B. All insulators to be unconditionally guaranteed for five (5) years. Any insulator that fails during the five (5) year period after acceptance by the Agency to be replaced by Contractor at no cost to the Agency, including any labor associated with removal and replacement of defective insulators.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Insulator installation is covered in Section 34 23 00, Overhead Contact System.

END OF SECTION 34 23 42
SECTION 34 23 44

OVERHEAD CONTACT SYSTEM SECTION INSULATORS

PART 1  GENERAL

1.01  DESCRIPTION

A. This Section covers the requirements for design, manufacture, furnishing, installation and testing section insulators as indicated in the Contract Documents.

1.02  SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Products - Description
E. Components
F. Protective Finish
G. Installation Requirements
H. Field Quality Control

1.03  RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 42 - Insulators
D. Section 34 23 01 - Catenary Fittings and Hardware
E. Section 34 23 00 - Overhead Contact System

1.04  QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.
1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit Shop Drawings for acceptance prior to fabrication with the following data:

1. Insulators:
   a. Electrical:
      1) Creepage length (inches)
      2) Insulation level (impulse withstand test voltage, kV)
      3) DC test voltage (kV)
   b. Mechanical:
      1) Attachment centers and overall length (inches)
      2) Shed diameters (inches)
      3) Core diameters (inches)
      4) Breakdown of weights, insulator and fittings (pounds)
      5) Tensile withstand load (pounds)
      6) Cantilever withstand load (pound-inches)
      7) Recommended maximum working tensile load (pounds)
      8) Recommended maximum working cantilever load (inch-pounds)
      9) Materials (including end caps and touch-up insulator sealants)

2. Manufacturers’ design safety factors

3. Drawings of hardware and components

4. Listing and description of components and hardware
5. Drawings and specifications required for field forming and setting of gliders.

6. For assemblies, list values of BIL, ultimate tensile strengths, ultimate torsional strength, weights (including weight of components), and electrical characteristics.

D. Submit Instruction Manuals covering complete instructions for installation, maintenance and testing including complete replacement parts lists. (CDRL)

E Submit certified copies of reports of the following tests. (CDRL)

1. Prototype tests.

2. Production tests.

3. Field-tests.

F. Submit full information, with supporting documentation, on the in-service history of the section insulators to be furnished in accordance with the Contract Documents. (CDRL)

G. Submit one complete section insulator of each type to the Authority for review and final acceptance. (CDRL)

1.06 STANDARDS

A. American Society for Testing and Materials (ASTM)

B47 Copper Trolley Wire

B. Federal, State and Local Jurisdictions:

Section Insulators and Installation shall comply with all Applicable Codes, Ordinances and Regulations.

PART 2 PRODUCTS

2.01 DESCRIPTION

A. Use Section Insulator Type KF with Gliders and No-Bo Type Insulator as manufactured by Impulse NC, INC. or accepted equal. Provide commutating (Bridging) or non-commutating (non-bridging) insulators as shown in the Contract Documents.
B. Provide section insulators as indicated in the Contract Documents and records with five years minimum service-proven operation. Section insulators to be capable of providing smooth current collection, with minimum interruption, by one to three pantographs running at a speed of up to 55 miles per hour for Simple Catenary Auto Tension (SCAT) installations and 50 miles per hour for Single Wire Fixed Termination (SWFT) installations. Section insulators to meet or exceed the following design requirements:

1. Electrical separation between contact wires of adjacent sections is maintained at all times, electrically isolating one section from the other.

2. Be able to remain stable (dynamically and structurally) under sustained lateral winds of 60 miles per hour.

3. Be able to withstand lateral winds of up to 90 mph without failure, including permanent deformation.

4. Assure smooth passage of the pantograph across the section insulator. Tilting during pantograph passage not to be severe so as to affect smooth pantograph contact with section insulator surfaces. Make allowance for the spring of the runners on impact of a fast moving pantograph. The section insulator shall be adjustable such that proper alignment with the contact wire can be maintained.

5. Ensure the moving pantograph is always in contact with the Section Insulator, ensuring as smooth as possible transition from contact wire to insulator and back to contact wire. The running surface shall be free of discontinuities which cause may cause impact damage to the pantograph or the insulator or result in bounce of the insulator,

6. Design to be such that when the Section Insulator is positioned in span, the central point is directly over the centerline of a static pantograph at normal temperature (75°F). Mid-span offset of the contact wire to be equal to zero or within limits accepted by the Authority.

7. Section insulator shall be designed such the pantographs drawing current while traversing the Section Insulator shall not cause damage to the Section Insulator or pantograph due to excessive arcing.

8. Provisions for torsion resulting from the passage of multiple pantographs combined with lateral wind loads at service speed shall be incorporated within the design of the section insulator.
9. Design factors of safety to be consistent with those specified for design of catenary system. The wire slippage and breaking strength of the device shall exceed the maximum breaking strength of the wire to which it is installed.

10. Comply with following electrical requirements:

   - Nominal voltage: 750 Vdc
   - Operating Voltage range: 525 Vdc to 900 Vdc

11. Satisfy environmental conditions as indicated in the Contract Documents.

12. Provide full performance within a conductor temperature range of 20°F to 130°F.

2.02 COMPONENTS

A. Provide components as indicated in the Contract Documents and in Manufacturer's catalog subject to acceptance by the Authority and as follows:

1. Arcing Horns and ARC Traps: Design skids with each end upturned to form arcing horns with a flashover taking place across the body unit, and not across insulation.

2. Magnetic Arc Extinguishers: Include with the magnetic arc extinguishers, when required, all components required to fasten the extinguisher to section insulator, and to protect section insulator from damage by a pantograph passing through while drawing current, or damage to the pantograph.

3. Arc Catcher: Tips of the arc catcher to be replaceable.

4. Telescopic Anti-Torsion Guide Tubes: Inner tube of the anti-torsion guide to be free to move vertically to lessen the impact of pantograph.

5. Hardware: Hardware to consist of manufacturer’s recommended items and include, but not limited to, bolts, U-bolts, washers, clamps (including contact wire clamps), turnbuckles, support connectors, braces, insulators and insulating beams.

2.03 PROTECTIVE FINISH
A. Section insulator components to have an accepted protective finish or inherently self-protecting. Ferrous metal components to be galvanized as indicated in Section 34 23 01, Catenary Fittings and Hardware.

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Section Insulator installation is covered in Section 34 23 00, Overhead Contact System.

B. Locate the insulator as indicated in the Contract Documents, and generally close to a supporting structure, but with required clearance maintained from the Section Insulator center to allow for registration of the contact wire.

3.02 FIELD QUALITY CONTROL

A. Field-test section insulators as recommended by the manufacturer.

B. Perform power section proving in accordance with section 34 23 90 to ensure complete electrical isolation between power circuits.

C. Field-tests will be witnessed by the Authority. Submit certified copies of the test results to the Authority for acceptance.

END OF SECTION 34 23 44
SECTION 34 23 50

OVERHEAD CONTACT SYSTEM LIGHTNING PROTECTION

PART 1  GENERAL

1.01  DESCRIPTION

A. This Section covers the requirements for designing, manufacturing, furnishing, installing, and testing of the lightning protection system for the overhead contact system (OCS) as indicated in the Contract Documents.

1.02  SECTION INCLUDES

A. Quality Control
B. Submittals
C. Standards
D. Materials
E. Warranty
F. Execution - General
G. Lightning Arrestors
H. Testing

1.03  RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures
B. Section 01 40 00 - Quality Requirements
C. Section 34 23 10 – OCS Wires, Cables and Terminations
D. Section 34 20 18 – Traction Electrification Grounding Requirements
E. Section 34 20 00 - Overhead Contact System
F. Section 34 30 40 – Traction Electrification Testing and Commissioning
G. Section 34 23 90 - Overhead Contact System Acceptance
1.04 QUALITY CONTROL

A. Refer to Section 01 40 00 - Quality Requirements, for general requirements and procedures.

1.05 SUBMITTALS

A. Refer to Section 01 33 00 – Submittal Procedures.

B. Submit manufacturer’s catalog cuts of proposed lightning arrestors (CDRL).

C. Submit factory test results (CDRL).

1.06 STANDARDS

A. Institute of Electrical and Electronics Engineers (IEEE)

   400 Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems

   C2 National Electrical Safety Code (NESC)

   C62.33 Standard Test Specification for Varistor Surge Protection Devices

B. Lightning Protection Institute

   LPI-175 Standard of Practice

C. National Fire Protection Association (NFPA)

   70 National Electrical Code (NEC)

   78 Lightning Protection Code

   780 Standard for the Installation of Lightning Protection Systems

D. Underwriters Laboratories (UL)

   UL 96 Lightning Protection Components

   UL 96A Installation requirements for Lightning Protection Systems

   UL 467 Grounding and Bonding Equipment
PART 2 PRODUCTS

2.01 MATERIALS

A. Provide DC arrestors and cables as specified in the referenced Standards, as indicated in the Contract Documents, and as required for a complete lightning protection system for the overhead contact system. Lightning arrestors shall be UL listed in accordance with NFPA 70 (NEC) Article 285.5.

B. Provide DC arrestors of the metal-oxide varistor (MOV) type rated at 1,280 Maximum Continuous Operating Voltage (MCOV) and capable of operating within the environment indicated in the Contract Documents. Arrestors shall be distribution class.

C. Provide DC arrestors with a minimum energy discharge capability of 3.3 kJ/kV at 1,280 volts for a nominal OCS system voltage of 750 volts DC.

D. Provide arrestors of high impact resistant ultra-violet stabilized polyester glass with element encapsulated in epoxy and a heat shrink sleeve providing added protection. Use stainless steel connection studs and hardware with a minimum of three eighth inches in diameter.

D. Provide insulated 4/0 hard drawn copper ground cable in accordance with Section 34 20 18 – Grounding and Bonding as indicated in the Contract Documents, and in accordance with applicable codes.

E. Provide ground rods in accordance with section 34 20 18.

2.02 WARRANTY

A. All arrestors furnished under this Contract shall have a minimum in service life of five (5) years from the date of Final Acceptance.

B. Any arrestor that fails during the five (5) year period after Final Acceptance by the Owner shall be replaced by the Contractor at no cost to the Owner, including any labor associated with the removal and replacement of the defective arrestor.
PART 3    EXECUTION

3.01    GENERAL

A. Locate and install all equipment so that it will be readily accessible for operation and maintenance.

B. Install lightning arrestors as indicated in the Contract Documents in accordance with the manufacturer’s recommendations and the NEC.

C. Install arrestors as close as possible to the device being protected with the conductor leads as short as possible, with no sharp bends mounted to the OCS feeder poles as shown on the Contract Drawings.

D. Install separate ground rods for arrestors and pole grounds. Arrestor ground wire shall be exothermically welded to the ground rod as shown in contract drawings and in accordance with section 34 20 18.

3.02    LIGHTNING ARRESTORS

A. Install lightning arrestors at cable feed points and other locations as indicated in the Contract Documents.

B. Provide all hardware as indicated in the Contract Documents and as required for a complete installation.

3.03    TESTING

A. Factory Testing: The units shall be thoroughly factory tested before shipment. Testing of each unit shall include but shall not be limited to quality assurance checks, MCOV and clamping verification tests. The MCOV testing shall consist of the unit(s) being burned-in at the applicable MCOV for a minimum of one (1) hour.

B. Test electrical resistance of arrestor ground system. Resistance shall not exceed 5 ohms in dry soil. Install additional ground rods as required to achieve 5 ohm resistance.

C. Field Testing: Perform testing as required by Section 34 30 40 – Traction Electrification Testing and Commissioning and as indicated in Contract Documents.

END OF SECTION 34 23 50
SECTION 34 23 80

POLE IDENTIFICATION AND WARNING SIGNS

PART 1  GENERAL

1.01  DESCRIPTION

A. The work specified in this Section covers the manufacture, supply and installation of OCS pole identification signs for the Overhead Contact System (OCS) as shown on the Contract Drawings and specified herein.

B. OCS Pole Identification signs shall be placed on all OCS poles as specified on the Contract Drawings.

1.02  SECTION INCLUDES

A. Quality Requirements

B. Submittal Procedures

C. Delivery, Storage and Handling

D. Products

E. Description

F. Fabrication

G. Preparation

H. Installation Requirements

1.03  RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures

B. Section 01 40 00 - Quality Requirements

C. Section 34 23 00 - Overhead Contact System

1.04  QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.
1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Submit a detailed list of all pole identification numbers for the Owner’s review and approval prior to commencing any work on signs.

C. Submit six (6) samples of pole identification signs to the Owner for approval prior to final order and fabrication.

1.06 DELIVERY, STORAGE AND HANDLING

A. All signs and materials shall be delivered, stored and handled in such a manner to avoid damage.

PART 2 PRODUCTS

2.01 DESCRIPTION

A. The signs shall be reflective, self-adhesive yellow-colored decals suitable for permanent installation that can be viewed by LRV Operators traveling in either direction on either track.

B. The Pole ID number shall be as shown on the OCS Layout drawings.

C. The Pole ID numerals shall be of the size shown on the Contract Drawings.

2.02 FABRICATION

A. All letters and numbers shall be on the front side of the sign only.

B. Signs shall be manufactured in a dry, temperature-controlled area.

C. All painted and adhering surfaces shall be prepared in accordance with the decal manufacturer’s recommendations and made free from dirt, oil and grease or other substances that prevent bonding.

PART 3 EXECUTION

3.01 PREPARATION

A. Surfaces to which signs and decals shall be attached shall be free of ice, dirt or foreign material.
3.01 INSTALLATION REQUIREMENTS

A. “Pole Number” identification signs shall be installed on all OCS poles as shown on the Contract Drawings.

END OF SECTION 34 23 80
PART 1 GENERAL

1.01 DESCRIPTION

A. This Section covers requirements for acceptance of the overhead contact system as indicated in the Contract Documents.

1.02 SECTION INCLUDES

A. Quality Control

B. Submittals

C. Acceptance Measurements

D. Visual Inspection

E. Clearance Envelope Tests

F. Electrical Tests

1.03 RELATED SECTIONS

A. Section 01 33 00 – Submittal Procedures

B. Section 01 40 00 - Quality Requirements

1.04 QUALITY CONTROL

A. Refer to Section 01 40 00, Quality Requirements, for general requirements and procedures.

1.05 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Types of Tests: Include all tests required for testing and commissioning of Overhead Contact System as indicated in the Contract Documents. (CDRL)

1. Acceptance Measurements

2. Visual Inspection of Completed Catenary
3. Clearance Envelope Tests for Pantograph and Vehicle
4. Overhead Contact System Electrical Tests

PART 2 PRODUCTS

NOT USED

PART 3 EXECUTION

3.01 ACCEPTANCE MEASUREMENTS

A. Upon completion of all construction, measure the contact wire height, stagger, and other required dimensions stated in the contract documents, and record the readings on the OCS Acceptance Measurement Table described in 3.01 B of this document, in the presence of the Authority's representative.

B. Complete fully and submit the OCS Acceptance Measurements Table for Authority's acceptance. The Contractor shall notify the Authority two weeks prior to recording OCS measurements. Measurements shall include the following:

1. Track designation

2. Wire Run Number as shown on the Layout Schedule.

3. Drawing numbers where the structures of wire runs are indicated.

4. Names of persons responsible for performing the acceptance measurements.

5. Sheet number of a Wire Run set

6. Equipment or catenary style being measured

7. Temperature of the conductor in degrees F during the time of measurement

8. Weather condition during time of measurement (e.g., windy, raining)

9. Date of measurement

10. Structure or pole number identification
11. Station Location of the structure or pole in feet as indicated in the Contract Documents.

12. Distance of pole or structure to the rail measured from the inside of nearest rail to the face of pole or structure.

13. Heights of foundation relative to the rail measured from top of the nearest rail to top (crown) of the foundation.

14. Cross-level difference of two rails measured to structure station (actual superelevation at the structure).

15. Blank (For use by the Authority)

16. Distance measured at structure from contact wire to vertical or superelevated centerline of track (referred to as stagger).

17. Blank (For use by the Authority)

18. Vertical distance between contact wire at the structure measured from top of the highest rail (referred to as contact wire height at support).

19. Blank (For use by the Authority)

20. Same as Item 14 above except measured at midspan

21. Blank (For use by the Authority)

22. Distance between contact wire and vertical or superelevated centerline of track measured at offset midspan (referred to as midspan effect).

23. Average of contact wire heights at supporting structure locations (at each end of span) minus contact wire height at midspan (referred to as presag)

24. Blank (For use by the Authority)

25. Rate of change of contact wire height between poles/structures equal to difference of contact wire heights at each pole/structure divided by span (referred to as gradient)

26. Vertical distance measured at the structure between the contact wire and the messenger wire
27. Rise or fall of counterweight from medium position

28. Counterweight - ambient temperature

29. Positions of counterweight stops

30. Vertical distance between the underside of building overbuilds, underside of the shop doors and roofs, and vertical or superelevated centerline of the track.

31. Electrical clearance from the messenger or contact wire support to underside of building or doorway with uplift force of 50 lbs. on the contact wire at the point of measurement.

32. At overlaps and turnouts - height of in-running and out-of-running contact wire above rail-referenced level at each structure. Provide separate columns for in-running and out-of-running contact wire.

33. Comments or remarks as required.

C. The Authority will use the Acceptance Measurements to determine compliance with the design and will inform the Contractor of necessary corrections.

D. The Contractor shall perform corrective actions to hanger lengths, hanger spacings, messenger and contact wire heights, balance weight anchor settings, jumpers, section insulators, contact wire bridges and contact wire and messenger wire terminations as required to provide an operable OCS acceptable to the Authority. All corrective actions shall be at no additional cost to the Contract.

E. Re-measure and record affected data and submit the results to the Authority for acceptance.

F. Contractor shall submit a complete and bound set of as-built hanger tabulations for each OCS span of each track, including crossovers, showing the number of hangers, hanger spacing and hanger length.

3.02 VISUAL INSPECTION

A. At Contact Wire Level, perform the following visual inspections:

1. Check fitness and tightness of all components.
2. Check split pins for 90 degree minimum bend and locknuts are secure.

3. Check contact wire for kinks, rolls, and damage.

4. Check messenger wire for damage to strands.

5. Check for correct steady arm fittings.

6. Check heel settings.

7. Check the jumpers are of correct type, have required travel capability, are properly fitted, and are well formed to reduce fatigue failure.

8. Check posture and position of pulley plates.

9. Check that hinge fittings have freedom to move under load.

10. Check that wire passing through a cantilever and not attached to it will clear any part of this cantilever by at least 3 inches throughout the range 20°F to 120°F.

11. Check for clearance and insulation between adjacent or crossing catenaries.

12. Check installation for locations of possible interference with passage of pantographs, including spots where pantographs could tangle with wires of suspension assemblies.

B. From Ground Level, perform the following visual inspections:

1. Check that counterweights have freedom to travel and that counterweight band does not bear on guide pipe.

2. Check that cantilevers have correct along-track offset.

3. Check that hangers are plumb and within design positions.

4. Check out safety requirements in accordance with CPUC GO-95 and other applicable safety codes.

3.03 CLEARANCE ENVELOPE TESTS

A. General: Purpose of tests is to verify clearances of light rail vehicles including pantograph from adjacent structures.
B. Pantograph Clearance Envelope: Perform tests initially with a rail mounted height and stagger gauge, having the same dynamic profile as the vehicle pantograph. Pantograph gauge shall provided by the contractor and constructed to dimensions provided by the Authority. Use the gauge to verify the mechanical clearances between pantograph and OCS components such as heels of steady arms and contact wire clamps, and electrical clearances between OCS/pantograph combination and civil structures such as bridges. Following these tests, perform final tests with an actual vehicle to verify initial results.

C. Vehicle Clearance Envelope: Perform the following tests with a vehicle towed or pushed through each track section.

1. Dead Slow Speed Tests at Walking Speed.
   a. Trackside Structural Clearances to Vehicle Body and Pantograph: This includes poles, bridges, awnings, wayside signaling, and electrical equipment housings.
   b. Vehicle Body Clearance Checked at:
      1) The ends of each vehicle
      2) The midspan between trucks

2. Slow Speed Tests. Sub-paragraph C1 at higher speeds. Raise test speeds in successive increments, not to exceed 10 mph each. Final slow speed test shall be performed at yard design speed. A video camera mounted to the test vehicle shall be utilized to record the pantograph movement during the final test run.

3.04 ELECTRICAL TESTS

A. Circuit Continuity

1. General: Purpose of test is to verify electrical continuity of overhead contact system. Coordinate testing with field test personnel as specified in Section 34 30 40, Traction Electrification Testing and Commissioning.

2. Procedures: Test entails short circuiting a discrete section of the OCS by connecting OCS to its rails at one end and applying dc voltage at other end. Perform tests as follows:
a. Connect along-track feeders that are electrically common to OCS.

b. Provide a dc source with a nominal current of 100 amperes and an applied voltage of 24 volts.

c. Record measurements of dc voltage and dc current. Compute circuit resistance from the measured values of voltage and current, and compare with design value furnished by Authority.

d. Retest any section having a discrepancy of more than 20 percent between design value and measured value to ensure all electrical connections are correctly made, or that there are no inadvertent ground connections to OCS which are reducing total length of loop.

3. Other Testing: Refer to Section 34 30 40 “Positive and Negative Feeder Cables” for hi-pot insulation testing requirements and procedures.

B. SECTION PROVING

1. Section Proving is a process of verification of the correct connection and isolation of each electrical segment of the OCS.

2. Contractor shall verify that:

   a. TPS feeder breakers are connected to the correct OCS section and not to any other OCS section.

   b. Disconnects and load break switches connect the correct sections of OCS together and are connected to any other OCS section.

   c. OCS sectionalization, provided through section insulators and/or insulated overlaps, ensures isolation of one OCS section from all other adjacent OCS sections.

3. The means of testing shall be through the energization of the OCS from Traction substations and the applicable opening and closing of circuit breakers, load breaks and disconnect switches. Contractor shall prove that appropriate sections of OCS are energized and de-energized by means of OCS voltage detection equipment. Any section of OCS that should be de-energized, but is found to have a voltage of 50 volts or greater will be deemed to have failed.
END OF SECTION 24 23 90
SECTION 34 30 10

TRACTION ELECTRIFICATION SHOP DC DISTRIBUTION SYSTEM

PART 1 – GENERAL

1.01 SUMMARY

A. Description:
   1. The Work of this Section consists of furnishing, installing, and testing the Traction Electrification System (TES) for the Expo Rail Operations and Maintenance Facility (OMF) as indicated on the Plans and specified herein.

   2. The Main DC switchboard, located in the Main Building Electrical Rooms, shall supply 750-volt dc power to 6 OCS sections via electrically interlocked disconnect switches and control stations and to four 750 V dc power outlet stations on Main Building Inspection tracks.

   3. The Secondary Building DC switchboard, located in the secondary Building Electrical Rooms, shall supply 750-volt dc power to 2 OCS sections in the Secondary Building and to 1 OCS Section in the Wash Building.

B. Section Includes:
   1. Installation
   2. Wiring and Conduit Work
   3. DC Switchboard Grounding
   4. Components Installation
   5. Field Painting
   6. Testing
   7. Cleaning

C. Related Sections:
   1. Section 26 05 00 – Basic Electrical Materials and Methods
   2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
   3. Section 34 20 18 – Traction Electrification Grounding Requirements
   4. Section 34 20 52 – Traction Electrification System Interface Requirements
   5. Section 34 21 40 – Traction Electrification Blue Light – ETS
6. Section 34 30 25 – Traction Electrification Cable and Wire
7. Section 34 30 30 – Traction Electrification DC Distribution Switchboards
8. Section 34 30 35 – Traction Electrification DC Positive and Negative Feeder Cables
9. Section 34 30 40 – Traction Electrification Testing and Commissioning
10. Section 34 81 00 – Traction Electrification Remote Terminal Unit

1.02 REFERENCES

A. Reference Standard – ANSI, ASTM, ICEA, NEMA, NEC, Codes. Comply with the requirements as specified in Section 34 05 00 – Traction electrification Basic Materials and Methods and Regulations of Jurisdictional Authorities.

1.03 PERFORMANCE REQUIREMENTS

A. Qualification – Products to be of manufactures who have been engaged in production of similar products for a minimum of 5 years.
B. Comply with the requirements as specified in Section 34 20 52 – Traction Electrification System Interface Requirements.
C. Shop production test shall be performed on components and assemblies and certified by manufacturer.

1.04 SUBMITTALS

A. General: Refer to General Conditions, for submittal requirements and procedures.
B. Submittals shall include shop drawings, schematics, product data such as catalog cuts and manufacturer’s literature, design calculations, and where appropriate, product samples.
C. Installation Drawings – Submit installation drawings including:
   1. Setting diagram, if anchoring in concrete is required
   2. Erection or assembly drawings, if shipped in sections or if any parts are not installed at the factory
   3. Interconnection diagrams
   4. Cable Schedules
D. Submit equipment identification nameplate sample, including legend.
E. Submit list of identification nameplate legend.
F. Submit certified test reports stating compliance of products with the specified requirements.

G. Submit field test procedures and copies of certified field test reports.

H. Operation and Maintenance Data: Submit such data in accordance with the requirements of the applicable Specifications Section, and include the following:
   1. Manufacturer’s operating and maintenance instructions parts list, illustrations, and diagrams for components
   2. List of recommended spare parts and special tools required

1.05 QUALITY ASSURANCE
   A. General: Refer to General Conditions, for quality assurance requirements and procedures.

1.06 DELIVERY, STORAGE, AND HANDLING
   A. Materials shall be securely wrapped, packaged, and labeled for safe handling in shipment and storage to avoid damage.

   B. Temporary Bracing: Brace and Package the dc switchboards to permit hoisting, lowering and skidding into position. Clearly label temporary bracing of equipment as “TEMPORARY BRACING: TO BE REMOVED BEFORE OPERATION”.

PART 2 – PRODUCTS

2.01 INTERCHANGEABILITY
   A. All components of the same type, rating, and functional characteristics shall be interchangeable.

2.02 VOLTAGE AND CURRENT RATINGS
   A. Voltage for the 750-volt dc traction power electrical equipment and components shall be 1,000 V dc nominal, with a 1-minute ac withstand capability of at least 3.7 kV rms, insulation level, with the capability of sustaining, without deterioration, spikes to 3,000 volts dc.

   B. Where not otherwise specified, components shall be as specified in Section 34 05 00 – Traction electrification Basic Electrical Materials and Methods.

   C. Current ratings shall be as specified herein, or as indicated on the Design Plans.

2.03 NAMEPLATES AND MARKING
   A. Standard Nameplates:
1. Each item of equipment shall be furnished with a manufacturer's nameplate. Nameplates shall provide the manufacturer's name and address, equipment type, and designation number, and the required electrical characteristics called for in the applicable ANSI and NEMA standards.

B. Special Nameplates:

1. Identification nameplates shall be furnished for all equipment. Nameplates shall consist of three-ply, laminated, rigid plastic plate engraved through black face to white core, and attached to panels by machine screws or stainless steel rivets.

2. Switchboard nameplates shall be inscribed with equipment function identification in 1-inch high characters. Nameplates for control and metering devices shall be inscribed with 1/3-inch high characters.

2.04 DC POWER SWITCHBOARD

A. General:

1. Furnish totally enclosed dc switchboards to provide means for controlling dc positive power circuits and power receptacles and to provide a grounded negative return connection to the running rails as indicated on the Design Plans.

2. The switchboards shall be factory pre-assembled, and at a minimum shall contain the specified switching and control equipment, and meet the requirements of the Contract Documents.

B. Enclosure:

1. Switchboard enclosure shall be freestanding, dead front, and designed for indoor use to NEMA 250, Type 4X. The enclosure shall be fabricated from molded, impact-resistant and fire-retardant fiberglass-reinforced polyester, having 1/4-inch minimum thickness. Minimum tensile strength shall be 1,500 pounds per square inch and maximum water absorption shall be 0.65 percent in 24 hours. Surface color shall be ANSI Z55.1, No. 61 (light grey). Additionally, the exterior surfaces shall be given a protective coat of clear polyester gel. The enclosure shall be sufficiently rigid to support all equipment in the individual compartments, and terminated cables under all normal operating loads and switching conditions.

2. Exterior hardware shall be stainless steel or non-ferrous metal. Doors shall be fastened to the enclosure with continuous steel hinges, providing a minimum 120-degree swing opening, and shall be furnished with a doorstep at the fully open position. Doors shall be gasketed and held closed by a three-point latch, with chrome-plated cast steel operating handle. The handle shall have provisions for padlocking in the closed position.
3. Enclosure shall be designed to permit lifting by jacks and slings, and be moved horizontally on rollers or skidded in any direction.

4. Insulated barriers shall be furnished between each fused switch and contactor unit, and the enclosure shall have no exposed grounded parts inside. The switchboard enclosure shall be provided with conduit hubs, for entry of power and control cable. Exact enclosure dimensions and provisions for conduit interfaces, shall be coordinated with the design of the external dc distribution system and the field installation requirements.

5. Non current-carrying exposed metallic parts shall be made electrically continuous by flexible copper insulated conductor, color green, of no less than No. 10 AWG size, connected to a tinned-copper terminal block.

C. Bus:

1. A dc positive bus shall be furnished for the full length of the switchboard assembly, and shall be made of electrical grade copper complying with ASTM B187. Bus bracing shall be rated for a momentary current of not less than 100 kA, rms.

2. Bolted bus connections, including bus taps, shall be silver-plated. Clamping bolts shall be cadmium-plated, or similarly coated, high-strength steel. Clamping system shall ensure that adequate pressure is maintained under repeated thermal cycling over the life of the switchboard.

D. DC Disconnecting Switches:

1. The dc disconnecting switches in the switchboard shall be no-load, single-pole, single-throw, and bolted-pressure type with manual front operator. The switches shall be designed, manufactured and tested in accordance with the applicable requirements of ANSI C37.41 and ANSI C37.45.

2. Switches shall have continuous current ratings as indicated on the Design Plans, without exceeding 122 degrees Fahrenheit rise above a maximum ambient temperature of 104 degrees Fahrenheit and shall have a certified momentary current rating of not less than 100 kA, rms.

3. Switch’s moving and stationary contact surfaces shall be silver plated copper. All other current-carrying parts shall be of electrical grade copper or copper alloy. Contacts shall be self-aligning, wear compensating, and with initial wiping action. Hinge and jaw contacts shall be bolted pressure type, with non-ferrous or stainless steel self-clamping mechanism, or other approved high-pressure type contact arrangement.

4. Each switch shall be furnished with an insulated manual operating handle, externally mounted. Handle positions corresponding to OPEN
and CLOSED status of switch contacts shall be shown by corrosion-resistant nameplates, permanently secured to the enclosure.

5. Each disconnect switch operating mechanism shall be furnished with electro-mechanical interlocks with the power contactor in the same circuit, so that switch and contactor operate as a unit, and the switch cannot be closed or opened under load. The switch shall be provided with an interlock comprised of a solenoid operated steel bolt, designed for operation on a 120 V ac control power supply. The interlock shall prevent the switch contacts from actually opening and closing when the solenoid is de-energized. Energization of the solenoid shall be made possible when the associated power contactor is open. In addition, the disconnect switch manual operator shall be of design that prevents opening of the enclosure door unless the operating handle is removed, which shall be possible only when the switch is in the OPEN position.

6. Auxiliary and Indicating Devices. The disconnect switches shall be equipped with all auxiliary and indicating devices shown on the Design Plans and as required for a safe and reliable operation of the associated power circuit. Minimal/complementary requirements shall include the following:

   a. The disconnect switch shall be furnished with auxiliary contacts (Forms A and B) as required for the operation of the interlocks and indication lights. The auxiliary contacts shall include at least one set of spares.

   b. A control push button shall be provided on the main disconnect switch enclosure door. Push button operation shall de-energize the associated feeder breaker in the TPSS, and permit energization of the interlock solenoid when the TPSS breaker is open. The solenoid shall be energized via Form-b auxiliary switch of the power contactor. Push buttons shall be heavy-duty, oil-tight, flush-mounted, and furnished with contact block providing 1-NO and 1-NC contact arrangement. Push button operator cap shall be color yellow and legend plate inscribed, “INTERLOCK RELEASE”.

   c. A control push button shall be provided on each branch disconnect switch enclosure door. Push button operation shall de-energize the associated contactor, and permit energization of the interlock solenoid when the contactor is open. The solenoid shall be energized via Form-b auxiliary switch of the power contactor. Push buttons shall be heavy-duty, oil-tight, flush-mounted, and furnished with contact block providing 1-NO and 1-NC contact arrangement. Push button operator cap shall be color yellow and legend plate inscribed, “INTERLOCK RELEASE”.

   d. An indicating light, with green color lens, shall be provided on each switch enclosure door above the specified push button. Legend plate shall be inscribed, “POWER OFF” for the branch circuits, and “SWBD POWER OFF” for the main disconnect switch. The
indicating light shall be energized through a Form-b auxiliary switch of the associated power contactor.
c. Line terminals of the switch circuits shall be drilled to accommodate NEMA 2-hole cable lugs for the size and number of copper conductors indicated on the Design Plans.

E. Power Fuses:

1. Current limiting dc power fuse shall be provided at the load terminal of each branch circuit disconnect switch. Fuses shall be rated for 1,000 V dc, shall be bolt-in type, and shall be furnished with visible trigger indication of fuse operation. Continuous current ratings shall be as indicated on the Design Plans.

F. Contactors:

1. DC power contactor shall be provided to control supply for each branch circuit feed.

2. Contactors shall be single-pole, single-throw, rated for 1,000 V dc, with continuous/interrupting current as shown on the Design Plans, and with 5,000 A dc making capability. The contactor's control circuits and operating coil shall be designed for operation with 120 V ac control power, and if necessary shall be furnished with a rectifier.

3. Contactor control circuit shall be designed for local OPEN control and remote CLOSE and OPEN control from shop power control stations as shown on the Design Plans and as specified in this Section. External circuit connections shall be wired to terminal blocks.

4. Contactors shall be provided with independent Form A and Form B auxiliary switch contacts, rated 10 A at 120 V ac, for electrical interlocking and position indication purposes as required. The auxiliary contacts shall include at least one set of spares.

G. Meters:

1. A voltmeter and an ammeter shall be furnished with the dc switchboard, connected in a manner as shown on the Design Plans. The meters shall be mounted on the main incoming line disconnect switch enclosure door, and shall be connected to the dc positive bus through isolation transducers. The moving elements shall be provided with zero adjustment accessible from the front of the meter without disassembly, and the moving elements shall be magnetically dampened. The cases shall be dust-tight, and glass window shall be non-reflecting.

2. Meters shall comply with ANSI C39.1; shall be analog, switchboard type, mounted semi-flush, not less than 4-1/2 inches square in size, with 250-degree linear scales, white dials, black markings and black pointers. Meters' accuracy shall be within 1 percent of the full-scale
3. Meters shall be connected to the positive bus through isolation transducers. The isolation transducers shall be rated for operation at 1,000 V dc on the primary side, and be able to sustain voltages up to 3,000 V dc for 1 minute without damage. Transducer accuracy shall be within 1 percent of full scale, or better. Transducer output shall be 4 to 20 mA, or 0 to 5 V signals, and coordinated with the associated meter, as required.

4. The voltmeter and ammeter shall be furnished with explanatory legend plates reading “BUS VOLTAGE” and “SWITCHBOARD CURRENT”, respectively.

H. Wiring and Terminals:

1. Instrument and control wiring shall be stranded copper and not smaller than No. 14 AWG, with 1,000 V minimum, NFPA 70 Type SIS insulation. Control wires exposed to the 750 V dc potential shall be rated for 2,000 volts, and shall be different color compare to those used for low-voltage power and control. Insulation shall pass the flame propagation criteria and flame test of IEEE Standard 383. Wire that crosses hinged panels or joints shall be Class C, minimum, stranded copper wire to ASTM B8. Each conductor shall be continuous without splices or taps from terminal to terminal. The wire ends shall be permanently fitted with ring type wire lugs for attachment to terminal studs.

2. All interconnecting circuit wiring between switch board units and compartments shall terminate at terminal blocks before being connected to devices. All interconnecting wiring across shipping sections shall be terminated at split terminal blocks. All switchboard internal wiring shall be installed, connected, and tested before shipment.

3. Provision shall be made for external cables and wiring to enter the switchboard as indicated on the Design Plans. Top entrances shall be provided with removable cover panels for field drilling of conduit or cable bush holes.

4. Internal wiring shall be identified at each termination with the equipment manufacturer’s wire number by means of a suitable plastic sleeve, with imprinted wire identification as shown on the manufacturer’s wiring diagram.

5. Terminal blocks shall comply with the requirements of NEMA ICS4, and shall be of the screw type with washer style head to accommodate ring-type wire connectors. Bases and inter-terminal barriers shall be of molded heavy-duty insulating compound of sufficient size to
accommodate terminals for No. 10 AWG wire. The metallic parts shall be nonferrous and corrosion-resistant.

6. Terminal blocks shall be identified using proper labeling. Terminals for external wiring connection shall be grouped according to purpose and direction. Each terminal block shall be provided with minimum of 20 percent spare terminal points.

I. Control Power Bus:

1. A 120 V ac 2-wire control power bus shall be furnished with the dc power switchboard, for powering the switch electro-mechanical interlocking, contactor control circuits, and other devices. Control power supply shall be obtained from the designated 120/208 V ac distribution panelboard in the Electrical Room. Control power bus shall be wired to terminal blocks within the incoming main disconnecting switch compartment.

2. A single-pole pullout fuse block shall be provided in the incoming main switch and each branch feeder switch compartment, to effectively isolate the unit electrical control circuits from the control power bus.

J. Indicating Lights:

1. All indicating lights on traction power equipment shall be light emitting diode (LED) based lamps, suitable for operation at 120 V ac.

2. LED lamps mounted on the switchboard and control panels shall be with bayonet bases, and shall be mounted in compact, rugged sockets. Lenses and bezels of the LED lamps shall be rectangular or circular, and or adequate size and height to permit reading from oblique angles.

3. The LED’s shall be rated for 100,000 hours or longer, at full voltage.

4. Indicating lights on equipment shall be clearly visible at 30-degree angle relative to the surface, and at a distance of 15 feet in a fully lit environment.

K. Incoming Line Status Indication:

1. The dc switchboard shall be furnished with a red warning light, indicating if the incoming 750 V dc feeder is hot. A legend plate reading “INCOMING FEEDER ENERGIZED” shall be placed below the red warning light. The light shall be connected between the incoming positive feeder (line side of the main disconnect switch) and the negative reference bus through a dropping resistor. The circuit shall be designed by the equipment manufacturer as part of the switchboard design, in accordance with the following guidelines. An alternative scheme may be acceptable, subject to Authority approval.

   a. The dropping resistor shall have suitable voltage and power ratings, and shall be connected to the positive side through an insulated cable. Dropping resistor shall be rated for operation at
least at 1,000 Vdc nominal, or higher. Resistor location shall be such as to prevent accidental contact during routine switchboard maintenance.

b. The warning light shall be connected between the dropping resistor and the negative bus/ground. The lamp shall comprise of a LED cluster, and shall be of design such that a failure of a single LED does not result in complete lamp failure.

c. An R-C snubber circuit shall be provided to protect the LED warning light from dc voltage spikes and surges of up to 2.5 kV, if needed.

L. Warning Signs:

1. A nameplate shall be furnished and permanently attached to the front face of each dc switchboard, inscribed, “WARNING HIGH-VOLTAGE KEEP OUT”. Nameplate shall be white over red laminated melamine, not less than 3/32-inch thick, complying with FS L-P-387. Red engraved letters shall be 2 inches high minimum.

2. Each disconnecting switch shall be provided with a permanent corrosion resistant warning sign mounted below the operating handle on the enclosure door. Sign shall read, “DO NOT OPERATE UNDER LOAD”, with a 2-inch high minimum letter size.

2.05 750 VDC OCS CONTROL STATIONS

A. Control stations, associated wiring, and raceways shall be furnished, as indicated on the Design Plans, to control the 750 volt dc power supply to 750 volt dc OCS Sections in the shop facilities.

B. Each control station shall consist of an assembly of the following components housed in a stainless steel NEMA Type 4X surfaced mounting enclosure:

1. Two-heavy duty, oil-tight momentary contact push buttons, with legend plates inscribed, “ON and OFF”. The ON push button shall have a flush head and green color cap. The OFF push button shall have a mushroom head, color red. Each push button shall be furnished with contact block providing 1-NO and 1-NC contact arrangement.

2. Two-full voltage, 120 V ac, LED indicating lights, one with red color lens and legend plate inscribed, “POWER ON” and one with green color lens and legend plate inscribed – POWER OFF.

3. A 2 amp 24 volt dc power supply to power magnetic door locks at location indicated on the Design Plans.

4. Enclosure shall be provided with corrosion resistant nameplate inscribed, “750 VOLT DC OCS POWER – CIRCUIT SI-1 (TYP)”. 
2.06 MAGNETIC DOOR LOCKS
A. Magnetic Door Locks, associated wiring, and raceways shall be furnished, as indicated on the Design Plans, to control access to the 2nd level platforms by locking the associated access doors.
   1. Provide locks that operate on 24 volt dc, provide 1000 lb. Hold Force and are UL1034 and BHMA Grade 1 certified.
   2. Each Magnetic Door Lock shall be equipped with an integral door position switch to sense the closed status of the associated access door.
B. Provide a Push to Exit Switch at location shown on the Design Plans which removes power from the Magnetic Door Lock for an adjustable 0-60 second time period.

2.07 FALL PROTECTION INTERLOCK
A. Provide Fall Protection Interlock Switch at locations shown on the Design Plans
   1. Coordinate Interlock Switch mounting and function with Fall Protection equipment supplier.
   2. Interlock shall prevent 750 VDC power application to the OCS unless the Fall Protection System Gates are in the fully open position.
   3. Interlock Switch shall be Omron Type Z or approved equal.

2.08 TRAIN PRESENCE/PLATFORM ACCESS CONTROL
A. Provide Train Presence/Platform Access Control at locations shown on the Design Plans
   1. Train Presence/Platform Access Control shall lock access gates to 2nd level platform unless a train is occupying bay spanned by platforms.
   2. Train presence shall be detected by Visible Red LED through beam transmitters/receivers at locations shown on the Design Drawings. Receiver shall contain integral single pole double through relay for control of magnetic door locks.
   3. Infrared LED transmitters/receivers shall be Telco Type SP 2000 or approved equal.

2.09 OCS POWER INDICATING LIGHTS
A. OCS Power Indicating Lights, associated wiring, and raceways shall be furnished, as indicated on the Design Plans, to when 750 volt dc power is present on the section associated with the indicating lights.
1. A RED LED indicating light shall be illuminated when the OCS Section is supplied with 750 volt dc.

2. A GREEN LED indicating light shall be illuminated when the OCS Section is grounded.

B. The OCS Power Indicating Lights shall be Lintern 900X-1 Glowlite with heavy duty steady burn LED medium base lamp or approved equal mounted above the associated OCS Section.

2.10 OCS POWER WARNING HORNS

A. Provide Warning Horns that will sound for 15 seconds (adjustable) before 750 VDC power is connected to the OCS. Horns shall be controlled by a time delay relay in the 750 VDC OCS Control Station.

1. The warning horns shall be Edwards ADAPTA-HORN; a vibrating horn, model #876-N5, 120 VAC, waterproof, or approved equal. The horn shall be mounted on 4” square box. Provide projector, Edwards model #872-PO.

2.11 750 VDC POWER OUTLET STATIONS

A. Control stations, associated wiring, and raceways shall be furnished, as indicated on the Design Plans, to control the 750 volt dc power supply to 750 volt dc power receptacles in the shop facilities.

B. Each control station shall consist of an assembly of the following components housed in a metal NEMA Type 4X surfaced mounting enclosure:

1. Two-heavy duty, oil-tight push buttons, with legend plates inscribed, “ON and OFF”. The ON push button shall have a flush head and green color cap. The OFF push button shall have a mushroom head, color red. Each push button shall be furnished with contact block providing 1-NO and 1-NC contact arrangement.

2. Two-full voltage, 120 V ac, LED indicating lights, one with red color lens and legend plate inscribed, “POWER ON” and one with green color lens and legend plate inscribed – POWER OFF.

3. Enclosure shall be provided with corrosion resistant nameplate inscribed, “750 VOLT DC POWER – CIRCUIT SI-1 (TYP)”.

2.12 750 VOLT DC POWER RECEPTACLES

A. 750 Volt DC Power Receptacles:

1. DC power receptacles shall be heavy duty environment resistant, comprised of one – 200 A main contact with 800 V dc service voltage rating, and two No. 12 AWG relay contacts with 240 V ac service voltage rating.
2. Relay contact length shall be 1/4 inch less than that of main contact. Relay contacts shall be wired into power circuit contactor for safety interlocking purposes, to prevent power contact from being energized unless mating plug is fully inserted, and to trip contactor before plug is fully withdrawn from receptacle.

3. Receptacle shell and plug skirt shall be keyed to ensure correct alignment of male/female contacts when plug is inserted.

4. Receptacle shell shall be furnished with a suitable environmental cover.

5. Receptacle shall be mounted on exposed junction box with angle adapter and threaded hub.

6. Receptacle shell may be all insulated construction, or corrosion resistant metal. Metal enclosed receptacles and plugs shall have provision for grounding connection.

7. Power receptacles shall be of Meltric Corporation type LC, or an approved equal.

8. Power receptacles shall be furnished with an extra flexible, rope lay, stranded (class K in accordance with ASTM B172) #4/0 AWG, coated, annealed copper 50 foot power cable, having low smoke and low toxic silicon rubber insulation thickness rated for 2kV in accordance with NEMA/WC8. Provide low smoke, zero halogen cross-linked modified polyolefin jacket. Provide hose hanger, Suncast DHH150 below receptacle for coiled power cable storage.

2.13 SHOP INTERRUPTER SWITCHES

A. Shop Interrupter Switches (SIS), associated wiring, and raceways shall be furnished, as indicated on the Design Plans, to remove all 750 volt dc power (750 VDC OCS and 750 VDC Power Receptacles) within the shop facilities.

1. The SIS shall be push button type and shall have a mushroom head, color red. Each push button shall be furnished with contact block providing 1-NO and 1-NC contact arrangement.

2. A nameplate shall be furnished and permanently attached above each SIS, inscribed, “SHOP INTERRUPTER SWITCH – PRESS TO REMOVE ALL 750 VOLT DC POWER”. Nameplate shall be white over red laminated melamine, not less than 3/32-inch thick, complying with FS L-P-387. Red engraved letters shall be 2 inches high minimum.
2.14 OCS POWER STATUS INDICATING DISPLAY

A. An OCS Power Status Indicating Display (PSID), associated wiring, and raceways shall be furnished to display the power status of each OCS power section within the main building.

1. The PSID shall consist of a minimum 12” x 18” engraved laminated “Artwork” type display indicating the overall outline of the building and each OCS section labeled and displayed.

2. A RED and a GREEN LED shall be associated with each OCS power section on the display.
   a. RED LED shall be illuminated when the OCS Section is supplied with 750 volt dc.
   b. GREEN LED shall be illuminated when the OCS Section is grounded.

2.15 750 V DC POWER CABLE

A. DC power cable for positive feeder and negative return circuits shall be as specified in Section 34 30 25 – Traction Electrification Cable and Wire.

2.16 WIRE RACEWAY SYSTEM

A. Furnish products forming wire raceway system and including but not limited to conduit, conduit fittings, cable trays, pull boxes, and supporting devices. These products shall be as specified in Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods, and as indicated on the Design Plans.

   All embedded conduit for the traction power distribution system shall be Fiberglass Reinforced Epoxy (FRE). Exposed conduit and conduit fittings for control cable shall be galvanized rigid steel. Exposed conduit and conduit fittings for 750 V DC power cable shall be FRE.

PART 3 – EXECUTION

3.01 INSTALLATION

A. Install, wire, connect, and test shop traction power distribution system complete and ready for operation in accordance with these Specifications, manufacturer’s instructions, and as shown on the Design Plans.

3.02 WIRING AND CONDUIT WORK

A. Install in accordance with Section 34 05 00 – Traction electrification Basic Electrical Materials and Methods.
3.03 DC SWITCHBOARD GROUNDING
A. Connect switchboard enclosure ground terminal block to shop grounding system.

3.04 COMPONENTS INSTALLATION
A. Install traction power system components, specified herein, at the locations shown on the Design Plans; secure, plumb, and level in true alignment with related adjoining work.
B. Furnish anchor bolts and anchorage items, where required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the jobsite to ensure correct placing of anchorage items.
C. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles, as required, to set and rigidly connect the work.
D. Provide temporary bracing, guys, or other devices, as required, to accomplish erection and to provide safety and stability until all work is in final position and approved.
E. Control placement and erection tolerance requirements so as to maintain strength, safety, serviceability, and appearance.
F. Repair or replace items damaged during installation to the satisfaction of the Authority at no additional cost.

3.05 FIELD PAINTING
A. After installations are complete, thoroughly clean all surfaces where shop paint is missing or abraded, all bare steel, including bolts, nuts, washers, and welds, and paint each item to match the original.
B. Galvanized materials that are scratched, cut, or in other manners have their protective coatings penetrated or damaged, shall be field coated with cold liquid galvanizing to the strength and finish of the original coating.

3.06 TESTING
A. Perform the following field tests:
   1. Check insulation resistance to ground for all power circuits with a megohmmeter (megger).
      a. 120 V ac systems: at 1,000 V
      b. Traction power cables: megger test at twice the installation voltage level (4 kV) for approximately 5 minutes
   2. Check circuit continuity using a low resistance ohmmeter.
3. Test operation of each disconnect switch including operation of solenoid-operated lock.

4. Test operation of each contactor and associated control circuits.

5. Verify all status indicating lights.

6. Test operation of dc power control stations.

7. Verify presence of voltage at each shop dc power receptacle when associated contactor is closed.

B. Provide qualified personnel with all tools, test equipment, and other required items to perform the testing. The Authority shall have qualified witnesses present at each test to observe the test and certify the recorded results.

C. Furnish written notice as to when all installed electrical equipment will be tested so that the Authority may be present to witness the test. A minimum of 10 days prior notice of proposed test shall be given.

D. Prepare and submit test procedure for each test a minimum 30 days before the test date. The procedures shall detail step-by-step test requirements and connections of test equipment and instrumentation.

E. At the Design Builder’s option, a representative of the manufacturer may be present.

F. The tests shall not alter the Design Builder’s guarantee of work and materials. All work and materials found to be in noncompliance with the Contract Documents shall be replaced and retested by the Design Builder.

G. Submit certified test reports for each test within 15 days after the successful completion of the test. Reproducible test data sheets shall be kept showing the results of all tests. The reproducible data sheets shall list both the acceptable or specified test limits, and the values actually measured. One copy shall be furnished to the Authority. One copy shall be retained by the Design Builder. Data sheets shall show the test set-up, the equipment used, the names of persons performing the test, the names of witnesses, the date, the location, and the serial number of the equipment under test. The test data sheets shall be reviewed by the Authority and may be accepted as submitted or additional test may be required. If additional tests are required, the Contractor shall include these test data with other data sheets.

3.07 CLEANING

A. Comply with the requirements as specified in General Conditions for Cleaning, Closeout Procedures and Section 34 30 00 – Basic Electrical Materials and Methods, and elsewhere on the Contract Documents.

END OF SECTION
PART 1 – GENERAL

1.01 SUMMARY

A. Description:

1. The Work of this Section includes the requirements for furnishing and installing wire and cable, and associated splices and terminations for the Traction Electrification System (TES) for the Expo Rail Operations and Maintenance Facility (OMF) as specified on the Contract Documents and as specified herein.

2. Cable splices shall be prohibited unless the Contractor can demonstrate to the satisfaction of the Authority that all other options have been exercised or they are indicated on the Design Plans.

3. Request and obtain formal approval from the Authority to incorporate splices prior to installing splice termination hardware/materials.

B. Section Includes:

1. General Installation Requirements
2. Circuit Separation
3. Installation of Conductors in Enclosures
4. Cable Pulling and/or Tension Calculations
5. Installation of Conductors
6. Installation of 750-Volt Conductors No. 2 AWG and Smaller
7. Identification of Cable and Wire
8. 750-Volt Splices and Terminations
9. Color Coding
10. Test Requirements
11. Cleaning

C. Related Sections:

1. Section 26 05 00 – Basic Electrical Materials and Methods
2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
3. Section 34 20 18 – Traction Electrification Grounding Requirements
4. Section 34 20 52 – Traction Electrification System Interface Requirements
5. Section 34 21 40 – Traction Electrification Blue Light – ETS
6. Section 34 30 10 – Traction Electrification Shop DC Distribution System
7. Section 34 30 30 – Traction Electrification DC Distribution Switchboards
8. Section 34 30 35 – Traction Electrification DC Positive and Negative Feeder Cables
9. Section 34 30 40 – Traction Electrification Testing and Commissioning
10. Section 34 81 00 – Traction Electrification Remote Terminal Unit

1.02 REFERENCES
A. ASTM International (ASTM):
   1. ASTM B8 Specification for Concentric-Lay-Stranded Copper Conductor, Hard, Medium, or Soft
B. Insulated Cable Engineers Association (ICEA):
   1. S-96-658 Non-Shielded 0 – 2 kV Cables
C. National Electrical Manufacturer’s Association (NEMA):
   1. NEMA WC 70 Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
D. Underwriters Laboratories, Inc. (UL):
   1. UL 486A Wire connectors and Soldering Lugs for use with Copper Conductors

1.03 SUBMITTALS
A. General: Refer to General Conditions, for submittal requirements and procedures.
B. Submit product data on the following items:
   1. Wire and cable
   2. Splicing and termination materials
   3. Cable pulling materials
C. Product data to be submitted for each type and size of wire and cable shall include the following:
1. Manufacturer of the wire and cable
2. Number and size of strands composing each conductor
3. Conductor insulation composition and thickness
4. Average overall diameter of finished wire and cable
5. Conductor ampacity at 86 degrees Fahrenheit ambient for three current-carrying conductors in raceway or cable or for single insulated conductor in free air.

D. Submit cable pulling calculations and cable installation procedures.

E. Submit certified factory cable test data in accordance with the Contract Documents and General Conditions – Submittal Procedures. Data shall include evidence that the cable conforms to the requirements of the specified UL, ICEA, and ASTM standards. A certification or published specification data statement by the manufacturer, to the effect that the cable conforms to the applicable ICEA standards and to these Specifications, will be acceptable evidence.

F. Develop and submit a cable and wire tag schedule.

G. Submit wiring test sheets.

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. All conductors shall be ASTM B8 stranded copper. Size and type of insulation shall be as specified in the Contract Documents, or otherwise specified.

B. Minimum size: No. 12 AWG, unless otherwise indicated.

2.02 750 VOLT CABLE AND WIRE

A. All conductors shall be 98 percent conductivity copper with insulation rated 90 C, wet or dry.

B. For size 1/0 AWG and smaller, NFPA 70 Type XHHW-2, Cross-linked-Thermosetting-Polyethylene-Insulated or NFPA 70 Type RHW-2, Ethylene-Propylene-Rubber-Insulated conductors, ICEA S-96-658 / NEMA WC 70 are approved for use.

C. For size 2/0 AWG and larger, NFPA 70 Type RHW-2, Ethylene-Propylene-Rubber-Insulated conductors, ICEA S-96-658 / NEMA WC 70 are approved for use.
2.03 750-VOLT SPLICES (ONLY USED IF FORMALLY APPROVED BY THE AUTHORITY)

A. In dry locations, use pre-insulated spring-wire connectors for No. 10 AWG conductors and smaller. Splices shall be 3M "Scotch-Lok", Ideal "Wing-Nut", Burndy or equal per UL 486A.

B. Splices No. 8 and larger shall use tin or silver plated copper compression sleeves as manufactured by Thomas and Betts, Burndy, or equal.

C. Splices in handholes and manholes, or underground splices, shall be made watertight with epoxy resin type splicing kits, "Scotchcast", or equal.

D. Insulation for aboveground splices and taps shall be heat shrink polyolefin, rated for 750 volts and 194 degrees Fahrenheit, and watertight. Manufacturer shall be Thomas and Betts, Raychem, or equal.

2.04 750-VOLT TERMINATIONS

A. In dry locations, use pre-insulated solderless type of termination for No. 10 AWG and smaller, where terminating on screw terminals. Use Thomas and Betts "Stakon" ring tongue, Panduit, or equal.

B. Terminations No. 8 and larger shall use tin or silver plated copper compression type lugs with NEMA bolt hole patterns as manufactured by Thomas and Betts, Burndy, or equal. Aluminum or aluminum alloy terminals shall not be used.

C. Terminations or taps in vaults or pullboxes, or underground terminations, shall be made watertight with epoxy resin type splicing kits, "Scotchcast", or equal.

D. Insulation for aboveground terminations shall be heat shrink polyolefin, rated for 750 volts, and weatherproof. Insulation shall be by Thomas and Betts, Raychem, or equal.

E. Terminations in circuit breaker lugs or where factory supplied lugs are provided in accordance with NEMA standards shall be in accordance with manufacturer's recommendations.

2.05 DC POSITIVE AND NEGATIVE FEEDER CABLES

A. DC Positive and Negative Feeder Cables shall comply with the requirements as specified in Section 34 30 35 – DC Positive and Negative Feeder Cables.

2.06 600-VOLT WIRE AND CABLE

A. 600 Volt and below wire and cable shall meet the requirements of 26 05 19 – Low-Voltage Electrical Power Conductors and Cable.

B. Multi-Conductor cables shall be Type TC Control Cable with Type XHHW Insulation with PVC overall jacket.
2.07 GROUNDING AND BONDING CONDUCTORS

A. Grounding and Bonding Conductors shall comply with the requirements as specified in Section 34 20 18 – Traction Electrification System Grounding Requirements.

2.08 CABLE AND CAPS

A. Cable end sealing caps shall be heat shrinkable, completely waterproof, utilize an environmental sealant, and be suitable for applications up to 1,000 volts. Caps shall be pre-coated with a thermoplastic adhesive that provides a complete environmental seal, and shall be easily removed and leave a clean, undamaged, cable end. Tape or other non-heat shrink products shall not be used for this purpose. Caps shall be Ray Chem type ESC, or equal.

2.09 WIRE TIES AND CLAMPS

A. Wire ties, clamps, and anchors shall be formulated for resistance to ozone and ultraviolet light, rated for outdoor service, and shall last the life of the Traction Electrification System. Wire ties shall be installed with tools with automatic tensioning devices, as supplied by the wire tie manufacturer. Wire ties shall be installed with sufficient tension to restrain the wiring without indenting the wire insulation. Nylon wire ties are prohibited.

B. If used, wire tie anchors shall be rigidly fastened to the equipment or a rigid structure. Adhesive-based wire tie anchors are not permitted. Wire ties shall not be used to secure positive and negative feeder cables, use wire clamps.

C. Wire tie width shall be selected for intended tensile load, and sufficient bearing to prevent insulation indentation and damage.

D. Wire clamps shall be porcelain, nylon or stainless steel covered with neoprene or silicon rubber similar to those manufactured by Delta-Star or Adel and suitable for interior or exterior applications. Wire clamps shall be sized for each harness such that no less than 90 percent of the harness circumference is securely clamped. Clamps shall be fastened with bolts and elastic stop nuts.

PART 3 – EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Provide and install conductors of the sizes and types as specified on the Design Plans.

B. Inspect all cable and wire for damage prior to installation. Damaged cable and/or wire shall not be installed.

C. Cable and/or wire shall not be pulled in raceway until all bushings are installed and raceway terminations are completed. Cable and/or wire shall
not be left extending out of raceway stubs or uncompleted raceways and/or cable trays.

D. In all raceways and/or cable trays where ac conductors are installed, a separate ground wire shall be provided, sized in accordance with the National Electrical Code (NEC), and installed in accordance with Section 342018 – Traction Electrification Grounding Requirements. Ground wires are not required in empty raceways and/or cable trays, and are prohibited in traction power ductbanks.

E. Unless otherwise specified on the Contract Documents, all conductors shall be installed in a raceway and/or cable tray. Exposed conductors are not permitted.

F. After conductors have been installed, the ends of conduits terminating in pullboxes, junction boxes, controller cabinets, and equipment cases shall be sealed with an approved type of sealing compound.

1. Approved fittings shall be provided between all cable and conduit openings to provide watertight seals, and withstand water pressure of 50 pounds per square inch without leakage. The seals shall be O-Z type CSBI, CSBE, or equal. All unused conduits for traction power and miscellaneous systems shall be provided with blank seals. A two part, fast setting, polymeric sealing compound similar to FX-571G from Fox Industries or equal shall be used.

3.02 CIRCUIT SEPARATION

A. Circuits of different voltages or systems shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.

B. The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit, manholes, handholes, and/or pullboxes, and shall be physically separated and secured in enclosures, junction boxes, or termination in equipment:

1. High voltage ac circuits
2. Dc positive feeder circuits
3. Dc negative feeder circuits, Low Voltage AC circuits, Low Voltage DC circuits.

C. Wiring operating at potentials differing by 50 volts or more shall not be harnessed or cabled together.

D. Wiring of different potentials within equipment enclosures shall be separated, routed, and secured such that contact or effects from Electromagnetic Interference (EMI) or faults between wiring of different systems is not possible. All wiring within an enclosure shall be insulated for the highest voltage in the enclosure, unless approved otherwise.
E. Separation and/or electromagnetic shielding shall be provided between the conductors of high current switching or transient generating equipment and the wiring of semiconductor, logic, or communication circuits such that interference does not occur between circuits.

3.03 INSTALLATION OF CONDUCTORS IN ENCLOSURES

A. The requirements below apply to all electrical equipment enclosures, including junction boxes.

1. All wiring within enclosures shall be attached to conductor supports rigidly fastened to the enclosure structure. Wiring supports shall be free from edges, bolt heads, or similar areas, and shall not interfere with nor contact enclosure covers.

2. Wiring entering removable enclosures shall be harnessed and secured to facilitate removal. Wires from different wire runs shall not be harnessed together or with internal wiring.

3. All wiring shall be secured such that there is no strain on wire terminals, multi-pin connector pins, or other wire termination hardware.

4. Wire dress shall allow for sufficient slack at terminals to provide for shock and vibration induced movements, equipment shifting, alignment, cover removal, and component replacement. Sufficient additional wire length shall be provided for retermination of wires without excess tension or splicing as follows:
   a. No. 10 and smaller - Three reterminations
   b. No. 8 and larger - Two reterminations

5. All wire shall be installed as continuous lengths without splices between terminations, unless specified on the Contract Documents.

3.04 CABLE PULLING AND/OR TENSION CALCULATIONS

A. Perform pulling and/or tension calculations in accordance with the cable manufacturer's recommendations, and these Specifications. The calculations shall be made by an Electrical Engineer registered in the State of California, and bear the seal and signature of the Electrical Engineer who is responsible for the calculations. Calculations shall be made for all conductors when installed in conduit under either of the following conditions:

1. The conduit run exceeds 300 feet horizontally and/or
2. The conduit run contains a total of over 180 degrees of bends

B. For pulling calculations, consideration shall be given to the following parameters - fill, coefficient of 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, the method of attaching the conductors to the pulling
equipment, and weight of the cables. These factors shall be calculated for each pull as required. Do not exceed the maximum allowable values of sidewall pressure, pulling strain on conductors or sheath, limits of pulling device, and pulling tension.

C. In general, do not exceed the following guidelines:

1. The maximum pulling strain on the cable with a pulling eye attached to the conductors is a function of the conductor area as follows: \( TM = 0.008 \times n \times CM \), where \( TM \) = Maximum tension (lbs), \( n \) = number of conductors, \( CM \) = area of each conductor (circular mils).

2. When a basket-weave grip is used in lieu of a pulling eye, the maximum tension shall not exceed the value calculated for the pulling eye method or 1,000 pounds per grip, whichever is less.

3. The sidewall pressure loads shall not exceed 300 lb/ft of bend radius, or the Wire and Cable Manufacturer's recommendation, whichever is less.

4. The jam ratio shall not fall between 2.8 and 3.2.

5. The coefficient of friction for the cables with lubrication shall be taken to be 0.35.

D. Cable pulling calculations shall be submitted in accordance with Article 1.04 herein.

3.05 INSTALLATION OF CONDUCTORS

A. Preparation:

1. Before installation of cables in raceway and/or cable tray, a suitable wire brush, swab, and mandrel shall be pulled through the conduit and/or cable tray to remove extraneous matter and to verify that the conduit and/or cable tray is free of obstructions.

2. Pull the cables in the presence of Authority representative.

B. Cable Pulling:

1. Cable shall be pulled in strict accordance with manufacturer's recommendations. Wire rope shall not be used to pull cable in non-metallic raceways. Cable shall be protected from damage at all times during installation, and shall never be dragged along the ground or obstacles.

2. Pulling lubricants shall be used to reduce friction. Lubricants shall be compatible with cable, jackets, insulation, and environment. When pulling three or four single conductor cables in one raceway, sufficient lubricant shall be used to meet all tension requirements. Only lubricants recommended by the cable manufacturer shall be used, unless formal approval from the Authority is obtained.
3. Unless both ends of the conductors are within voice or visual range, two-way radios or portable phones shall be used by the Contractor to maintain contact between the feeding and pulling ends of the conductors.

4. Cable feeder tubes and nozzles shall be used on all pulls to protect cables and reduce pulling tensions. Do not pull conductors over the edges of boxes or raceways. A roller-bearing swivel shall be attached between the pulling rope and pulling basket or eye, in order to avoid any tendency to twist the cable.

5. Cable reels shall be set-up in tandem so that cable may be fed into the raceways without changing direction of bend. Supply reels shall be turned while pulling cable to assist in reducing tension. Crossovers or kinks, which can increase pulling tensions and result in damage to conductors or insulation, shall be avoided.

6. Cable shall not be pulled by the conductors, unless contaminants and moisture can be sealed out of the cable. Where pulling grips are used, damaged ends shall be removed as soon as cable has been installed. Cable ends shall be sealed with heat shrink end caps at conclusion of pulling. Temporary cable tags shall be attached to the cable as soon as it is pulled.

7. All conductors shall be installed in conduit at the same time. Wire or cables must be grouped or bundled and fed directly into conduits, shall not be individually removed from a conduit, and shall not be pulled into a conduit that already contains conductors.

8. Cut ends of cable, whether on reels or in raceways and/or cable tray, shall not be allowed to remain exposed. Whenever a cable is cut, the ends shall be sealed by heat shrink end caps and taped to prevent entrance of dirt and moisture before permanent connections are made.

9. If the Contractor observes manufacturing defects in cable being pulled, such cable shall be replaced.

10. All lubricants shall be removed from the cable in the pullboxes and vaults after pulling-in is complete.

11. All wire or cable that has been removed from raceways, cable trays, or equipment once installed is regarded as used and defective material and shall immediately be removed from the job site. This work and the related re-installations costs shall be performed by the Contractor at no additional cost.

C. Cable Supports in Vertical Runs:

1. Methods of support and maximum spacing for vertical conductor supports shall be as specified in the NEC, as specified by the cable manufacturer, or as indicated on the Contract Documents.
grips may be used. Under no circumstances shall the terminals, to which it is connected, solely support the cable.

D. Cabling in Vaults and Pullboxes:

1. Furnish and install cable racks, cleats, and supports to rack and anchor the cables in the pullboxes and vaults as required in Section 34 20 52 – Traction Electrification Interface Requirements, or as specified on the Contract Documents.

2. When installing cable, sufficient slack shall be left in each vault and pullbox to allow for proper racking around the vault and pullbox. Cable shall be temporarily supported until it can be shaped into its final location on racks or hangers. Shaping shall be done as soon as cable pull has been completed, leaving 6 inches of straight cable out of raceway before shaping to racks.

3. Unless the Contractor can demonstrate to the Authority the pull tensions adhere to the wire/cable manufacturer’s requirements, wire and cable shall not be pulled through vault or pullbox. Cable shall not be pulled in two directions from a vault or pullbox, unless the cable vault or pullbox cover opening is equal to 24 times the diameter of the cable. Establish that the cable can be installed without exceeding the cable minimum bending radius.

4. Cables shall be trained as close to the vault or pullbox walls as possible and retain the minimum cable-bending radius. Cable racks shall be adjusted for optimum support of cables and splices. Racks shall be added as necessary so that each splice is supported by two racks, one on either end of the splice. Cables shall be securely fastened to the racks using wire ties or wire clamps, 1/4 inches or larger.

E. Installation of Cable in Conduit with Power Winches:

1. In determining whether to install conductors in conduit by hand or with power winches, factors to be considered include the size and weight of conductors, length of conduit run, and installation requirements of the Contract Documents.

2. Power pulling equipment, including the power winch, rope, sheaves, mandrels, baskets, and attachments, shall be manufactured for the purpose of pulling wire, and shall be by Greenlee, or approved equal. The winch shall be equipped with a pulling tension device to accurately and continuously monitor the tension. Conductors shall not be pulled with winches that utilize metallic cable or wire rope for pulling, or winches that are not made exclusively for conductor installation.

3. A set-screw mandrel type device or a basket grip type device manufactured for the purpose shall be used to attach the cable to the pulling rope. Attachment by other means is not permissible. A swivel
shall be placed between the pulling rope and the device used to grip the wire or cable.

4. Cable reels shall be free from damage and turn freely. The cable reels shall be mounted level on reel jacks, and positioned for the removal of cable by hand. Adequate means shall be provided to prevent physical contact of wire and cable with abrasive surfaces such as the edges of manholes and conduit ends. Pulleys and sheaves may be used to direct the wire or cable into conduits; however, the diameter of the pulleys shall not be smaller than the minimum conductor-bending radius.

5. Develop a cable installation plan for each conduit run where cable is to be installed using power winches, and address the following considerations:
   a. Cable pulling calculations, including calculated maximum permissible tensions for the exact cable to be installed as required in other Sections of the Contract Documents
   b. The equipment set-up including sheave and reel diameters and installation methods, including methods to protect cable during installation

6. Pulling tension shall be continuously monitored for each pull, and the maximum values recorded and retained. Pulling tension shall not exceed the manufacturer's recommended values for longitudinal tensions and sidewall pressure, as determined by actual pulling calculations.

7. Pulling shall be done at a constant velocity, and the pay-off reel shall be tended throughout the pull. Once a wire or cable pull is started, it shall proceed without stopping until completion.

8. Bending radius during installation, including pulleys and sheaves, shall not be less than 12 times the wire or cable diameter. The cable shall be fed straight into the duct in the pay-off vault or pullbox and straight out of the duct at the pulling vault or pullbox.

3.06 INSTALLATION OF 750-VOLT CONDUCTORS NO. 2 AWG AND SMALLER
   A. Conductors No. 2 AWG and smaller may be installed using a spring steel tape and pulled in by hand.

3.07 IDENTIFICATION OF CABLE AND WIRE
   A. Reference Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods, for additional requirements.
   B. All cables shall be identified at both ends and in each enclosure, box, pullbox, and vault with identifiers as specified on the Contract Documents. In addition, all ac main feeders, 240 volts or higher, shall be identified as to phase.
C. Tags for identification of individual cable conductors and field-installed wires within equipment cabinets shall be the sleeve type as manufactured by Raychem Corporation, Thermofit Marker System (TMS) or approved equal. The application of the conductor nomenclature shall be in accordance with the manufacturer's instructions and shall result in a permanently bonded and legible identification.

D. Feeder Identification Markers: Fungus and water resistant, self-laminating vinyl, with opaque blank write-on section.

E. Control Wire and Cable Identification Markers: Fungus and water-resistant, factory-printed, self-adhesive vinyl, with printing protected by clear, permanent overcoat.

F. Tags for identification of multi-pair or multi-conductor cables shall be the flat plastic laminated types. Tags shall be 1-1/2 inches long by 3/4 inch wide with one, 5/16 inch hole located in the center of the width. The untreated tag shall be milk white “vinylite”, or approved equal.

G. The identifying nomenclature space shall allow for three rows of lettering, and the tag material shall be capable of receiving typed-on characters by conventional means. The height of the lettering shall not be less than 1/8 inch.

H. After lettering, both the face and backside of the tag shall be covered with a clear plastic coating, vinylite, or approved equal.

3.08 750-VOLT SPLICES AND TERMINATIONS

A. Soldering of conductors is not permitted.

B. All wire shall be continuous from box to box and outlet to outlet. Splices shall be made only in outlets, boxes, and pullboxes.

C. No splices or taps shall be permitted in service feeder conductors. Splices or taps in branch circuits or feeders will be permitted only in outlet, pull, or junction boxes.

D. When splicing or terminating the conductor, remove the conductor insulation without injury to the conductor. When terminating in lugs, leave the insulation intact up to terminals. Conductor insulation shall butt to the lug shoulder without exposed conductor showing.

E. Where conductors No. 8 AWG or larger are to be connected to any apparatus, bus work, switch, or fuse blocks, they shall be connected by means of compression type lugs, unless otherwise indicated. All lugs shall be permanently bolted to give maximum contact surface.

F. Compression splices and terminations shall be installed in accordance with the manufacturer's recommendations. Splices and terminations for conductors No. 2 AWG and below may be made with a mechanical indenter tool. Splices and terminations larger than No. 2 AWG shall be
made with a hydraulic hexagonal jawed tool, as manufactured by Thomas and Betts, or equal.

3.09 COLOR CODING
A. All wiring shall be color coded as follows:
   1. 208Y/120 or 120/240 volt systems shall be A-phase black, B-phase red, C-phase blue, neutral white, ground green.
   2. 480Y/277 volt system shall be A-phase brown, B-phase orange, C-phase yellow, neutral gray, and ground green striped.
   3. Wires 6 AWG and smaller shall be color-coded by using wire insulation of the designated color.
B. Use color code single-conductor control wires as follows:
   1. 480/277 volt circuits, blue with yellow tracer
   2. 208/120 volt circuits, yellow with blue tracer
C. Color code multiple-conductor control wires in accordance with NEMA WC5 and ICEA.
D. Solid color coatings and tracers shall be a strongly adherent paint or dye not injurious to the insulation, which will not be obliterated by pulling into a conduit or raceway.
E. On-site coloring of ends of conductor may be permitted by the Authority upon receipt of satisfactory evidence that the Contractor is unable to obtain color-coded wire and cable as specified. Certification shall be provided from the cable manufacturer that the paint or dye proposed for field application is durable and noninjurious to the insulation.

3.10 TEST REQUIREMENTS
A. After field wiring has been pulled in place and terminations to equipment and devices have been completed, ensure that the installed wiring is correctly installed, and verify the absence of open circuits, short circuits, ground connections, and insulation failure by performing continuity and insulation tests. These tests shall be performed and test sheets submitted to the Authority before energization of the equipment. The test sheets shall list each wire by unique designation and equipment to which it is connected. The test sheet shall list the location of the test, include the date, and be signed by the test engineer to certify that each wire is tested successfully.

3.11 CLEANING
A. Comply with the requirements as specified in General Conditions for Cleaning, Closeout Procedures and Section 34 05 00 – Traction
Electrification Basic Electrical Materials and Methods, and elsewhere on the Contract Documents.

END OF SECTION
SECTION 34 30 30
TRACTION ELECTRIFICATION YARD DC DISTRIBUTION SWITCHBOARDS

PART 1 – GENERAL

1.01 SUMMARY

A. Description:
   1. The Work of this Section consists of furnishing, installing, and testing the DC Distribution switchboard for the Traction Electrification System (TES) for the Expo Rail Operations and Maintenance Facility (OMF) as indicated on the Plans and specified herein.
   2. The Yard switchboard is located in the OMF rail yard.

B. Section Includes:
   1. Installation
   2. Wiring and Conduit Work
   3. Components Installation
   4. Field Painting
   5. Testing
   6. Cleaning

C. Related Sections:
   1. Section 26 05 00 – Basic Electrical Materials and Methods
   2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
   3. Section 34 20 18 – Traction Electrification Grounding Requirements
   4. Section 34 20 52 – Traction Electrification System Interface Requirements
   5. Section 34 21 40 – Traction Electrification Blue Light – ETS
   6. Section 34 30 10 – Traction Electrification Shop DC Distribution System
   7. Section 34 30 25 – Traction Electrification Cable and Wire
   8. Section 34 30 35 – Traction Electrification DC Positive and Negative Feeder Cables
   9. Section 34 30 40 – Traction Electrification Testing and Commissioning
1.02 REFERENCES
Comply with the requirements as specified in Section 34 05 00 – Traction Electrification Basic Materials and Methods and Regulations of Jurisdictional Authorities.

1.03 PERFORMANCE REQUIREMENTS
A. Qualification – Products to be of manufactures who have been engaged in production of similar products for a minimum of 5 years.
B. Comply with the requirements as specified in Section 34 20 52 – Traction Electrification System Interface Requirements.
C. Shop production test shall be performed on components and assemblies and certified by manufacturer.

1.04 SUBMITTALS
A. General: Refer to General Conditions, for submittal requirements and procedures.
B. Submittals shall include shop drawings (layouts, schematics and wiring), product data such as catalog cuts and manufacturer’s literature, design calculations, and where appropriate, product samples.
C. Installation Drawings – Submit installation drawings including:
   1. Setting diagram, if anchoring in concrete is required
   2. Erection or assembly drawings, if shipped in sections or if any parts are not installed at the factory
   3. Interconnection diagrams
D. Submit equipment identification nameplate sample, including legend.
E. Submit list of identification nameplate legend.
F. Submit certified test reports stating compliance of products with the specified requirements.
G. Submit field test procedures and copies of certified field test reports.
H. Operation and Maintenance Data: Submit such data in accordance with the requirements of the applicable Specifications Section, and include the following:
   1. Manufacturer’s operating and maintenance instructions parts list, illustrations, and diagrams for components
2. List of recommended spare parts and special tools required

1.05 QUALITY ASSURANCE

A. General: Refer to General Conditions, for quality assurance requirements and procedures.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Materials shall be securely wrapped, packaged, and labeled for safe handling in shipment and storage to avoid damage.

B. Temporary Bracing: Brace and Package the dc switchboard to permit hoisting, lowering and skidding into position. Clearly label temporary bracing of equipment as “TEMPORARY BRACING: TO BE REMOVED BEFORE OPERATION”.

PART 2 – PRODUCTS

2.01 INTERCHANGEABILITY

A. All components of the same type, rating, and functional characteristics shall be interchangeable.

2.02 VOLTAGE AND CURRENT RATINGS

A. Voltage for the 750-volt dc traction power electrical equipment and components shall be 1,000 V dc nominal, with a 1-minute ac withstand capability of at least 3.7 kV rms, insulation level, with the capability of sustaining, without deterioration, spikes to 3,000 volts dc.

B. Where not otherwise specified, components shall be as specified in Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods.

C. Current ratings shall be as specified herein, or as indicated on the plans.

2.03 NAMEPLATES AND MARKING

A. Standard Nameplates:

1. Each item of equipment shall be furnished with a manufacturer’s nameplate. Nameplates shall provide the manufacturer’s name and address, equipment type, and designation number, and the required electrical characteristics called for in the applicable ANSI and NEMA standards.

B. Special Nameplates:

1. Identification nameplates shall be furnished for all equipment. Nameplates shall consist of three-ply, laminated, rigid plastic plate
engraved through black face to white core, and attached to panels by machine screws or stainless steel rivets.

2. Switchboard nameplates shall be inscribed with equipment function identification in 1-inch high characters. Nameplates for control and metering devices shall be inscribed with 1/3-inch high characters.

2.04 DC POWER SWITCHBOARD

A. General:

1. Furnish totally enclosed dc switchboard (Yard) to provide means for controlling dc positive power circuits and to provide a negative return connection to the running rails as indicated on the plans.

2. The switchboard shall be factory pre-assembled, and at a minimum shall contain the specified switching and control equipment, and meet the requirements of the Contract Documents.

B. Enclosure:

1. Switchboard enclosure shall be freestanding, dead front, and designed for outdoor use to NEMA 250, Type 3R. The enclosure shall be fabricated from molded, impact-resistant and fire-retardant fiberglass-reinforced polyester, having 1/4-inch minimum thickness. Minimum tensile strength shall be 1,500 pounds per square inch and maximum water absorption shall be 0.65 percent in 24 hours. Surface color shall be ANSI Z55.1, No. 61 (light grey). Additionally, the exterior surfaces shall be given a protective coat of clear polyester gel. The enclosure shall be sufficiently rigid to support all equipment in the individual compartments, and terminated cables under all normal operating loads and switching conditions.

2. Exterior hardware shall be stainless steel or non-ferrous metal. Doors shall be fastened to the enclosure with continuous steel hinges, providing a minimum 120-degree swing opening, and shall be furnished with a doorstop at the fully open position. Doors shall be gasketed and held closed by a three-point latch, with chrome-plated cast steel operating handle. The handle shall have provisions for padlocking in the closed position.

3. Enclosure shall be designed to permit lifting by jacks and slings, and be moved horizontally on rollers or skidded in any direction.

4. Insulated barriers shall be furnished between each fused switch and the enclosure shall have no exposed grounded parts inside. The switchboard enclosure shall be provided with conduit hubs, for entry of power and control cable. Exact enclosure dimensions and provisions for conduit interfaces, shall be coordinated with the design of the external dc distribution system and the field installation requirements.
5. Non current-carrying exposed metallic parts shall be made electrically continuous by flexible copper insulated conductor, color green, of no less than No. 10 AWG size, connected to a tinned-copper terminal block.

C. Bus:

1. A dc positive bus shall be furnished as indicated on the plans, and shall be made of electrical grade copper complying with ASTM B187. Bus bracing shall be rated for a momentary current of not less than 100 kA, rms.

2. Bolted bus connections, including bus taps, shall be silver-plated. Clamping bolts shall be cadmium-plated, or similarly coated, high-strength steel. Clamping system shall ensure that adequate pressure is maintained under repeated thermal cycling over the life of the switchboard.

D. DC Disconnecting Switches:

1. The dc disconnecting switches in the switchboard shall be no-load, single-pole, single-throw, and bolted-pressure type with manual front operator. The switches shall be designed, manufactured and tested in accordance with the applicable requirements of ANSI C37.41 and ANSI C37.45.

2. Switches shall have continuous current ratings as indicated on the plans, without exceeding 122 degrees Fahrenheit rise above a maximum ambient temperature of 104 degrees Fahrenheit and shall have a certified momentary current rating of not less than 100 kA, rms.

3. Switch’s moving and stationary contact surfaces shall be silver plated copper. All other current-carrying parts shall be of electrical grade copper or copper alloy. Contacts shall be self-aligning, wear compensating, and with initial wiping action. Hinge and jaw contacts shall be bolted pressure type, with non-ferrous or stainless steel self-clamping mechanism, or other approved high-pressure type contact arrangement.

4. Each switch shall be furnished with an insulated manual operating handle, externally mounted. Handle positions corresponding to OPEN and CLOSED status of switch contacts shall be shown by corrosion-resistant nameplates, permanently secured to the enclosure.

E. Wiring and Terminals:

1. Instrument and control wiring shall be stranded copper and not smaller than No. 14 AWG, with 1,000 V minimum, NFPA 70 Type SIS insulation. Control wires exposed to the 750 V dc potential shall be rated for 2,000 volts, and shall be different color compare to those used for low-voltage power and control. Insulation shall pass the flame
propagation criteria and flame test of IEEE Standard 383. Wire that crosses hinged panels or joints shall be Class C, minimum, stranded copper wire to ASTM B8. Each conductor shall be continuous without splices or taps from terminal to terminal. The wire ends shall be permanently fitted with ring type wire lugs for attachment to terminal studs.

2. All interconnecting circuit wiring between switch board units and compartments shall terminate at terminal blocks before being connected to devices. All interconnecting wiring across shipping sections shall be terminated at split terminal blocks. All switchboard internal wiring shall be installed, connected, and tested before shipment.

3. Provision shall be made for external cables and wiring to enter the switchboard as indicated on the Design Plans. Top entrances shall be provided with removable cover panels for field drilling of conduit or cable bush holes.

4. Internal wiring shall be identified at each termination with the equipment manufacturer’s wire number by means of a suitable plastic sleeve, with imprinted wire identification as shown on the manufacturer’s wiring diagram.

5. Terminal blocks shall comply with the requirements of NEMA ICS4, and shall be of the screw type with washer style head to accommodate ring-type wire connectors. Bases and inter-terminal barriers shall be of molded heavy-duty insulating compound of sufficient size to accommodate terminals for No. 10 AWG wire. The metallic parts shall be nonferrous and corrosion-resistant.

6. Terminal blocks shall be identified using proper labeling. Terminals for external wiring connection shall be grouped according to purpose and direction. Each terminal block shall be provided with minimum of 20 percent spare terminal points.

PART 3 – EXECUTION

3.01 INSTALLATION

A. Install, wire, connect, and test DC Distribution switchboard complete and ready for operation in accordance with these Specifications, manufacturer’s instructions, and as shown on the plans.

3.02 WIRING AND CONDUIT WORK

A. Install in accordance with Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods.
3.03 COMPONENTS INSTALLATION

A. Install traction power system components, specified herein, at the locations shown on the plans; secure, plumb, and level in true alignment with related adjoining work.

B. Furnish anchor bolts and anchorage items, where required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the jobsite to ensure correct placing of anchorage items.

C. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles, as required, to set and rigidly connect the work.

D. Provide temporary bracing, guys, or other devices, as required, to accomplish erection and to provide safety and stability until all work is in final position and approved.

E. Control placement and erection tolerance requirements so as to maintain strength, safety, serviceability, and appearance.

F. Repair or replace items damaged during installation to the satisfaction of the Authority at no additional cost.

3.04 FIELD PAINTING

A. After installations are complete, thoroughly clean all surfaces where shop paint is missing or abraded, all bare steel, including bolts, nuts, washers, and welds, and paint each item to match the original.

B. Galvanized materials that are scratched, cut, or in other manners have their protective coatings penetrated or damaged, shall be field coated with cold liquid galvanizing to the strength and finish of the original coating.

3.05 TESTING

A. Perform the following field tests:

1. Check insulation resistance to ground for all power circuits with a megohmmeter (megger).
   a. 120 V ac systems: at 1,000 V
   b. Traction power cables: megger test at twice the installation voltage level (4 kV) for approximately 5 minutes

2. Check circuit continuity using a low resistance ohmmeter.

3. Test operation of each disconnect switch including operation of solenoid-operated lock.
B. Provide qualified personnel with all tools, test equipment, and other required items to perform the testing. The Authority shall have qualified witnesses present at each test to observe the test and certify the recorded results.

C. Furnish written notice as to when all installed electrical equipment will be tested so that the Authority may be present to witness the test. A minimum of 10 days prior notice of proposed test shall be given.

D. Prepare and submit test procedure for each test a minimum 30 days before the test date. The procedures shall detail step-by-step test requirements and connections of test equipment and instrumentation.

E. At the Authority option, a representative of the manufacturer may be present.

F. The tests shall not alter the Authority guarantee of work and materials. All work and materials found to be in noncompliance with the Contract Documents shall be replaced and retested by the Contractor.

G. Submit certified test reports for each test within 15 days after the successful completion of the test. Reproducible test data sheets shall be kept showing the results of all tests. The reproducible data sheets shall list both the acceptable or specified test limits, and the values actually measured. One copy shall be furnished to the Authority. One copy shall be retained by the Contractor. Data sheets shall show the test set-up, the equipment used, the names of persons performing the test, the names of witnesses, the date, the location, and the serial number of the equipment under test. The test data sheets shall be reviewed by the Authority and may be accepted as submitted or additional test may be required. If additional tests are required, the Contractor shall include these test data with other data sheets.

3.06 CLEANING

A. Comply with the requirements as specified in General Conditions for Cleaning, Closeout Procedures and Section 34 05 00– Traction Electrification Basic Electrical Materials and Methods, and elsewhere on the Contract Documents.

END OF SECTION
SECTION 34 30 35
TRACTION ELECTRIFICATION DC POSITIVE AND NEGATIVE FEEDER CABLES

PART 1 – GENERAL

1.01 SUMMARY

A. Description: The Work of this Section includes the requirements for furnishing, testing, and installing the DC positive and negative feeders and associated splices and terminations for the Traction Electrification System (TES) for the Expo Rail Operation and Maintenance Facility (OMF) as specified on the Contract Documents and as specified herein.

B. Section Includes:
   1. Installation Requirements for DC Positive and Negative Feeder Cables

C. Related Sections:
   1. Section 26 05 00 – Basic Electrical Materials and Methods
   2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
   3. Section 34 20 18 – Traction Electrification Grounding Requirements
   4. Section 34 20 52 – Traction Electrification System Interface Requirements
   5. Section 34 21 40 – Traction Electrification Blue Light – ETS
   6. Section 34 30 10 – Traction Electrification Shop DC Distribution System
   7. Section 34 30 25 – Traction Electrification Cable and Wire
   8. Section 34 30 30 – Traction Electrification DC Distribution Switchboards
   9. Section 34 30 40 – Traction Electrification Testing and Commissioning
   10. Section 34 81 00 – Traction Electrification Remote Terminal Unit

1.02 REFERENCES

A. ASTM International (ASTM):
   1. ASTM B8 Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

3. ASTM D2802 Standard Specification for Ozone-Resistant Ethylene-Alkene Polymer Insulation for Wire and Cable

B. National Electrical Manufactures Association (NEMA):
   1. NEMA WC 70 Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy

C. Underwriters’ Laboratories, Inc. (UL):
   1. UL 1581 Reference Standard for Electrical Wires, Cables and Flexible Cords

D. Federal, State, and Local Authorities: All applicable codes and regulations.

E. Materials and components manufactured to applicable foreign standards, including metric standards, are acceptable, provided that the Contractor submits written evidence, in the English language, that they are equal or superior to those complying with the standards listed above, and written approval is obtained from the Authority. Weights and dimensions shall be converted to English units.

1.03 SUBMITTALS

A. General: Refer to General Conditions, for submittal requirements and procedures.

B. Submit the following:
   1. Shop drawings
   2. Catalog cuts
   3. Factory test reports
   4. Field test reports
   5. For all items covered under this Section

PART 2 – PRODUCTS

2.01 GENERAL

A. Cable construction standards, definitions of terms, and conductor insulation shall be in strict accordance with applicable publications of ICEA for the cable provided. Insulated feeder cables shall have Class D and Class H stranding as noted. Conductors for insulated feeder cables shall be copper.
B. The feeder cable selected shall be coordinated with the sizes of conduits installed under this and other Contracts to avoid potential jamming of three single cables during pulling of cables. The jam ratio calculations shall substantiate that the selected feeder cable is not susceptible to jamming.

2.02 MATERIALS

A. DC Feeder Cable:

1. Description: Insulated feeder cable shall be copper, with ethylene-propylene rubber insulation, 2,400 volts unshielded, as indicated.

2. Conductors: Conductors for insulated feeder cable shall be coated, soft drawn copper, complying with ASTM B8 and B189, covered with a double wrapped separator tape.

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Voltage Rating</th>
<th>Stranding</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/0 AWG</td>
<td>2400</td>
<td>Class H</td>
<td>Copper (Feeder Cable)</td>
</tr>
<tr>
<td>750 Kcmil</td>
<td>2400</td>
<td>Class H</td>
<td>Copper (Feeder Cable)</td>
</tr>
<tr>
<td>500 Kcmil</td>
<td>2400</td>
<td>Class H</td>
<td>Copper (Negative Return Cable)</td>
</tr>
</tbody>
</table>

3. Insulation: Cable shall be insulated with low-smoke, flame-retardant, ozone-resistant, ethylene-propylene rubber compound, complying with ASTM D2802 and ICEA S – 95- 658, and rated for 194 degrees Fahrenheit operating temperature and 230 degrees Fahrenheit hot spot. The minimum insulation thickness shall be 90 mil, Ethylene-Propylene Rubber.

4. Jacket: Low-smoke, UV resistant, flame-retardant, ozone-resistant, non-halogen, polyolefin thermosetting compound, meeting the flame test requirements of UL 1581 and IEEE 383. Minimum jacket wall thickness shall be 65 mils.

5. Shielding: Shielding is not required.

6. Cable Identification: The following information shall be printed on jacket, using contrasting color ink, at not more than 2-foot intervals:
   a. Manufacturer’s name
   b. Year of manufacture
   c. Conductor size
   d. Voltage rating
   e. Insulation type and thickness

B. Jacket type and thickness.

2.03 TESTING

A. Prior to Shipment: The standard dielectric withstand tests shall be performed on each reel of cable prior to shipment. A certified copy of the
test report for each reel of cable shall be furnished to the Authority prior to shipment. A copy of the test report shall also be packed with each reel. Test voltage and insulation test requirements shall be in accordance with ICEA S-68-516 and ICEA S-95-658.

B. After Installation: Prior to installing lugs, undertake a standard dielectric withstand tests on each of the DC positive and negative feeder cables. A certified copy of the test report for each cable shall be furnished to the Authority for review and approval. Test voltage and insulation test requirements shall be in accordance with ICEA S-68-516 and ICEA S-95-658.

2.04 REELS AND PACKING

A. Reels shall be constructed of good materials, and shall afford proper protection to the cable during shipment and handling.

B. A watertight seal shall be applied to each end of the cable to prevent the entrance of moisture during transit or out-of-door storage.

C. A durable label shall be securely attached to each flange of each reel. Each label shall indicate the purchase order number, name of manufacturer, reel number, length of cable on reel, description of cable, weight of reel and rolling direction, and source of manufacture.

PART 3 – EXECUTION

3.01 INSTALLATION REQUIREMENTS FOR DC POSITIVE AND NEGATIVE FEEDER CABLES

A. Additional installation requirements for the insulated DC positive and negative cable are specified in Section 34 05 00 – Traction Electrification Basic Methods and Materials and Section 34 30 25 – Traction Electrification Cable and Wire.

B. .Adhere to the following unique requirements that relate to negative feeder cables only:

1. Coordinate the negative return cable installation at impedance bond and rail connection locations with the signaling system contractor.

C. Adhere to the additional requirements and specifications of the Related Sections listed by reference in Article 1.01C herein.
PART 1 – GENERAL

1.01 SUMMARY

A. Description:

1. The Work of this Section includes the requirements for the field testing and commissioning of the Traction Electrification System (TES) for the Expo Yard Operations and Maintenance Facility as indicated on the plans and specified herein.

2. Planning, carrying out, and documenting all field tests concerning the TES as required in these Specifications and for providing personnel, equipment, and assistance for the Systems Integration Testing.

3. Furnish all tools, testing equipment, and accessories required for the tests performed by the Contractor.

4. The test equipment shall remain the property of the Contractor and shall be used by the Contractor and Contractor-appointed personnel. All responsibility of the field-test equipment shall be the Contractors.

B. Section Includes:

1. General
2. Field Service Engineer
3. Installation Verification Tests
4. Systems Integration Test Support
5. Special Tests
6. Acceptance Records

C. Related Sections:

1. Section 26 05 00 – Basic Electrical Materials and Methods
2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
3. Section 34 20 18 – Traction Electrification Grounding Requirements
4. Section 34 20 52 – Traction Electrification System Interface Requirements
5. Section 34 21 40 – Traction Electrification Blue Light – ETS
6. Section 34 30 10 – Traction Electrification Shop DC Distribution System
7. Section 34 30 25 – Traction Electrification Cable and Wire
8. Section 34 30 30 – Traction Electrification DC Distribution Switchboards
9. Section 34 30 35 – Traction Electrification DC Positive and Negative Feeder Cables
10. Section 34 81 00 – Traction Electrification Remote Terminal Unit

1.02 PRICE AND PAYMENT PROCEDURES
A. General: Separate measurement of payment will not be made for the Work required under this Section. All costs in connection with the Work specified herein will be considered included with the related item of work in the General Conditions, or incidental to the Work.

1.03 REFERENCES
A. American National Standards Institute (ANSI):
   1. ANSI C37.14 Low-Voltage DC Power Circuit Breakers used in Enclosures
   2. ANSI C37.16 Preferred Ratings, Related Requirements and Application Recommendation for Low-Voltage Power Circuit Breakers and AC Power Circuit Breakers
   3. ANSI C37.17 Trip Devices for AC and General-Purpose DC Low-Voltage Power Circuit Breakers
   4. ANSI C37.21 Switchgear Assemblies Including Metal-Enclosed Bus
   5. ANSI C37.100 Definitions for Power Switchgear
   6. ANSI C57.12.91 Test Code for Dry-Type Distribution and Power Transformers
   7. ANSI C57.13 Requirements for Instrument Transformers

B. Institute of Electrical and Electronic Engineers (IEEE):
   2. IEEE 81 Guide for Measuring Ground Impedance of a Ground System
C. National Electrical Manufacturers Association (NEMA):

1. NEMA BU I  Busways
2. NEMA EI 2  Instrument Transformers
3. NEMA SG 3  Low Voltage Power Circuit Breakers
4. NEMA SG 5  Power Switchgear Assemblies
5. NEMA SG 6  Power Switching Equipment
6. NEMA TR 1  Audible Sound Levels for Dry Type Transformers
7. NEMA WC 3  Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81)
8. NEMA WC 8  Ethylene-Propylene-Rubber-Insulated Wire and Cable

1.04 SUBMITTALS

A. General: Refer to General Conditions, for submittal requirements and procedures.

B. Field Service Engineer: Submit the following concerning the field service engineer:

1. Resumes of the field service engineer and supporting personnel. Submit a resume for each individual nominated a minimum of 120 days prior to the approved scheduled date for the commencement of job duties.

2. Field service engineer's logs.

C. Test Documents: Submit a Test Program Plan, test procedures, and test reports concerning all field tests specified herein. Test Plan shall include step by step procedures to verify all equipment and connections made by this Contractor integrate into the TES including the TPSS furnished and installed by others. Submit test documents for approval 60 before the planned start of any testing. Provide 15 days’ notice for any testing be conducted. Test documents shall be in accordance with the requirements of Section 34 05 00 – Traction Electrification Basic Materials and Methods.

1.05 QUALITY ASSURANCE

A. General: Refer to General Conditions for quality assurance and procedures.

B. Perform the Work included in this Section in accordance with the requirements of the Contractor’s Quality Control Program, as approved by the Authority.

C. Perform the following:
1. Material qualification testing and certification for acceptance of materials, components, and assemblies.

2. Job control testing of in-progress work being performed in shops, factories, and on-site.

3. On-site inspection of specified work elements.

PART 2 – PRODUCTS

2.01 MATERIALS

A. General

1. Provide all tools, instruments, calibration devices, meters, and other equipment necessary to connect, monitor, adjust, and carry out the field tests.

2. Provide spare parts as required to conduct the start-up and testing of the TES.

3. Furnish all other equipment and personnel services necessary to test and commission the TES, including participation in Systems Integration Testing.

PART 3 – EXECUTION

3.01 GENERAL

A. This Section covers the requirements for field tests to be performed by the Contractor on the TES and associated equipment, materials, and accessories, furnished under this Contract.

B. Coordinate sequence of installation verification tests with the Authority. Ensure that all tests for the TPSS and other equipment have been completed and approved by the Authority if required for installation verification tests to be completed.

C. Coordinate all field tests with the Authority. If aspects of the installation of the traction power equipment or the test setup are not in accordance with the installation instructions, it shall immediately be brought to the Authority's attention.

3.02 FIELD SERVICE ENGINEER

A. Provide the services of a qualified field service engineer at the project site, to assist as required during startup, final inspection, TPSS-field testing, other systems testing, and Systems Integration Testing.

B. Following approval to proceed, the field service engineer shall notify the Authority of traction power system energization and start-up.
C. The field service engineer shall have a thorough knowledge of the TES and the installation, start-up, and testing requirements for all components and systems furnished under this Contract.

D. The field service engineer shall be available on site 5 working days after notification. Weekly logs shall be maintained and submitted. Logs shall show tasks performed with dates and duration.

3.03 INSTALLATION VERIFICATION TESTS

A. Field installation of the TES equipment and materials shall be subjected to installation verification inspections and tests on completion of the Work. The installation verification tests shall be carried out in accordance with detailed and pre-approved procedures, considering the types of tests involved. In the case of functional tests for example, after successfully testing each function, the function shall be checked off on the applicable control schematic with a yellow marker and on the detailed step-by-step test procedure. The following field tests shall be performed on the TES following completion of the installation:

1. Equipment Assembly Inspection: Verify that the assembled on-site equipment, components, bus, and accessories are correctly installed and labeled in accordance with approved shop drawings.

2. Grounding Connections Inspection: Verify that all grounding connections of equipment and enclosures are in place and are properly made.

3. Circuit Continuity Tests: Verify the continuity of all power and control circuits between the substation and the external system. In conjunction with the continuity test, check whether the wiring connections match those on the approved shop drawings.

4. Functional Tests: Perform functional tests on all equipment, devices, and circuits including relays, annunciator panel, and switchgear controls to verify that they function in accordance with the final approved control schematics and meet the requirements of these Specifications.
   a. Control circuits shall be tested prior to the operational tests with the controls energized, but with the controlled equipment and devices disconnected or otherwise made inoperable.
   b. For these tests, the control functions shall be checked for proper operation by actuating each contact that initiates a control operation and then following the control sequence through the various affiliated devices to ascertain that the correct results are obtained for each condition of interlocking.
   c. The actuating of contacts, as required to initiate an operation and to set up the interlocking conditions, shall be performed by simulating operating conditions.
d. All alarms of the annunciator panel shall be tested for correct indication by simulating each alarm condition at the equipment end.

3.04 SYSTEMS INTEGRATION TEST SUPPORT

A. Provide labor, tools, and vehicles to support Authority-led systems integration testing. The cost of providing System Integration Test Support shall be paid by the Authority. The systems integration tests shall be performed to verify the proper operation and performance of TES provided as part of this Contract, as well as the systems provided by others, such as TPSS, shop tracks, Passenger Vehicle, local and remote alarms, controls, indications and communications. Systems integration tests may include:

1. LRM Vehicle-related tests
2. Yard Control Tower/communication system interfaces with the TPSS
3. End to End SCADA tests
4. Energization tests
5. OCS Section proving and verification
6. TPSS short circuit tests
7. TPSS performance tests
8. OCS burn in tests

B. Testing support shall include:

1. Provision and connection of testing equipment in accordance with a specific test plan to be provided by others, or developed in coordination with the Contractor.
2. Operation of substation equipment (in accordance with the procedures and instructions of a specific test plan).
3. Witnessing the testing.
4. Disconnecting testing equipment when testing is completed.
5. The minimum personnel and vehicle requirements in support of systems integration testing shall be:
   a. 1 – Field Engineer
   b. 2 – Electricians
   c. 1 – Vehicle, pick-up truck

C. Advise the Authority regarding test procedures, analysis of results, and recommended correction actions.
3.05 SPECIAL TESTS

A. Special tests may be called for, at the discretion of the Authority, on equipment provided under the Contract. Special tests shall be performed to verify compliance of the equipment and components with the Contract Documents. The cost of such special tests required by the Authority on equipment or components that are proven to comply with the Contract Documents will be at the expense of the Authority. The cost of special tests on equipment or components that are proven not to comply with the Contract Documents shall be borne by the Contractor and shall be at no expense to the Authority.

3.06 ACCEPTANCE RECORDS

A. Records shall be made of all tests listed under this Section in accordance with the requirements of the Contract Documents.

END OF SECTION
SECTION 34 42 00
GENERAL TRAIN CONTROL REQUIREMENTS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. American Railway Engineering and Maintenance-of-Way Association (AREMA) Communications and Signals (C&S) Manual of Recommended Practice.

B. Related Specification Sections include, but are not limited to:

1. Section 01 10 00 – Summary
2. Section 01 33 00 – Submittal Procedures
3. Section 01 35 23 – Worksite Safety Requirements
4. Section 01 56 37 – Worksite Security Requirements
5. Section 01 78 23 – Operation and Maintenance Data
6. Section 01 78 39 – Project Record Documents

1.02 SUMMARY

A. Work covered in this Section includes, but is not limited to, final design, procurement, installation, integration, and testing to provide a compliant train control system as described in the Contract Documents and Drawings.

B. The Yard Facility shall be signaled, comprised of non-vital track circuits, powered yard-type switch machines, interlockings with home signals and train-to-wayside communications (TWC). Entrance/exit routing capability shall be designed at the facility control console, located in the control room. The train control system shall be controlled from one or more (as required) signal rooms. Solid-state interlocking equipment shall be used and shall be GE ElectroLogIXS, Alstom VPI, or AnsaldoMicrolok II, using non-vital interface cards.

C. The Yard Control Console shall be designed for N-X logic control of the yard train control system, including switch and route control and indication, track circuit occupancy indication and trouble and fault alarms and indications.

D. The Yard Facility Train Control System shall interface with the mainline on the West Side near Stewart Street, and on the East Side prior to the mainline abutment for the grade separation at Centinela Avenue.

1.03 DEFINITIONS & ABBREVIATIONS

A. Refer to the AREMA Communications & Signals Manual of Recommended Practice, Volume 1, Part 1.1.1, RecommendedDefinitions, for definitions.

B. Abbreviations

1. AC Alternating Current
1.03 SUBMITTALS

A. No work shall be performed prior to submittal to and approval by, the Engineer. Any work performed prior to submittal approval shall be at the Contractor’s risk.

B. All submittals are provided to the Authority for review and approval.

C. Preliminary Design: Submit proposed plans, procedures, data sheets of proposed materials, application logic, installation details, shop drawings, mechanical drawings, proof of compliance with applicable standards, and other pertinent data required to fully demonstrate the Contractor’s proposed plan for the manufacture, installation, testing, and maintenance until substantial completion, of the train control system. Submit for the Engineer’s approval within 60 days after Notice to Proceed.

D. Final Design: Submit documentation of the final design for the train control system. The documentation shall include apparatus tabulations, circuits, layout drawings with complete wiring details, route and aspect charts, house layouts and rack layouts. Documentation shall include application logic in ladder logic format.

E. Construction Sequencing Plan: Submit a Construction Sequencing Plan for each separate installation phase. The Plan shall contain, at a minimum, the following:
1. A narrative description of the work to be undertaken at the designated location. The narrative shall include evidence of coordination with non-train control related construction personnel, and shall show the construction activities are being performed in a logical and efficient manner. The plan shall reflect an integrated construction plan such that non-train control and train control construction activities do not interfere with, prevent, undo or otherwise impinge on each other. The Contractor is responsible for correct sequencing and shall not be compensated for work that has to be removed and repeated to accomplish a requirement not previously included in planning. This includes improper planning in procurement of materials.

E. Circuit drawings indicating any required modifications to new systems or existing circuits where only a segment of the new work can be completed or the complete system must be placed in operation in phases. Submit these temporary interface drawings for the Engineer’s approval, a minimum of 30 days prior to the scheduled cutover.

1. Revisions to existing circuit plans shall use the "X's" and "O's" convention to show changes. Encircling the change with “X’s” shall identify deletions. Encircling the change with “O’s” shall identify additions. The Contractor may, with the prior approval of the Engineer, alternately use the "Red In"/"Yellow Out" convention if Contractor provides seven colored copies of the drawing.

F. Detailed test plan, detailed test procedures, test data, and final test reports as detailed in this and other specifications.

G. Request approval from the Engineer prior to making any deviation, modification, or changes to the approved design drawings. During the field testing/cut-over period, obtain the approval of the Engineer’s representative on site for any deviations, changes, or modification to the design drawings.

H. Signal system shop drawings and design submittals shall include CADD files in MicroStationV8 or AutoCAD formats. Signal circuit drawings shall conform to Authority’s CADD standards. Submit electronic files on DVD-ROM.

I. As-Installed drawings shall include any changes made during installation and field testing. Installation drawings shall be included in the As-Installed drawing packages.

J. As-Built Drawings shall contain all documentation required for final design, and shall include all changes to the as-installed drawings made during the integrated testing.

1. As-Built drawings shall not be accepted until all punch-list items have been cleared and all Non-Compliance Reports have been resolved.
K. Any other submittal called out in the specifications.

1.04 SYSTEM DESCRIPTION
A. The Contractor shall provide all materials and installation services required for complete working train control system, as described herein, and as shown on the Contract Drawings.

B. Contractor furnished software and components shall be new and manufacturer certified. The software and components shall be designed for the application for which they are proposed. Used or remanufactured components shall not be utilized.

C. The Yard Facility shall be signaled, comprised of non-vital track circuits, powered yard-type switch machines, interlockings with home signals and train-to-wayside communications (TWC). Entrance/exit routing capability shall be designed at the facility control console, located in the control room. The train control system shall be controlled from one or more (as required) signal rooms. Solid-state interlocking equipment shall be used and shall be GE Electrologixs, Alstom VPI, or AnsaldoMicrolok II, using non-vital interface cards.

D. The Contractor will be responsible for providing the train control system from the West side of Stewart Street on the yard lead from B: 15+55 including signals Y2 and Y4, track circuit 91-03T, and TWC loops on both sides of Stewart Street which shall be used to request Stewart Street crossing activation to allow the train to enter or exit the yard. The signal for the route into or out of the yard shall not clear until verification is received that the gates are down.

E. The mainline contractor shall be responsible for all train control work between stationing B: 30+79 to B: 33+00, excluding the IJs at those locations, and any bonding to locations outside these limits. The mainline contractor shall also be responsible for the installation and programming of the TWC loops that control signals 90-8S, 90-8N, and cab loop 90-05L.

F. No circuit is considered to have met the requirements of these Specifications for function and safety until the circuit has been tested according to the Authority approved installation and integration test procedures and the test results have been submitted and approved by the Authority. Any circuit changes made to meet the function and safety requirements of these Specifications shall be considered as included as part of the Work. Such changes shall be clearly documented as part of the As-Built drawings or in a memo if not applicable to the drawing.

G. All track connections required in embedded areas will be made in a track connection box as shown in the Contract Drawings.

H. Coordinate with other disciplines for requirements regarding locating and protecting previously installed underground equipment. Details of signal cable runs, conduit runs, and pullbox installations including number, size, and type of cable are shown in the signal drawings of the Contract Drawings Conduit runs and pullbox locations, as shown, are the preferred locations. In case of conflict between the signal drawings and other Contract Drawings, the signal drawings take precedence as to detail, and in the event of conflict as to placement of equipment, the Engineer will determine the correct placement.
1. Make any minor deviations in location (within 10 feet of the location as shown on the civil drawings of the Contract Drawings) as part of the Work. Deviations in excess of 10 feet may be subject to the changes provisions of General Conditions. Location of conduit, ductbank, etc. shall be accurately shown on the as-built drawings.

I. All underground signal cables shall be installed in rigid non-metallic conduit (minimum schedule 40) encased in concrete. Non-metallic electrical conduit shall be used only for embedment or in ductbanks. Stub-ups shall be rigid metallic conduit.

J. Any components or equipment proposed by the Contractor as an equal to those specified in these Specifications, which are not currently in use on the Authority's system, or that do not have spare maintenance parts in the Authority’s stock, will require the Contractor furnish sufficient spare components equal to 10% of the quantity order or a minimum of two (2) additional units, whichever is greater. The Authority will notify the Contractor if any proposed component or equipment falls under these requirements.

The Contractor shall also arrange for manufacturer provided training for Authority maintenance and supervisory personnel for any component, equipment, or software not currently in use by the Authority on the train control or Rail Operating Center systems. Spares and training are to be furnished by the Contractor at no additional expense to the Authority.

K. All Contractor field personnel shall receive safety training in accordance with Section 01 1000– Summary, 01 35 23 – Worksite Safety Requirements, and 01 56 37 – Worksite Security Requirements.

1.05 FAIL-SAFE DESIGN REQUIREMENTS

A. As used in these specifications, fail-safe design shall mean that whenever an equipment failure, human error or failure to act, or adverse environmental condition affects the specified operation of a system involved with the safety of life or property, that system shall revert to a state known to be safe.

B. Failure of a circuit or equipment that results in an indication of a dangerous or most restrictive condition, whether or not there is in fact actual danger, shall have met the fail-safe requirements. Conversely, a failure that results in an indication of safe or nonrestrictive condition when, in fact, a dangerous condition may exist shall not have met the fail-safe requirements.

C. Vital applications, such as detector locking of switches, shall be based on the following principles that permit the attainment of fail-safe operation in all known or discovered failure modes:

1. **Closed Loops**: Fail-safe circuits shall employ the closed loop principle and shall protect against open circuits, shorts, or any combination thereof.

2. **Vital Relays**: Relays used in vital circuits.
3. **Vital Circuits**: All line circuits, which energize a vital relay, shall be two-wire, double-break circuits and shall be energized from an ungrounded direct current (DC) power supply.

4. **Grounds**: Components or wires becoming grounded shall not cause an unsafe condition.

5. **Spurious Oscillations**: Any amplifier, generator, or device element, active or passive, breaking into spurious oscillations shall not cause an unsafe condition.

6. **Filters**: Filters used in fail-safe circuits shall be designed to prevent undesired signals from appearing at the filter output at levels which could cause an unsafe condition.

1.06 **DELIVERABLES**

A. All previously described submittals.

B. Manufacturer's warranties.

C. Instruction sheets.

D. Parts lists.

E. Operations and Maintenance Manuals: Submit to the Engineer 10 sets of application, installation, operating, and maintenance manuals. Include complete material ordering reference numbers for each type of product.

F. All other documents required by the Specifications relevant to the design manufacture, installation, testing, and placing into service the Train Control System as determined by the Authority.

G. Spare parts (as required by Contract).

H. Any tools or diagnostic equipment required by the Specifications.

1.07 **AS-BUILT DOCUMENTATION**

A. This Section shall supersede Section 01 78 39 – Project Record Documents and Contract Documents and Drawings regarding as-built drawings only.

B. The As-Built drawing sets shall show all approved circuit and wiring changes made during installation and integration testing prior to placing it in service, and any approved changes made after placement in service. Changes shall be dated and noted in revision box by the Contractor's responsible Signal Engineer. Identify the date that the location was tested and placed in service in the revision block of the drawings. As-Built drawings shall be CADD drawings and have no handmade revisions on the drawings.

C. In addition to the as-built drawings provided to the Engineer, one set shall be bound and shall be kept in the instrument enclosure at a location and manner approved by the Engineer. As-built drawings shall be clean and legible. The as-
built drawings shall not be removed from the field location after the location is placed in service without the prior written approval of the Engineer.

D. The final as-built drawings shall be 11 inches by 17 inches, unless authorized by the Engineer to substitute another size.

E. Each circuit that continues on another drawing shall be annotated with drawing number and routing information for the continuation of the circuit.

F. The circuit drawings shall show all individual circuits. Typical circuits will not be accepted.

G. The location plans shall 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 shall be drawn if cable information cannot be shown in a neat and organized manner on the location plans.

H. Conduit and ductbank plans shall show cable installed in each conduit, and indicate conduit that are available as spares, as well as any that could not have the mandrel or cable pulled through due to blockage.

I. The shop drawings shall be detailed equipment drawings for each type of equipment installed.

1.08 WARRANTY

A. Provide warranties for all equipment and material covering parts and labor for one year from the date equipment or material is "placed in service".

PART 2 – PRODUCTS

2.01 EQUIPMENT – GENERAL

A. Signaling materials and equipment shall be the products of manufacturers regularly engaged in the production of such material and equipment and shall be the manufacturer's latest design. The materials and equipment shall have shown proven performance in North America for a minimum of three (3) years. Materials and equipment shall be delivered to the job-site in unbroken packages, reels, or other forms of containers.

B. All materials and equipment shall conform to the recommendations of AREMA C&S Manual, except as modified in the Specifications and Contract Drawings.

C. Reference to specific equipment and manufacturers is intended to establish quality, overall design, and fit, subject to compliance with all criteria specifications. Equipment equal to or exceeding the specifications and requirements may be used subject to the Engineer's written approval. Should alternate equipment be accepted, perform all necessary work to fit the alternate equipment to these specifications and to revise the Contract Drawings. All details to show alternate equipment to be equal to or exceeding the Specifications and Requirements shall be provided to the Engineer for review and approval.
D. Commercially Available - Provide electronic and electrical components and materials that are commercially available from at least two sources, and manufactured within the area covered by the North American Free Trade Agreement (NAFTA) wherever possible.

2.02 ELECTRICAL AND ELECTRONIC COMPONENTS

A. Design and construct fusing of all DC power supplies and circuitry according to the following requirements:

1. Circuit breakers and fuses shall be the correct side-band rating for circuit current interruption and shall protect the electrical equipment and circuits from short-term and long-term overloads.
2. Fuses shall be sized to protect the wire.
3. Fuses shall be in the positive leg of the power supply.
4. Fuses shall be of the nonrenewable indicating type.
5. All branch feeds for a circuit shall be from the same fuse to prevent fuse cascading due to branch fusing carrying loads for other circuits.
6. Fuses shall be no smaller than 5 amperes unless otherwise shown on the Drawings.
7. Loads shall be divided so that no normal operating current is more than 75 percent of the fuse rating.
8. Fusing shall be functionally oriented to minimize the equipment affected by a blown fuse (i.e., per track, switch control circuits, etc.)
9. Fuse clips shall be constructed to retain their resilience under all installation and service conditions and to ensure a positive contact between the clips and the fuse.

B. Printed Circuit (PC) Cards and Connectors:

1. The PC cards shall be mounted in 19-inch card files unless otherwise approved by the Engineer.
2. The PC wiring shall be organized so that wires serving the same function shall be connected to the same terminal of PC cards. PC cards containing the same circuitry and programming, where applicable, shall be interchangeable between subsystems.
3. The design and construction of PC cards of the same subsystems shall be the same. Cards of different subsystems shall be of the same design and construction wherever practicable.
4. PC cards shall be of glass epoxy construction. Card material shall meet the requirements of NEMA, Type FR-4. Cards shall have sufficient thickness to permit easy insertion and removal, and shall be physically keyed to protect against incorrect interchange. Circuits shall be formed by etching. Conductor material shall be copper and shall be protected from exposure to air.
5. PC cards containing components that may be damaged if a plug connector or plug-in unit is removed while the equipment is energized shall be clearly identified in the Operations and Maintenance Manual(s). PC cards shall be marked or labeled with a warning note on the individual board, be conspicuously located on the module, or by an alternate means as approved by the Engineer. A means shall be provided to remove power from the module or card file.

6. Components mounted on the PC card, weighing more than 1/2 ounce or with a displacement of more than 1/2 cubic inch, shall have a mechanical supporting attachment to the card separate from all electrical connections.

7. Do not stack or piggyback PC sections in order to accomplish changes or modifications to wiring or components on printed circuit cards.

8. Connectors shall have plating with a minimum thickness of 0.00005 inch.

C. Printed Circuit Card Files

1. There shall be not more than one type of card file for each size of PC card. The card file plug boards shall be registered to agree with the registry of the associated PC card. PC cards shall not project beyond the front of the equipment rack when mounted in the card file.

2. Card files shall be installed in dust-proof cabinets and protected with dust covers.

3. Insulated cable clamping devices shall be located on the back of the file in such a way that wires terminating in the files shall be installed in a neat and secure bundle, rigidly supported, and protected to prevent chafing of insulation. Cabling provision on the file shall permit wires to enter or leave the file from both the right and left sides. Such cabling shall not restrict access to the card file when the rear covers of the card files are removed.

2.03 Train-to-Wayside Communication (TWC)

A. The Contractor shall provide a TWC system compatible with Hanning & Kahl GmbH & Co's HCS-V system. TWC transponders shall be provided at the following minimum locations:

1. Approach to all wayside signals

2.04 Broken Rail Detection

A. Broken rail detection shall be provided throughout yard.

B. A broken rail shall de-energize the associated track circuit.

2.05 Wayside Signals

A. Wayside and dwarf color light signals shall be provided to indicate movement authority, block occupation and route locking information to train operators. The signals shall be installed to
govern movements into, through and out of the Yard. Signal Aspects shall use Light Emitting Diode (LED) technology. Wayside signals shall be installed for left hand running whenever possible using Authority’s standard transit color light signals. All interlocking signals shall be continuously illuminated and clearly visible from the operating cabs of the rail equipment for a distance of at least 500 feet.

B. The Contractor shall provide signal number plates for each signal. The signal number plate shall be placed under the lowest signal lens in the assembly. Signal plates shall meet the requirements of the AREMA C&S Manual, Section 14.6.1. The alphanumeric characters shall be a minimum of 3 inches high.

2.06 OPERATIONAL REQUIREMENTS

A. Graceful Degradation of Service - The design shall provide for graceful degradation of service as a result of component failures. The design shall minimize the impact to service for each component failure. Techniques for achieving this shall include but not be limited to:

1. No shared oscillators or other functions between modules except between two modules when necessary to meet requirements for failed IJ detection, EM1 prevention, or other specified requirements.

2. Failure-isolating resistors in circuits external to the TC equipment rooms except where necessary to provide full operating voltage per equipment requirements such as grade crossing warning equipment.

3. Circuit logic designed and organized as far as possible to minimize effects of failures.

4. Selection of separate energy distribution circuits for each tunnel's equipment and alternative control modes.

5. Any failure detection circuit of train control equipment shall combine to light the summary trouble light external to the case or bungalow.

2.07 MAINTAINABILITY

A. The design and installation of the equipment shall provide for the ease and speed of troubleshooting and repair for all components.

B. Modular Design

1. Use modular design throughout. Organize electrical and mechanical components in rack-mounted, plug-in assemblies to the greatest degree practicable.

2. There shall be no mixing of separate functions within one plug-in assembly without Engineer’s approval.
3. Mount equipment serving similar functions in the same relative location on racks or assemblies.

C. **Interchangeability:** Provide parts, components, and assemblies performing like functions that are physically and functionally interchangeable. Those that are not functionally interchangeable shall not be physically interchangeable.

D. **Accessibility:** Provide accessibility to system elements by using the following techniques:

1. Panels and openings shall be of sufficient size, quantity, and placement to permit ready access from a normal or service work area. Access to replace components or wiring shall not require removal of other assemblies not associated to the component.

2. Use self-retaining fasteners wherever possible.

3. Special-access opening tools shall not be required unless necessary to prevent vandalism.

4. Incorporate latch hold-open devices, where practicable, as an additional safety factor.

5. Components that are most frequently maintained or adjusted inside equipment cabinets shall be the most accessible.

6. Provide means to facilitate handling of heavy or less accessible components.

E. **Indications and Test Points:** Provide indicators and test connectors at points in a circuit that isolate functions necessary for rapid troubleshooting. This shall include but not be limited to oscillator outputs, modulator outputs, amplifier outputs, level detector outputs, and relay driver outputs.

2.08 **PADLOCK**

A. Equip each train control component with Contractor furnished padlocks. Use one padlock at each entry location to restrict entry to the inside of the component(s). Contractor shall install Authority furnished padlocks at final acceptance.

2.09 **ELECTROMAGNETIC COMPATABILITY (EMC)**

A. **EMC Control Program:** Provide an EMC control program for the Train Control System that shall ensure that train control equipment operates in the electromagnetic environment without causing or suffering harmful interference due to electromagnetic emission or reception. The primary objective shall be to develop equipment and installation parameters that assure an electromagnetically compatible system. This objective shall be achieved through coordination of Train Control System equipment selection, design and installation with the electromagnetic environment. Included in this environment are traction power and AC power distribution systems, communications systems, vehicle systems, and other nearby facilities.

B. **Techniques:** The primary techniques and methods available (employ any or all as required) for achieving EMC include:
1. Selection of operating frequencies.
2. Control of harmonics of the operating frequencies.
4. Attenuation of conductive, inductive, and radiated interference by separation, shielding, or other methods.

C. **EMI Sources:** Principal EMI sources include the traction power system ripple current and the vehicle propulsion subsystem.

### PART 3 – EXECUTION

#### 3.01 INSTALLATION

A. All equipment installation shall be as described in these Specifications or as shown in the Contract Drawings.

B. Ensure equipment within the Train Control Bungalow is securely anchored and fastened in the bungalow upon completion of the bungalow installation. When securing equipment, maintain isolation between ground systems as required in these Specifications.

C. An updated, detailed set of the approved signal design drawings shall be kept at each field location for equipment as it is placed in-service.

D. Provide rail bonding for all turnouts as shown on the Contract Drawings or as required by the Engineer.

E. Perform and document all tests and inspections in accordance with Authority approved test procedures.

F. Perform acceptance testing and commissioning of the signal system as a normal part of the Work.

G. No circuit is considered to have met the requirements of these Specifications for function and safety until the circuit has been tested according to the Authority approved installation and integration test procedures and the test results have been submitted and approved by the Authority. Any changes made to meet the functional and safety requirements of these Specifications shall be considered as included as part of the Work. Such changes shall be clearly documented as part of the as-built drawings or in a memo to the Authority if not applicable to the drawings.

#### 3.02 SAFETY

A. **General:** Perform all work in conformance with the approved safety plan and with industrial and local codes.

B. **Vehicle Clearance:** The design and installation of the train control equipment shall not interfere with the dynamic clearance of the vehicle.

C. **Personnel Clearance:** The design and installation of the train control equipment shall not interfere with the clearance envelope for personnel on walkways or with
the purposes of crosswalks, room entrances, vents, drains, or the maintenance of equipment, whether train control or other types of equipment.

D. **Tripping Hazards:** The design and installation of train control equipment shall not create a tripping hazard on a walkway or, to the greatest degree practicable, the right-of-way in general. If the installation should require a conduit or cable to cross a walkway, the conduit or cable shall not be routed on the surface but shall be embedded or cut into the concrete (or black-top), with the walkway then restored to its normal condition. Cables in the right-of-way outside the cable duct bank shall be in flexible or rigid conduit as required and secured in a manner to avoid tripping hazards.

### 3.03 FIELD PAINT MATERIALS

A. **Touch-up Paint for Signal Manufacturer Finishes:** Touch-up paints recommended by signal manufacturer, including aluminum touch-up paint shall be used.

END OF SECTION 34 20 00
SECTION 34 42 16

TRAIN CONTROL – CONNECTORS, WIRES AND CABLES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS


B. Connector Standards - Connectors shall meet the applicable requirements listed below, where they do not conflict with the requirements specified herein:

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOD</td>
<td>MIL-STD-454</td>
<td>Standard General Requirements for Electronic Equipment</td>
</tr>
<tr>
<td>DOD</td>
<td>MIL-STD-202</td>
<td>Test Method Standard for Electronic and Electrical Component Parts</td>
</tr>
<tr>
<td>ASTM</td>
<td>A167</td>
<td>Specification for Stainless and Heat-Resisting Chromium – Nickel Steel Plate, Sheet and Strip</td>
</tr>
<tr>
<td>ASTM</td>
<td>D3159</td>
<td>Standard Specification for Modified ETFE - Fluoropolymer Molding and Extrusion Materials</td>
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</table>

C. Referenced Standards

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREMA C&amp;S Manual</td>
<td>Section 10</td>
<td>Wire and Cable</td>
</tr>
<tr>
<td>ASTM</td>
<td>B3</td>
<td>Standard Specification for Soft or Annealed Copper Wire</td>
</tr>
<tr>
<td>ASTM</td>
<td>B33</td>
<td>Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes</td>
</tr>
<tr>
<td>ASTM</td>
<td>B189</td>
<td>Standard Specification for Lead-Coated and Lead-Alloy Coated Soft Copper Wire for Electrical Purposes</td>
</tr>
<tr>
<td>ICEA</td>
<td>S-56-434</td>
<td>Polyolefin Insulated Communications Cable - Outdoors</td>
</tr>
</tbody>
</table>
IEEE 383  Standard Type Test of Class 1E Electrical Cables, Field Splices, and Connections

DOD MIL-W-81044  Wire, Polyalkene Insulation, Crosslinked

DOD MIL-W-81822  Solid Conductor Wire

NFPA 70  National Fire Protection Association – National Electric Code (NEC)

NEMA WC70  Non-shielded 0-2 kV Cables

1.02 SUMMARY

A. This Section includes requirements for all cable and wire to be used for Train Control and Train Control power system wiring within, to and from wayside shelters, bungalows, junction boxes, and factory wired mechanisms along with associated connectors and terminals. The Work consists of furnishing, installing, labeling and terminating all wire and cable related to the train control system.

B. System Description

1. Material and workmanship of the cable provided shall be of the highest quality, assuring durability for minimum life expectancy of 40 years. Cables shall be suitable for use in the environment to be encountered on a railroad Train Control system, and shall be certified for continuous operation, in wet or dry locations, with no conductor failing in continuity or with loss of insulation to cross or ground less than one mega-ohm.

1.03 SUBMITTALS

A. All submittals are provided to the Authority for review and approval.

B. Required submittals:

1. Cable Qualification Data – Submit technical data describing each type of wire and cable that the Contractor proposes to furnish prior to purchase or manufacture of material. The data shall be sufficient to ensure that the cable complies with the requirements of these Specifications. The submittal shall include evidence that the flame test requirements, specified herein, are satisfied.

2. Connector and Terminal Block Qualification Data – Submit technical data describing each type of terminal block and/or connector to be used. The submittal shall identify the application for which the connector is to be used. Connector technical data shall include:

   a. Molded connector blocks.
   b. Protective shells for blocks.
c. Locking and keying devices.
d. Strain-relief clamping devices.
e. Extractable pin-and-socket contacts (if applicable).
f. Special terminal insertion or extraction tools.
g. Manufacturer’s part numbers.

3. Solderless Wire Terminals: Submit product data for terminals and manufacturer recommended crimping tools to the Authority for approval. The submittal shall include a sample board made up of samples of the different types and sizes of terminals intended for use on this Contract.

4. Technical Qualification Data: Submit technical qualification data describing each type of wire and cable that the Contractor proposes to furnish in compliance with the requirements. The data shall be complete enough to ensure that the cable complies with each requirement of the specifications for both materials and construction. This submittal shall include data showing that the flame test requirements are satisfied.

5. Factory Test Report: Submit factory test reports for each reel of cable and tests performed on samples prior to shipment. The report shall identify at a minimum the description of the cable, reel number, part number, length of cable, and pass/fail values for the requirements as well as the measured values.

6. Inspection Reports: Submit all inspection reports required in this Specification.

7. Termination Data: Submit termination data for each type of termination intended for use with the cable. Data shall include as a minimum catalog cuts, and data specifying the material, plating, and dimensions. For catalog cuts with multiple items, the Contractor shall clearly identify data to be evaluated by the Authority.

8. Installation: Submit installation procedures for each cable pull. Include installation details, methods, and related criteria for cable such as maximum pulling tensions allowed, pulling tension to be utilized, equipment to verify pulling tension, pulling lubricant to be used, and methods of keeping the cable from kinking. Identify site-specific problem areas such as locations where cable duct bank changes sides, transitions, etc. Identify specific cable conduit assignments.

9. Quality Assurance: Submit a list of cable manufacturer’s installations complying with the past performance and experience requirements specified herein.

10. Source Quality Control Tests: Submit the following test procedures and results:
   a. Conductor Size and physical characteristics.
   b. Insulation HV and IR tests.
   c. Physical dimension tests.
   d. Special test on materials in coverings.
   e. Final HV, IR, and conductor resistance tests on shipping reels.
11. Any other submittal called out in the specifications.

1.04 DELIVERABLES

A. Connectors and Terminal Blocks – Provide devices for the mechanical locking and keying of the connector halves.

1.05 QUALITY ASSURANCE

A. Cable manufacturer's qualifications shall be as follows:

1. Past Performance and Experience: Demonstrated previous successful experience in supplying cable to the railway or transit industry for use as vital signal control cables. A list of such installations shall be provided for each cable manufacturer to be considered.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Shipping Lengths: Cable shall be furnished in lengths suited to the installation requirements. All cable shall be shipped on reels, and protected from damage in shipment by heavy wrapping or wood lagging.

B. Reel Design: Each length of cable shall be wound on a separate reel. Reels shall be substantial to withstand reasonable handling and shall be designed such that the inner end of the cable shall be accessible but protected from injury. The diameter of the drum shall be at least 14 times the cable diameter to prevent damage to the cable during reeling. The arbor hold shall admit a spindle 2-1/2 inches in diameter without binding.

C. Cable Winding on Reels: Cable shall be closely and tightly wound in each layer on reels. Both ends of the cable shall be accessible and sealed to prevent the entrance of moisture and securely fastened so they do not become loose in transit.

D. Reel and Cable Information: Each reel shall contain on the outside flange, in legible and weather resistant print, 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.

E. Reel Rolling Instruction: An arrow shall be painted on one flange of each reel pointing the opposite direction from the outer end of cable with the words "Roll This Way".

F. Each reel of cable shall be inspected by the Contractor at the time of delivery to ensure that no physical damage occurred during shipment, and that the reel covering and cable seals are not missing or damaged. A copy of these inspection reports shall be submitted to the Authority. Damaged or rejected cable shall be replaced by the Contractor at no cost to the Authority. The Authority reserves the right to inspect the cable and reject damaged cable at any time.

PART 2 – PRODUCTS
2.01  INTERNAL WIRE AND CABLE

A. Definition: Interior cabling is defined as that cabling installed internal to the train control enclosures and cases.

B. Stranded Wire for General Use

1. Design Requirements: Stranded wire shall meet the following requirements:
   a. Conductor - Stranded soft annealed copper, ASTM B3.
   b. Coating - Tin or lead, ASTM B33 or B189.
   c. Insulation - Ethylene Tetrafluoroethylene (ETFE) per ASTM D3159-91a, or cross-linked Polyalkene per MIL-W-81044.

2. Identification: Mark each stranded wire at maximum intervals of 36 inches with the following information:
   a. Manufacturer's name.
   b. Size of conductor.
   c. Type of insulation.


C. Modem Cable

1. Modem cables shall be C-L-X Type SP-OS manufactured by Okonite Co., or equal.

2. Modem cable shall be protected by a moisture impervious, continuously welded, corrugated, aluminum sheath with an overall EFTE fluoropolymer jacket.

3. Individual twisted pairs shall be separately shielded with an aluminum polyester tape to provide shield isolation between pairs of 100 mega-ohms per 1000 ft. minimum.

D. Multi-Conductor Cable

1. Multi-conductor cable shall consist of individual or twisted pairs of stranded, insulated conductors bundled in cylindrical form using non-hygrosopic, flame-resistant fillers and tape, with the jacket fitting tightly to form a firm assembly.

2. Assembly: Assembly of multi-conductor cables shall conform to the AREMA C&S Manual, Part 10.3, except as otherwise specified herein. Individual conductors or twisted pair(s) shall be assembled into a tight, cylindrical form. Assemble individual or twisted pairs helically and with adjacent layers wound in opposite directions. The lay of a twisted pair shall be 1.5 inches +/- 0.5 inch maximum. Where shielded cable is required, provide braided shields of aluminum or copper.

3. Binder Tape: Helically apply fabric or Mylar tape with a minimum of 25
percent overlap of the layer to serve as a binder to each layer of two or
more wires. Provide tape of a thickness not less than 0.005 inches and
compatible with the other materials in the cable.

4. Conductor Size: Minimum conductor size shall be 20 AWG.

5. Flame Test: Multi-conductor cables shall pass the vertical tray flame test
as detailed in IEEE Standard 383. Maintain circuit integrity for five
minutes minimum during the test.

6. Identification: Identify each cable conductor with number or color if cables
are terminated with connectors. For cables not terminated with
connectors, each cable conductor shall be color coded.
   a. Color code stranded wires in multi-conductor cable in accordance
      with ICEA S-56-434.
   b. Mark the cable outer sheath at maximum intervals of 36 inches
      with the following information:
      1) Manufacturer's name.
      2) Year of cable manufacture.
      3) Number and size of conductors.
      4) Type of insulation on conductors.
      5) Type of jacket insulation.
      6) Voltage rating.

E. Solid Wire for Wire Wrap

1. General: Use solid wire only for wire wrap applications within modules.
   Solid wire shall be in accordance with the requirements of MIL-W-81822
   where those requirements do not conflict with these Specifications.

2. Conductor: Minimum conductor size shall be 26 AWG. Conductors shall
   be soft annealed copper, ASTM B3 (type A only). Conductors shall be tin
   coated per ASTM B33.

3. Insulation: Ethylene tetrafluoroethylene (ETFE).

F. Wire Terminations

1. Wires shall be terminated with solderless ring tongue terminals for
   connection to terminal strips or binding posts. Terminals shall be
   insulated and shall include an insulation grip. Terminals shall be the same
   as used to terminate exterior wires of the same size. "Flag" terminals may
   be used in tightly confined areas or crowded terminal blocks. Terminals

G. Connectors and Terminal Blocks

1. Construction: Connector blocks shall be either crimp and insert type or
   solder type such as AMP M series connector, Amphenol Blue Ribbon, or
   approved equal. Maximum number of terminal pins per connector shall be
   50. Provide connector blocks used for vital circuits with a surface leakage
distance of not less than 0.25 inch between the contact and any other
contact or metal. Surface leakage distance for non-vital circuits shall not be less than 0.10 inch between the contact and any other contact or metal. Terminal blocks shall be modular with solderless connections of the quick-connect tab, binding post and nut, screw terminal barrier, or wire wrap type. Terminal blocks shall conform to the AREMA C&S Manual, Part 14.1.5.

2. Materials: Metal parts shall be either stainless steel or nickel plated brass.

3. Features: Provide each connector with the following features:
   a. A strain relief device for wiring external to a module. When used with a multi-conductor cable, it shall grip the cable outer jacket.
   b. A shield for each half of the connector which extends beyond the mating surface.
   c. Gold plated contacts with a minimum plating thickness of 0.00002 inches.
   d. Mechanical devices to allow the connector assemblies to be keyed such that they must be connected in the correct position relative to each other and be connected only to its corresponding receptacle.

4. As alternate, terminal blocks for all applications except entrance rack and power bus applications may be channel-mounted type, equipped with spring loaded connectors meeting UL and VDE standards as manufactured by Wiedmuller, Phoenix, Enterlec, Wago, or Authority approved equivalent.

2.02 EXTERNAL WIRE AND CABLE

A. General

1. Definition: Exterior cabling is defined as that cabling installed external to the train control enclosures and cases. Except where use of interior cable is specifically approved, use exterior cable for power, signal, control, grounding, and instrumentation circuits.


3. Flame Test: Exterior wire and cable shall pass the IEEE 383 Standard vertical tray flame test and not develop any short circuits for 5 minutes.

4. Temperature Rating: Exterior cabling shall be certified for continuous operation at 90°C, in wet and dry locations, above and below ground, in trays, troughs, conduits and duct banks.

5. Service Life: Exterior wire and cable shall have insulating and jacketing materials capable of a 40-year minimum service life.

6. Individual cable make-up and conductor sizes shall be as shown on the Contract Drawings.
B. Cable Construction

1. Rating: Cable shall be constructed to the voltage rating, insulation material, and jacket material as specified herein. Signal power cable shall have a rating of 1000 volts. Signal control cable shall be rated at 600 volts.

2. Insulation: Insulation shall be Ethylene Propylene Rubber (EPR) which meets or exceeds NEMA WC70. The insulation shall be a zero halogenated compound. Insulation thickness shall meet the requirements of the AREMA C&S Manual - Part 10.3.17 Table I - Table II.

3. Assembly: Cable assembly shall meet the requirements of the AREMA C&S Manual - Part 10.3.17. The conductors shall be assembled with suitable fillers, where necessary, and a taped cushion layer. A 7 mil flat copper alloy tape shall be helically applied and a cable jacket applied overall.

4. Outer Jacket: Cable jacket shall be Hypalon (chlorosulfonated polyethylene) or approved equal, which meets or exceeds NEMA WC70. The jacket shall be a low smoke zero halogen when specified.

5. Track Wire
   a. Track wire shall be Okonite-Okolene (EP-PE) manufactured by Okonite Co., or equal.
   b. Track wire shall meet the requirements of AREMA C&S Manual, Part 10.3.15.

6. Signal, Switch, and Express Cable
   a. All external cable shall be installed in conduit. No conduit shall be direct buried.
   b. Conductors number six (#6AWG) and smaller shall be solid. Conductors number 4 (#4AWG) and larger shall be stranded.
   c. Armored cable shall meet the requirements of AREMA C&S Manual, Part 10.3.17.
   d. Any cable installed in conduit or trough for its entire run is not required to be armored, but shall meet the requirements of AREMA C&S Manual Part 10.3.16.

7. AC Power Cable
   a. AC power shall be Okonite-FMR (EP) Okolon (CSPE) Type TC Cable manufactured by Okonite Co., or equal.
   b. Cable shall meet the requirements of AREMA C&S Manual, Part 10.3.16.
C. Cable Identification and Conductor Markings

1. Jacket Identification: Cabling shall have the following information permanently imprinted on the surface of the outer jacket, at maximum intervals of 24 inches:
   a. Manufacturer’s name.
   b. Number of conductors.
   c. Size of conductors.
   d. Voltage rating.
   e. Year of manufacture.
   f. Sequential footage markings.

2. Conductor Identification: Imprint individual conductors of multi-conductor cables with the conductor identification at intervals not more than 6 inches. The identification shall be a printed number.

3. General Identification: Jacket and conductor markings shall be of a color which contrasts with the material on which they are imprinted and shall be of sufficient size to be easily recognized and legible.

2.03 SOURCE QUALITY CONTROL

A. Coordinate with the Authority regarding inspections and factory tests. The Authority shall have the right to make factory inspections and witness tests, as necessary, to determine if the wire or cable meets the requirements of this Specification. The Authority shall have the right to reject wire or cable that is defective in any respect.

B. Provide, at the point of production, apparatus and labor for the following tests:

   1. Conductor size and physical characteristics.
   2. Insulation HV and IR tests.
   3. Physical dimension tests.
   4. Special tests on materials in coverings.
   5. Final HV, IR, and conductor resistance tests on shipping reels.

PART 3 - EXECUTION

3.01 CABLE APPLICATION

A. NEC shall take precedence over these Specifications if their requirements are more stringent.

B. Cable conductor sizes, quantities, and voltage ratings as indicated herein are intended as a minimum. Exceed these minimums whenever necessary to meet NEC requirements or to provide a complete working system meeting the specification requirements.
1. Inter-Room Train Control Cable (Line Wire): Multi-conductor (19C) No. 14 AWG minimum, Class B, 600 V rated.
2. Power Frequency Track Circuit Cable: Multi-conductor Twisted Pair (2C) No. 8 AWG minimum, Class C, 1,000 V rated.
3. Yard Wayside Signal, Switch Control and Indication Cable: Multi-conductor Cable (5C, 7C, or 12C), No. 14AWG minimum, Class B, 600 V rated.
4. Yard Switch Machine Power Cable: Multi-conductor Cable (2C) No. 8 AWG minimum, Class C, 600 V rated minimum.
5. Ground Cable: Single conductor No. 6 AWG minimum, Class C, 600 V rated, jacket color green (green may be pigmented or surface painted, if not deleterious to jacket life).
7. All other circuits not specifically identified shall have as a minimum conductor size No. 14 AWG, 600 Volt rated single conductor or multi-conductor cable.
8. Audio Frequency Cable: Multi-conductor (2C) No. 14 AWG minimum, twisted pair Class C, 1000 Volt rated.
9. TWC: Multi-conductor (4C) No. 12 AWG minimum, shielded, 600 V rated in ballasted area and single-conductor (1C) No. 9 AWG minimum with jacket in embedded area.

3.02 FACTORY TESTING

A. Production Testing

1. Production Tests: Tests shall be made on samples selected at random at the place of production. Each test sample shall be taken from the accessible end of different reels. Each reel that is selected and its corresponding sample shall be identified. Each full-reel length of single conductor cable and of individual conductors intended for use in multi-conductor cable, prior to application of outer jacket and prior to cabling or twisting, shall be randomly wound on spools, immersed in water, and subjected to the following tests after 6-hour immersion. Test procedures shall be in accordance with NEMA WC 70. Manufacturer shall have the option of AC or DC dielectric testing as allowed by NEMA.

2. AC Voltage Test: Each length of insulated conductor shall be subjected to and shall withstand the AC test voltage in NEMA WC 70. Apply voltage between conductor and water (ground) for no less than 5 minutes duration. There shall be no signs of puncture, overheating, or self-healing of punctures.

3. Insulation Resistance Test: Every individual length of insulated conductor shall be subjected to an insulation resistance test which shall be made while each conductor is submerged. The insulation resistance constant
"K", in the industry standard formula, when corrected to 15.6 degrees, C shall not be less than 20,000 mega ohms/1000 feet.

4. DC Voltage Test: Each length of insulated conductor shall be subjected to and shall withstand the DC test voltage in NEMA WC 70. Apply voltage between conductor and water (ground) for no less than 10 minutes duration. Sufficient time shall be allowed between this test and the insulation resistance test to prevent polarization from affecting the results.

B. Final Tests: Test each full-reel length of completed cable in accordance with the procedures given in NEMA WC 70. Multi-conductor cables shall be dry-tested. Single conductor, jacketed cables shall be immersed in water for 6 hours. DC resistance of conductors shall meet the requirements of NEMA WC 70. Insulation resistance of each conductor shall be tested to verify that the quantitative requirements described herein are met. Alternating current tests shall be conducted on each insulated conductor as described above, except the cable shall be dry. Apply voltage between conductors for 5 minutes.

C. Sample Testing: Statistical sampling plans shall be in accordance with approved procedures. Sample selection and frequency shall be in accordance with NEMA WC 70 for insulation and jacket compounds.

D. Qualification Testing: The qualification tests listed in NEMA WC70 shall be performed on a prototype basis. Prior testing on identical construction and material will be acceptable subject to the Authority's review and approval. In addition to the test requirements previously stated, all cable shall meet the requirements of IEEE 383 flame tray test.

E. Inspection

1. Inspection by the Authority: The Authority or its designated representative shall have the right to make inspections and witness tests at the wire and cable manufacturer's facility as it deems necessary to determine if the wire and cable meet the requirements of this section. The Authority or its designated representative shall have the right to reject cable that does not comply with these requirements.

2. Certification: Deliver certified test reports for each reel of cable at least two calendar weeks before the reel is shipped from the manufacturer's plant. The test report shall show the results of tests performed on the cable of each reel to be shipped.

3.03 INSTALLATION PREPARATION

A. Metallic Trough Preparation.

1. Inspect the cable trough for structural correctness and cleanliness prior to accepting an area for installation to proceed.

2. Remove any sharp edges that could damage cable prior to, and during installation of cable.
B. Conduit Preparation - Mandrel each conduit to remove foreign material, then clean and blow or swab dry each conduit before installing cable. Maintain conduits in a clean and dry condition during the installation process until each conduit is sealed as specified. Mandrel sizes to be used are provided in the table below:

<table>
<thead>
<tr>
<th>Duct Size (in.)</th>
<th>Diameter (in.)</th>
<th>Working Load (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
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<tr>
<td>6.0</td>
<td>5.81</td>
<td>4800</td>
</tr>
</tbody>
</table>

C. Cable Pulling Calculations

1. 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 shall 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 shall be calculated for each pull as required and shall not exceed the maximum allowable values of sidewall pressure, pulling strain on conductors or sheath, limits of pulling devices, and pulling tension.

2. Pulling tensions shall be calculated for both directions to determine which direction results in less pulling tension on the cable. The lower tension direction shall be used. The following guidelines shall apply:

   a. The maximum pulling strain on the cable with a pulling eye attached to the conductors is a function of the conductor area as follows: \( TM = 0.008 \times n \times CM \), \( TM = \) Maximum tension (lb), \( n = \) Number of conductors, \( CM = \) Area of each conductor (circular mils).

   b. When a basket-weave grip is used in lieu of a pulling eye, the maximum tension shall not exceed the value calculated for the pulling eye method or 1,000 lb per grip, whichever is less. c. The
sidewall pressure load shall not exceed 300 lb/ft or the cable manufacturer's recommended, whichever is less.

c. The jam ratio shall not exceed 2.8.
d. The coefficient of friction for the cables with lubrication shall be 0.35.
D. Manhole and Pullbox Preparation

1. Inspect manholes and pullboxes for structural correctness and cleanliness prior to accepting an area as suitable for installation to proceed. Dewater and remove dirt and trash from manholes and pullboxes prior to and during installation of cable.

2. Remove covers as required for installing cable. Covers shall be placed along right of way so that movement of construction vehicles is not impeded. Care should be taken to prevent damage to the covers. Contractor shall be responsible for any damage to cover during cable installation. If any damage is evident prior to cable installation, it should be brought to the attention of the Authority.

3. Install manhole cable channels and hooks prior to installing cable.

4. Core drill into pullboxes and install conduit where required prior to installing cable.

3.04 EXTERNAL WIRE AND CABLE INSTALLATION

A. General:

1. The installation of external wire and cable shall conform to AREMA C&S Manual Parts 10.4.1, except as specified herein.

2. All external cable runs shall be in conduit in accordance with the Contract Drawings.

3. The Contractor shall separate signaling cables from parallel run of AC feeder cables, where adjacent locations are fed from one AC service location.

4. The installation of cable shall be shown on the 30 day look ahead schedule. The Engineer shall be notified immediately if the installation plan for the current day is changed.

5. Provide sufficient slack in cable conductors at terminating posts to enable three re-terminations of the conductor without requiring replacement of cable conductors.

6. In certain types of installation, the cable cannot be constrained; therefore, ample cable slack shall be provided for additional flexibility due to vibration of such equipment.

7. Cable shall not be bent to a radius less than 10 times the cable diameter during installation or as finally installed. Do not bend cables to a radius less than manufacturer's recommendation.

8. Distribution cable runs shall be continuous without splices between cable terminating locations. Express cable runs longer than cable lengths shall be spliced together in junction box, instrument case, or other acceptable shelter. Prior to any cable or wire splicing, obtain the Authority's approval. Method of splicing and splice kit shall be submitted for approval prior to any splice being performed. Approval will not be granted for cables
damaged by the Contractor or vandalized by others. It is the responsibility of the Contractor to protect all cables until final installation.

9. Identify individual cable conductors at each cable termination with plastic tags, as specified in Section 34 42 60, Train Control Miscellaneous Products. Identify and terminate all spare conductors in each cable.

10. Seal cable entrance openings in equipment enclosures and junction boxes with either compression type fitting or pliable sealing compound after the cable is in place. Use sealing compound to seal the area around cable where the cable emerges from the end of a conduit, wireway or duct bank. Seal and plug all spare conduits.

11. For all multiple conductor cable terminations, carefully remove the outer sheath of the cable to a point a minimum of 3 inches from the cable entrance. At the end of the cable sheath or covering, apply two layers of plastic electrical tape or heat-shrinkable tubing.

12. Terminate all cable conductors in conductor sequence from top to bottom.

13. Cable shields or sheaths shall be grounded at the entrance to signal shelters and shall float when terminated in field apparatus.

14. Install the cable per the approved Cable Plan and approved Installation Plan. The Contractor shall provide any installation hardware necessary to route, support, terminate, or protect any cable installation.

B. Installation in Pullboxes

1. Cables shall be laid in pullboxes, and not pulled into place. Cables shall not be pulled tightly around bends. Crossover of cables shall be minimized.

2. Refasten covers when cable installation is complete. The installation procedure shall ensure that covers are not misplaced or damaged during handling.

C. Installation in Conduit

1. Crossover of cables shall be avoided when cables are pulled into conduits. Care shall be taken to prevent cables from being pulled tight or kinked in conduit fittings. Cables to be installed in a single conduit shall be pulled simultaneously in order to reduce the number of cable pulls, and to prevent damage to cables.

2. Pulling apparatus shall be in good working condition and provided with a smooth variable speed control for pulling. The pull, once started, shall not stop until complete. Stranded steel or a manila hemp pulling line shall be used for pulling cable. Nylon line shall not be used due to its elongation under tension. A dynamometer shall be used at the pulling end of the installation to measure pulling tension. This value shall be recorded for each pull.

3. Procedures for feeding cable into the conduit shall be established by the Contractor. Feed-in tubes, sheaves, cable reel jacks, and other appropriate tools necessary to provide proper bending radii and minimal
friction during installation shall be used. Direction or training of the cables on entering and exiting the conduit shall coincide with other parts of the installation arrangement so that the cable is not damaged or overstressed.

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

5. Install local cable runs between wayside equipment in direct fixation and wayside junction boxes in conduit. See track connection box details and locations in Contract Drawings.

6. Where cable transitions from manholes, pullboxes or duct banks to individual conduit, conduit ends shall be fitted with end bells to prevent damage to cable.

7. Furnish and install clamps or other cable restraining hardware in manholes or other areas where support is required for cable entering or leaving conduit.

8. Furnish and install potheads and filling compound in accordance with approved instructions.

9. Where cable leaves the ground at other than buildings or in foundations, the cable shall be protected by a bootleg or other covering extending above the ground line. Fill top of such protective coverings with a sealing compound.

10. Special Protection: Provide appropriate special protection for cables in areas where the cables are unavoidably exposed to hazardous conditions, such as vibration or sharp corners on equipment. Replace any cable that is installed but subsequently damaged prior to acceptance as a result of the Contractor's failure to provide such special protection.

D. Termination

1. All conductors shall be terminated with insulated ring tongue terminals unless otherwise specified. The terminals shall have insulation grip barrel. All crimped terminals shall be crimped with the crimping tool designed specifically for that terminal.

E. Cable Damage

1. The Contractor shall immediately call to the Authority's attention any damaged cable observed, whether prior to installation, occurring during installation or construction, or discovered by observation after installation. The method of correction shall be in accordance with the Authority's written instruction. The Contractor shall promptly repair any damage found.

3.05 INTERNAL WIRE AND CABLE INSTALLATION

A. General
1. Internal wire and cable shall be installed in accordance with applicable requirements of AREMA C&S Manual, Part 10.4.1, and as specified herein.
   a. Wires and cables shall be installed in a neat manner. Cables in trays shall be laid there in and not pulled into. Cables shall be installed with a minimum amount of crossover in the trays and shall not be pulled tightly around bends. All exposed wires and cables entering or leaving equipment racks or housings shall be protected from abrasion or sharp metallic edges.
   b. Nylon straps shall be provided and installed for bundling and cabling of conductors where two or more single conductors are exposed in internal rack bundles, cable trays or whenever wires are to be bundled. Tape shall not be used for this purpose. Straps shall be installed at intervals of 24 inches or shorter if required to maintain good standards along the cable run. Wires of multi-conductor cables exposed by the stripping of cable jacket for terminations shall be trained in a neat manner and tied approximately every 3 inches with nylon straps.
   c. There shall be no point-to-point redundancy of wires for increased current capacity.
   d. Strain relief shall be provided where needed.
   e. Wire or cable splices are not permitted.
   f. All wires and cables shall be fully protected against any contact with any surface other than that designed specifically to support or protect them.
   g. Wires and cables shall be laid in place with sufficient slack at the bends such that wires and cables will clear the inside bend surface of the wireway to prevent crushing of insulation.
   h. All wire and cable shall be free of kinks and insulation damage. Wire installation shall not be subject to accumulations of moisture or foreign matter.
   i. Wire and cable dress shall allow for sufficient slack to provide for shock and vibration induced movements, equipment shifting, alignment, cover removal and component replacement.
   j. Wiring and cabling dress in harness arrangements shall be tied with a high strength approved dielectric tie designed not to damage wire insulation. Wires and cable ties shall be trimmed and located to eliminate damage from sharp edges.
   k. All wires and cables shall be clear of metal edges, bolt heads and other interference points and have electrical clearance from covers.

2. Terminations: No more than two wires shall be terminated in connector pins or relay plugboards. Terminations on connector posts shall be limited to three wires per post. Tag all wires according to the requirements of Section 34 42 60 Train Control Systems Miscellaneous Products.
3. AC Wiring: Twisted pair wiring shall be provided for AC power distribution between racks, rack buses and modules.

4. Wire Size: Wiring of sufficient size shall be utilized to prevent voltage drop that could affect circuit or equipment operation. The minimum size of the interior wiring shall be as indicated below:
   a. General rack wiring - No. 18 AWG
   b. Power distribution wiring - No. 14 AWG
   c. Module wiring - No. 26 AWG

3.06 MODULE WIRING

A. Unless otherwise Authority approved, all module and display panel wiring shall be accomplished with solderless connections using solid wire for wire wrap connections, and stranded wire for crimped connections as specified herein. Minimum wire size shall be No. 22 AWG, for stranded wire and No. 24 AWG for solid wire.

3.07 RACK WIRING

A. Unless otherwise Authority approved, all vital rack wiring shall be accomplished with Authority approved solderless connections. Wire for vital approved solderless connections. Wire for vital rack wiring shall be stranded wire as specified herein, minimum size No. 16 AWG or multi-conductor cables as specified herein.

B. All nonvital rack wiring shall be accomplished with approved solderless connections. Wire for nonvital rack wiring shall be stranded wire as specified herein, minimum wire size No. 22 AWG or multi-conductor cables as specified herein.

C. Wiring terminations to vital relay plugboards shall use approved crimped or soldered terminals.

D. Rack wiring shall be neatly tied into compact bundles. Main bundles and branches shall be secured to the racks in a manner that preclude physical damage due to pressure of abrasion and prevent the wire weight from being supported by the wire termination, connections, or plug connection. Arrangement of wire bundles and cables shall be such that they do not interfere with visual inspecting, troubleshooting or repair of rack-mounted equipment.

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3.08 RACK-TO-RACK WIRING
A. All rack-to-rack wiring shall be routed via the overhead cable trays with sufficient slack between cable tray and each rack to which the cable or wire is connected.

1. Vital Racks: All rack-to-rack wiring for factory wired housings shall be accomplished using single conductors tied into bundles to form unjacketed multi-conductor cables. For relay circuits, unjacketed multi-conductor cables shall consist of individual conductors of size 16 AWG or larger wire and shall have a maximum tie spacing of 6 inches. Vital microprocessor cables may be made up of 20 AWG wires in terminated in keyed plugs.

2. Nonvital Racks: All rack-to-rack wiring for nonvital racks shall be accomplished using multi-conductor cables as specified herein and nonvital plug connectors as specified within these Specifications. All nonvital racks shall have a plug coupler panel to terminate all wiring from the rack.

3. Nonvital Racks to Vital Racks: All wiring between nonvital racks and vital racks shall consist of single conductors, tied into bundles, between the nonvital rack plug connector panel and vital rack connection points. These individual conductors shall consist of size 20 AWG or larger wire and have a maximum tie spacing of 6 inches.

3.09 ENTRANCE TO INSTRUMENT RACK WIRING

A. Wiring from entrance racks to instrument racks shall be accomplished using stranded wire, as specified herein, minimum size No. 20 AWG, as approved by the Authority.

3.10 HIGH VOLTAGE WIRING

A. Internal wire used in circuits directly connected to the rails and internal wire used in circuits that operate at voltages in excess of 600 volts shall meet the requirements of External Cable, as specified herein.

3.11 ENERGY DISTRIBUTION

A. Energy loops on vital and nonvital racks shall not exceed 2 rows.

1. Vital Racks: Unless otherwise approved, all wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Wiring shall be sized for maximum circuit load, but shall not be less than a stranded wire, size No. 16 AWG. Rack-to-rack wiring shall be accomplished with solderless connections.

2. Nonvital Racks: All wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 20 AWG. Rack-to-rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 14 AWG.
3.12 AC POWER WIRING

A. The Contractor shall use either the 600 volt cable approved for exterior wiring or use THHW insulated wire for AC power distribution connecting to the electric power panels. Notification of the wiring to be used shall be provided to the Engineer in writing prior to installation. Wire size and installation methods shall meet or exceed the NEC.

3.13 FIELD QUALITY CONTROL

A. Test all installed cable in accordance with the requirements of Section 34 42 58, Signal Systems Testing, and AREMA C&S Manual, Part 10.4.30.

END OF SECTION
SECTION 34 42 24

TRAIN CONTROL BUNGALOW EQUIPMENT

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   1. AREMA Communications and Signals Manual of Recommended Practice (C&S Manual)

1.02 SUMMARY

A. This section includes specifications for furnishing and installation of the train control bungalow equipment, including, but not limited to, the following items:

   1. Vital relays
   2. Non-vital relays
   3. Timer equipment
   4. Batteries
   5. Battery Chargers
   6. DC power supplies
   7. Transformers
   8. Microprocessors
   9. Ground detectors
   10. Lightning protection
   11. Filters
   12. Equipment Racks
   13. Fire Detection System
   14. Intrusion Detection System
   15. Communication Equipment
   16. Electrical and Electronic Components
   17. Track Circuits

1.03 SUBMITTALS

A. All submittals shall be provided to the Authority for review and approval.

B. Required Submittals:

   1. **Product Data**: Product information and catalog cuts of equipment and devices specified herein. For catalog cuts with multiple items, the Contractor shall clearly identify data to be evaluated by the Authority.

   2. Submittals of circuits shall be part of the Book of Plans submitted for each Train Control location. Microprocessor logic shall be converted to relay logic circuits and shall be included in the Book of Plans.

      a. Circuit drawings shall at a minimum, include the following:

         1) Each wire connecting from point to point shall have a unique nomenclature.
2) Nomenclature shall be assigned based on circuit function.
3) As the wire passes a point, the nomenclature shall remain the same, providing the function remains the same.
4) Numerically stepped prefixes or suffixes shall not be used. Each component or terminal shall have a unique location code. Wire nomenclatures in the same circuit shall carry the same base nomenclature and change by numerically stepped prefixes at each break due to a contact. Wire nomenclatures on the negative side of a coil will follow the same convention but will have the suffix “N”. Wires connected to an energy loop will carry the same nomenclatures as the name of the energy.

b. Circuit books shall have a drawing (or drawings) which contain the following:

1) A rack arrangement listing of relays used.
2) Sheet number where the relay control is located.
3) Relay contacts that are used and the contacts that are spare for each relay shall be identified.
4) Sheet number where each used relay contact is located.
5) Drawings that depict rack and sideboard layouts.
6) Drawings showing component arrangement and location, and multi-conductor connectors, including material tabulation numbers.
7) Drawings showing material tabulation numbers, and include the manufacturer's part number.
8) Drawings showing used and spare pin connectors with used pin connectors marked with the page number of the drawing on which the pin connectors can be found. Relay and relay contacts shall have a coordinate designation that corresponds to its location on the rack or mounting bars.
9) Drawings shall be arranged for easy reading and not crowded or cluttered, with a minimum of crossed or offset lines.
10) Rack detail drawings accurately showing the rack dimensions, dimensions of features (i.e. mounting holes, shock mounts, grounding bolts, etc.) equipment location, mounting brackets, spare space.
11) Drawings should include:
   a) Index
   b) System Block Diagram
   c) Single line track plan with control lines
   d) double line track plan
   e) Cable plan showing all breaks and JBs
   f) Energy distribution drawings
   g) Route and aspect chart

c. Nomenclature and symbols shall be defined on a separate drawing or drawings.

3. Design circuits and arrangement plans using symbols consistent with AREMA practices.
4. Design circuits to provide a minimum of one independent front/back contact on the first relay of that function and on the last series repeater of that function. Exception - No spare contact requirement on switch control relays.

5. Use lightning arrestors and secondary surge suppressors to protect against lightning and other voltage surges for circuits going outside of train control bungalows or cases. Line-to-ground arrestors used for connections to the rail shall be accompanied by appropriately rated in-line fusing to prevent an alternate path to ground for traction return current.

6. In the event of power loss, momentary false occupancy, or unforeseen events (such as simultaneous attempts to claim opposing switch positions), the logic shall automatically reset when the conditions permit normal safe operations to resume.

7. Provide ability to manually cancel route request and put signal to stop from either the yard control panel or TWC.

8. **Samples**: Samples of vital and non-vital relays upon request by the Authority.

9. **Relay Identification Tags**: Submit the type of relay identification tag, including methods of mounting as specified in Section 34 42 60, Miscellaneous Train Control Products.

10. **Relay Office Record Test Form**: Submit for each vital relay provided under this Contract as found in the AREMA Communications and Signals Manual. The use of typewritten characters shall be used to fill in all information requested on the form and then verified in the field in its final configuration, for accuracy of relay serial number, location and relay identification. Indexing of form cards shall be by serial number and turned over to the Authority upon final verification.

11. **Relays**: Submit relay specifications, manuals and drawings showing contact stacking arrangements, type of relay identification tag, and mounting and supporting arrangements for all relay types to be used in this Contract. Include documentation for relay operation, testing, adjustment, wiring, contact insertion and removal, and plugboard mounting and assembly.

12. **Contact Clips**: Submit product data, removable contact clips and crimping tool to be used for work covered under this Section.

13. **Transformers**: Submit drawings, wiring diagrams and performance data for all transformers to be provided and installed under these Specifications.

14. **Transformer Calculations**: Submit calculations used to determine the size of transformers required to feed loads created by equipment being provided and installed under this Contract. All transformers shall be rated to carry 125% of total load continuously.

15. **Fire Detection System**: Submit details of the fire detection system, including wiring diagrams and installation drawings.

16. **Intrusion Detection System**: Submit details of the intrusion detection system, including wiring diagrams and installation drawings.
17. **Track Circuits**: Submit product data for the proposed track circuits for use on the Project. The submittal shall include as a minimum, the following:

   a. Layout, circuit drawing and documentation stating that shunting and all other performance requirements have been met.
   b. Application information such as track circuit length capability, pre-shunt and post-shunt distance, and cable distance possible for track circuit connection from transmitter or receiver module.
   c. Parts list
   d. Component drawings and data describing loops or other wayside equipment.
   e. Installation drawings identifying materials and methods to be used for each type of installation. Submit product data such as catalog cuts and installation procedures as required to fully describe the installation for the yard. At a minimum the data shall include hardware data, methods of wire and conduit routing, stress relief, and rail attachment.

18. **System Power Schematic**: Submit a power distribution schematic for each location. It shall include a single line diagram of the power distribution, including approximate expected load for each circuit, and required 120 volt breaker sizes.

19. **Power Supply and Battery Charger**: Submit power supply technical data for each type of power supply and battery charger. Include as a minimum input and output voltage tolerances, physical dimensions, temperature ranges, monitoring and alarm features, regulation without battery, and sufficient technical data to assure each of the specification requirements are satisfied.

20. **Battery**: Submit proposed battery to be utilized and all battery mounting and rack details.

   a. Include as a minimum the battery materials, ampere-hour and voltage characteristics, temperature characteristics, and physical dimensions. Identify the initial battery sizes for each type of location, subject to adjustment based on final approval of the power calculations submitted with the power distribution schematic.
   b. Provide battery mounting detail technical data, including construction details, physical dimensions, and verification of seismic construction, assembly and installation procedures. Also provide technical data on acid resistant drain pans.

21. **Microprocessor Material and Circuits**: Submit product information for each type of circuit card/module/subsystem to be used for this Contract. Include all product data, assembly drawings, circuits, parts lists, p.c. board layouts, support calculations, and describe the proposed application of each for this Contract.

22. **Microprocessor Application Logic**: Submit application logic diagrams shown in standard relay logic using standard AREMA signal practices. Include with the submittal all information necessary to interpret the diagram and its interface with the wayside equipment. This includes but not limited to:

   a. Input/output (I/O) assignments and associated plug connector pin assignments;
   b. I/O LED assignments;
c. Documentation showing all hardware selectable switches (DIP, program plug, etc.); and identification of the options or conditions associated with each.

d. Wayside interfacing circuits.

e. List of abbreviations and variable names and their function.

f. Identification of subroutines and their function (if applicable).

g. Identification of any timing requirements with interfacing equipment.

23. **Microprocessor Documentation**: Documentation for each location shall be made at each of the submittal levels identified below. Each submittal or re-submittal shall identify revision dates and history for logic diagrams and EPROM's with serial number.

a. Design Review

b. As-Shipped

c. As-Built - In addition to the logic diagrams, at the As-Built level, the Contractor shall include any additional documentation associated with the logic. This includes Booleans source code (if Contractor's programming method includes Boolean code), assembly language or machine language, notes inserted in the program about special operating or software features at this location and identification of individual logic components by serial number.

24. **Racks**: Submit mechanical and installation drawings for each type of rack. Include structural details, hardware (e.g. relay mounting bars, cable supports, ground posts, and equipment shelves), rack finish, parts lists and rack mounting details.

25. **Installation Drawings**: Submit installation drawings of each bungalow and case layout. Drawings shall include mounting methods/materials and dimensions to verify clearance requirements, conduit routing and stub-up locations (or other cable entrance details), grounding.

26. Factory, Installation, and Integration Test Procedures and Results.

27. Any other submittal called out in these specifications.

1.04 **QUALITY ASSURANCE**

A. Vital relays shall meet the requirements of AREMA C&S Manual Part 6.2 where these requirements do not conflict with the requirements given in this section.

B. Non-vital relays shall meet the requirements of AREMA C&S Manual Part 6.3 where these requirements do not conflict with the requirements given in this section.

C. Relays of each type or style shall be uniform in size, contact assembly and in coil resistance.

D. Relays specified shall be capable of rated performance through an operating temperature range of minus 40 degrees F to plus 160 degrees F.
E. The Contractor shall inspect and test each transformer prior to shipment. Inspection shall conform to the Contractor’s approved Factory Inspection and Testing Procedure.

F. Transformers shall be in accordance with the AREMA C&S Manual, Part 14.2.10 for Single-Phase Transformers.

G. Each track circuit component shall be inspected prior to shipment. Inspections shall conform to the Approved Factory Inspection Procedure.

1.05 DELIVERY AND STORAGE

A. Vital relays shall be shipped separately from the racks or cases in which they are to be used. They shall be individually packaged, each in a corrugated carton with the relay part number printed on the outside of the carton. Relays shall be stored in a protected area until tested and installed.

B. Non-vital logic relays and heavy-duty interfacing relays may be mounted and shipped in the equipment racks or cabinets in which they are to be used. Non-vital general purpose interfacing relays shall be mounted and shipped on the printed circuit boards on which they are to be used.

C. Batteries shall be stored and delivered in a fully charged state. Batteries shall not be stored for more than 90 days. Batteries shall be shipped separately from housings in which they are to be used.

D. Transformers shall be protected from damage throughout delivery, storage, and handling.

E. Non-vital heavy duty interfacing relays shall be mounted in cabinets that have front plates which do not support combustion and shipped in the equipment racks or cabinets in as specified.

F. Non-vital general purpose interfacing relays shall be mounted and shipped on the printed circuit cards on which they are to be used.

G. Each power distribution component shall be inspected prior to shipment.

H. All signal power distribution equipment shall be protected from damage during shipping and delivery.

I. Equipment provided under this section shall not be shipped until the factory test results have been approved by the Authority.

PART 2 - PRODUCTS

2.01 GENERAL RELAYS


1. Relays of the same type shall be uniform in design and contact assembly.
2. **Relay Mounting**: Relays shall be mounted in cabinets only after cabinets have been installed. As relays are mounted, record relay serial numbers corresponding to cabinet location. Relays shall be secured against vibration. Vital relay plugboards shall be front-frame mounted. Vital relay plugboards shall be secured with bolts, lock washers, and nuts.

3. **Vital Relay Plugboards**: Plugboards for plug-in vital relays shall be provided with removable contacts. The plugboard shall be designed so that the removable contact shall have a direct connection with the relay coil and the relay contact prongs. The plugboards shall conform to AREMA C&S Manual, Part 6.2.1. The wiring to each removable plugboard contact shall carry the Authority approved tag indicating the relay contact or coil number assigned to the wire. The back of the plugboards shall be tagged to indicate the nomenclature of the relay for which the plugboard is wired. The contact numbering system shall be uniform for each type of relay used.

4. **Keying**: The relays and plugboards shall be mechanically keyed to prevent relays of the incorrect style, contact arrangements, or operating characteristics from being inserted on any given plugboard. Keying on relays and plugboards shall be the manufacturer's standard keying.

5. **Surge Suppression**: Surge suppression for all vital DC relay coils shall be provided. A transient sensing device, such as a transorb, shall be connected in parallel with each relay coil, and shall be built into the relay or its plugboard, or shall be mounted to the back of the plugboard in a manner that has been approved by the Authority.

6. **Contact Resistance**: The contact resistance of vital relays shall meet the requirements of the AREMA C&S Manual, Part 6.2.1.

B. Unless otherwise indicated on the Contract Drawings, vital DC relays shall be plug-in type and rack mounted.

1. Relays shall be identified with manufacturer's name, model number, contact identification, and serial number.

2. They shall be interchangeable with relays of the same type used elsewhere.

3. A machine-printed permanent relay name tag shall be mounted on the relay, or its cover if so equipped. The name tag shall be replaceable, but shall not come off due to vibration, heat or humidity.

4. Relays shall be equipped with a hand grip or other means to facilitate removal from or insertion into plugboards.

5. Plug-in relays shall be equipped with a latching mechanism or other type of fastening arrangement to provide firm attachment of the relay to its plugboard, and prevent the relay from becoming loose or from falling out of the base when bumped or subjected to vibration.

6. A sufficient number of contacts for the number of circuits to be controlled plus spare contacts shall be provided. Each relay shall have at least one spare
dependent front-back contact, or one spare independent front and one spare independent back contact.

7. All relays shall be furnished with transparent dustcovers of non-flammable material. A provision shall be made for ventilation for heat dissipation, where required.

2.02 VITAL RELAYS

A. Vital DC Relays

1. These shall conform to the recommendations of the AREMA C&S Manual Parts 6.2.1 and 6.1.5 except as otherwise specified.

   a. These shall operate on a nominal voltage in the range of 9 to 32 volts and be capable of continuous operation. The operating voltage selected shall be compatible with the power supplies specified.

   b. Arc suppression for vital relay coils shall be built into the relay or attached to the plugboard.

   c. Each relay shall have a minimum of four independent front contacts, two dependent front-back contacts, and two independent back contacts, unless otherwise approved by the Authority. Contact arrangements shall be identical for similar types or relays except special function relays.

   d. All front contacts shall be silver-to-metalized carbon contacts. Metal-to-metal contacts, front and back, may be allowed for limited applications as approved by the Authority (e.g. ground detector code transmitter, code following relay for flashing indications).

   e. Biased neutral vital relays shall be designed so that gravity alone will prevent the armature from picking up if the permanent magnet is deenergized or if no current is flowing through the coil. They shall be designed so that up to fifty (50) times working energization applied for two seconds at both normal and reverse polarity will not affect their operating characteristics, and will not pick up their armature on reverse polarity.

   f. Vital plug-in relays, except vital time-element relays and special application relays shall be equipped with front current testing terminal post. Test points shall be provided to enable testing of voltage from the front of the relay.


1. Each vital biased-neutral relay shall have a minimum of four independent front contacts, two dependent front-back contacts, and two independent back contacts unless otherwise approved by the Authority.

2. All front contacts shall be silver-to-metalized carbon contacts. Metal-to-metal contacts, front and back, may be allowed for limited applications only if specifically approved by the Authority.
C. **Switch Operating Relays or Biased Neutral Controller:** One normal and one reverse switch operating relay, or equivalent, shall be provided for each switch movement. Switch operating relays used to control the polarity of the operating current for switch movements shall meet the same requirements as specified herein above except as follows:

1. Each switch operating relay shall have a minimum of either two dependent front-back contacts or two independent front contacts and two independent back contacts. Each contact shall be equipped with a magnetic blow-out feature to effectively interrupt high currents and minimize contact wear. Each contact shall be capable of interrupting the normal switch movement operating current.

D. **Switch Overload Relay:** One switch overload relay shall be provided for each switch movement. Each switch overload relay shall be equipped with a timer which will cause the relay to energize 8 seconds after a switch position change is requested should the switch fail to achieve correspondence with the requested position. Upon expiration of the 8 second timer, the switch overload relay shall de-energize the active contactor. Upon request of the switch to the alternate position, the overload relay shall release allowing operation of the alternate contactor and simultaneously the timer will reset and initiate the timing cycle to verify completion of the alternate switch position request.

1. Switch overload stick relays shall be equipped with two separately wired, non-biased coils, one to be placed in series with the switch machine motor to detect overloads and the other to be used as a holding coil in the stick circuit. When an over-current condition is detected, the overload stick relay shall remain energized until the call for the switch operating relay is removed or reversed.

2. These shall be equipped with sufficient number of make-before-break contacts to perform the required functions.

E. **Vital AC Relays:** Vital AC track relays shall be two-element vane-type induction relays, 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 3 volts to 8 volts, inclusive, applied to the control winding. The minimum pick-up current shall be 0.28 amps applied to the control winding.

1. Each vital AC relay shall have a minimum of two independent front contacts and two independent back contacts, unless otherwise approved by the Authority. Each front contact shall be of the silver-to-metalized carbon type.

2. Vital AC relays shall meet the requirements established by AREMA C&S Manual, Part 6.1.35 except as otherwise specified.

### 2.03 NON-VITAL RELAYS

A. Non-vital relays required to provide a complete and working train control system shall be furnished. Non-vital relays shall include, if needed, general purpose interfacing relays and heavy duty interfacing relays. Product information for all non-vital relays and timer equipment shall be submitted for approval.
1. Non-vital logic relays (normal acting and magnetic stick) and non-vital heavy duty interfacing relays shall be of the plug-in type. Relays of the same type shall be uniform in design and contact assembly.

2. Non-vital general purpose interfacing relays shall be mounted on plug-in type printed circuit cards and shall be non-soldered to conductors on the cards. Non-vital relays shall be mechanically secured to the plugboard.

3. A machine printed permanent relay name tag shall be mounted on each relay. The relay name tag shall be easily replaceable but shall not come off due to vibration.

4. Individual relay covers and the cabinet in which a number of relays are mounted shall permit viewing the relay contacts without removal or disassembly.

5. Printed Circuit Cards
   a. Each printed circuit card on which non-vital, general purpose interfacing relays are mounted shall have one LED indicator light mounted along the front edge of the card for each relay in such a manner that the lights can be readily viewed for troubleshooting. The indicating light shall be operated by a contact on the relay so that it will be illuminated whenever the relay is picked up. Each indicating light shall be identified, both on the printed circuit card and on the transparent front plate of the card cage, with the name of the relay it indicates.
   b. Groups of printed circuit cards on which non-vital, general purpose interfacing relays are mounted shall be installed in metal printed circuit card cages that have transparent front plates of nonflammable material. The design of the card cage shall permit viewing each relay indicator light without disassembly or other mechanical manipulation.

2.04 TIME-ELEMENT RELAYS
   A. Time-element relays shall be motor driven or solid state type.
   B. Motor driven time-element relays shall have a minimum of two independent timing contacts that will close only at the end of the adjusted timing cycle, and two independent check contacts that, when closed, shall check the normal, or de-energized position of the relay.
   C. Time-element relays shall be operated at nominal voltage range from 9 to 32 volts DC. Energization with higher voltage shall not reduce the time interval.
   D. The operation shall be as follows:
      1. The preset timing interval shall begin when energy is applied.
      2. At the completion of timing interval, the timing contacts shall close and remain in this position until the energy is removed from the relay.
      3. Upon removal of energy, the timer shall reset to zero time, causing the timing contacts to open.
E. Time-element relays shall be equipped with a timing adjustment device external to the relay cover that can be sealed. When the adjustment device is unsealed, the timing interval shall be adjustable 5 seconds to 8 minutes. Interval increments shall be as follows:

1. From 5 seconds to 60 seconds in increments of one second or less.
2. From 1 minute to 8 minutes in increments of one second.

F. When the adjustment device is sealed it shall not be possible to adjust the timing interval. Once adjusted, the timing interval shall repeat with an error of no more than plus or minus 7 percent under expected variations in operating voltage and ambient temperature conditions.

G. Calculations shall be performed to determine time release settings for time element relays provided under this Contract. Contractor shall perform these calculations in accordance with AREMA C&S Manual Part 2.4.20, where applicable. These calculations shall be submitted to the Authority prior to installation of the bungalow in the field.

2.05 RELAY PLUGBOARDS

A. Plugboards for plug-in vital relays shall be provided with removable-type contacts.

B. Connecting wires shall be attached to the removable contacts. Wires attached to the removable contacts shall be crimped only with the manufacturer's recommended ratchet type crimping tool.

C. Plugboards shall be designed so that the removable contact shall have a direct connection with the relay contact prongs.

D. Vital relay plugboards shall be equipped with a registration plate to prevent relays of the wrong style, contact arrangement, or operating characteristics from being inserted.

E. Each plugboard shall have a tag, or other approved means of identification, indicating the nomenclature of the relay for which the plugboard is wired.

F. Wiring to each removable plugboard contact shall carry an Authority-approved tag indicating the relay contact number or coil number assigned to the wire.

G. Each vital relay plugboard shall be equipped with a current and voltage testing facility.

2.06 RELAY TERMINAL CRIMPING TOOL

A. The manufacturer's recommended crimping tool shall be used for all crimp connections. Solder connections shall not be used except by approval of the Authority. Two (2) of each manufacturer's recommended crimping tool shall delivered to the Authority with the required spare parts.

2.07 BATTERIES

A. Storage Batteries
1. Each cell of the battery assembly shall be hermetically sealed.

2. Battery shall be leak and spill proof. No electrolyte shall be lost when battery is stored or mounted in any position, or if a cell container should become ruptured.

3. Battery shall not be capable of explosion under any condition including a short circuit discharge.

4. Battery shall produce the rated capacity when operated in any position.

5. Battery shall be capable of a minimum of 1000 charge-discharge cycles to 80% discharge without loss of capacity.

6. Battery shall not release gas, fumes, or any toxic substances when operated under normal conditions, or when charged or discharged at a maximum recommended rate.

7. Battery shall be capable of normal operation and suffer no damaged after being frozen and thawed.

8. Battery shall not require charging voltages of more than 2.25 volts per cell to maintain rated capacity and life.

9. Battery shall, if totally discharged, be capable of being recharged to rated capacity with charging voltages of no more than 2.30 volts per cell.

10. Battery shall be “maintenance free,” meaning that no addition of water will be required and no overcharge will be required.

11. The Contractor shall calculate loads based upon the equipment proposed. All batteries shall be sized for a minimum 4-hour standby capacity, excluding the yard switches.

B. Battery Chargers

1. Battery Charger shall be Cragg Railcharger model ETC-12V or Authority approved equal.

2. Charger shall be a panel-chassis combination with a perforated protective cover. The design shall provide natural convection cooling.

3. Front mounting shall be designed to mount in a standard 19-inch rack space with EIA hole spacing.

4. Front panel shall contain one voltage failure light, output ammeter and output voltmeter. Meter accuracy shall be plus or minus two percent with nominal voltage readings at center scale.

5. Terminal binding posts for input, output and alarm circuits shall be provided. Each terminal shall be insulated from the frame of the unit.

6. All chargers shall be clearly and permanently labeled with manufacturer’s name, serial number, part or model number, and input and output rating.
7. Battery charging equipment shall be designed for continuous operation.

8. Battery charging equipment shall be designed to deliver rated outputs with input voltage of 100 to 130 volts AC, with a 60 or 100 Hz, single phase, two wire input.

9. Battery charging equipment shall have a reserve capacity at least 25% above calculated requirements.

10. Each charger shall be provided with independently adjustable float and recharge voltages, current limiting and automatic charge control. The battery charger shall have automatic electronically controlled temperature compensation for float voltages.

11. Terminal markings for AC and DC terminals shall be permanent.

12. Battery chargers shall be capable of withstanding 600 volts, 60 Hz applied for one minute between both input leads connected together and the case; between both output leads connected together and the case; and between both input leads connected together and both output leads connected together.

13. Failure detection circuitry shall include, alarming of failures that affect the ability of power supply to deliver rated load. A normally closed independent contact shall be provided for connection of external circuitry for alarm indication.

14. Battery charging systems shall include a battery eliminator circuit and a battery elimination switch. Operation of the switch shall not cause any subsystem to fail. Surge suppression and filtering shall not be eliminated by operation of the switch.

2.08 DC POWER SUPPLIES

A. Direct current power supplies shall meet the following requirements:

1. Operate satisfactorily in both single and parallel (continuous current sharing) modes;

2. Input voltage rating shall be for connection to a 120 VAC, single-phase, 60 Hz ungrounded power system;

3. Outputs shall be isolated from ground;

4. Semiconductors shall be silicon type with JEDEC numbers;

5. Transformers shall not emit audible noise in excess of 75 db, referenced to 0.0002 dynes/cm2 at a distance of 2 feet, at rated voltage and current;

6. For each type supply, the equipment and ratings shall be identical throughout the system, and the equipment shall be interchangeable;

7. Output voltage shall be nominal plus/minus 5 percent with input variations from 105 to 130 VAC at a temperature of 40 degrees C;

8. Output voltage from zero to full load shall not vary more than 3 percent within a temperature range of 0 to 50 degrees C;
9. Provide current limiting and adjustable overvoltage protection. Current limiting shall limit output current to no more than 130 percent of the 40 degrees C rated current rating;

10. Provide an adjustable undervoltage detection circuit which shall de-energize a relay with form-C contacts when the output voltage of the power supply falls to a set value. The undervoltage circuits shall reset automatically when the undervoltage condition is removed. The relay outputs shall alarm as indicated;

11. Power supplies shall utilize a diode auctioneering form of loadsharing. Both normal and reserve power supplies shall be on-line at all times with the normal power supply providing 50 percent of the load demands and the reserve power supply providing the remaining 50 percent;

12. Both the normal and the reserve power supply shall be designed and rated for continuous operation at a minimum of 125 percent of the full (normal plus reserve) load; and,

13. Power supply output ripple shall not exceed one percent.

14. Power supplies shall be protected as indicated in these Specifications and approved design drawings; and,

15. Power supplies shall be clearly and permanently labeled with the manufacturer's name, serial number, part or model number, and input and output rating.

2.09 SIGNAL TRANSFORMERS

A. General: The Contractor shall calculate the sizes of the signal transformers required to feed the loads for the equipment. The transformers shall be air cooled, dry type, and shall be in accordance with AREMA C&S Manual Part 14.2.10 for single phase transformers. Product information for signal transformers shall be submitted to the Authority for approval.

1. Taps: Primary and secondary taps of all power transformers, except track transformers, shall be brought to a terminal board mounted inside the transformer case. Power transformer secondary windings shall have a minimum of two taps above and two taps below the computed voltage and shall have a 10 percent tap/change ratio. Primary windings shall be equipped with taps to accommodate a 20% variance from the supply voltage. A lead for each secondary winding connection and two leads for the primary winding shall be brought out of the transformer case through wall bushings. Primary winding taps shall be provided on terminal boards with bolted jumpers or straps for tap changing.

2. Isolation: Means shall be provided to isolate each transformer for maintenance without interruption in the primary train control power supply.

3. Rating: Provide transformers capable of carrying the entire rated load plus 50 percent. Flux density shall be sufficiently below saturation at rated voltage to allow excitation by a minimum of 10 percent overvoltage.

B. Contractor shall furnish one transformer of each rating used in the system.
C. All transformers shall be air-cooled unless otherwise Authority approved.

D. Transformers shall be provided for train control power isolation purposes, track circuits and general purpose transformers as required in these Specifications or approved design drawings.

E. Track transformers shall be provided with sufficient primary and secondary voltage taps to adjust for varying feeder voltages between 100 and 125 volts.

F. Transformers shall not emit audible noise in excess of 75 dB, referenced to 0.0002 dynes/cm² at a distance of two feet at rated voltage and current.

G. Primary and secondary taps shall be brought to terminals mounted inside the transformer case. A connection for each secondary tap and at least two connections for the primary winding shall be brought out of the transformer to suitable. All terminals shall be identified in an Authority approved manner.

H. Track feed transformers required for power frequency track circuits shall be equipped with terminal boards containing terminals for primary and secondary leads.
   1. Secondary windings shall be arranged to provide for varying voltage in one-volt steps up to a maximum of 15 volts. Terminal boards shall comply with AREMA C&S Manual Requirements.
   2. Primary voltage shall be 120 VAC. All track feed transformers shall have a volt-ampere rating sufficient to handle the operating load. Track transformers shall not be susceptible to DC saturation by propulsion currents.

I. Transformers for train control power shall be single phase with 480 volt, 60/100 hertz, primary windings and 120 volt, 60/100 hertz, secondary windings. Transformer windings shall contain Class H insulation with four, 2-1/2 percent full capacity taps. Two taps shall be above the nominal voltage and two below the nominal voltage. The transformer enclosures shall be of drip-proof construction and provided complete with provisions for wall mounting.
   1. Each train control power transformer required for a bungalow location shall be rated at a minimum of 15kVA.

J. Transformers shall be installed as shown on Authority approved design and installation drawings.

K. Track transformers shall be rack mounted.

L. Train Control power and general power transformers shall be wall mounted.

M. Isolation transformers may be wall mounted.

2.10 MICROPROCESSORS

A. General:
   1. The Contractor shall provide vital and non-vital microprocessor-based solid-state equipment. Such equipment shall meet all applicable requirements of the AREMA Communications and Signal Manual of Recommended Practices.
2. The equipment shall be provided complete with the isolation and power regulation devices to ensure its performance and reliability upon installation.

3. System shall be based upon solid-state microprocessor technology and not require offline storage devices for operation or startup.

4. Microprocessor units shall consist of a single processor with CPU(s), I/Os and memory, printed circuit boards and associated cables, plugs, wire connectors, terminal boards, data transmission equipment, power supplies, power conditioning equipment, instrument racks and hardware, and use closed loop feedback and continuous self-checking to maintain vital integrity.

5. Modifications or upgrades to solid-state equipment provided by Contractor or its suppliers shall be made to equipment delivered to Metro or its designee.

6. Software revisions shall be verified through validation and verification to prevent accidental or unintentional changes.
   a. Subsequent submittals of Application Program Logic shall use a method of reduced validation whereby the new program is compared to the previous version and only the changes are depicted in addition to the entire program.

7. If commercial AC power is required as an input to the racks or any equipment provided for the microprocessor interlocking, such voltage shall not exceed 120VAC.
   a. Terminals on the rack or unit energized with commercial AC power shall be grounded or have terminals or provisions for grounding.
   b. Cord connected equipment not of the double insulated type shall have a ground conductor and plug.

8. Provide grounding, bonding, surge suppression devices, materials and wiring to minimize damage to equipment from atmospheric lightning strikes and conducted transient voltage strikes.

9. Equipment shall be provided complete with necessary isolation and power regulation devices to ensure proper performance and reliability.
   a. Design, fabrication and installation shall be such as to make it immune from noise and transients.
   b. Solid-state equipment shall be immune to electrostatic discharges to devices and surfaces exposed to human touch during operation or servicing.

10. Modular Design - Equipment shall be rack mounted in card files module complete with accessories and shall be modular in design.
    a. Plug-in printed circuit cards shall be used wherever possible and they shall be keyed or configured such that a card cannot be installed in the incorrect position.
b. Electronic components, except primary surge protection and voltage adjusting resistors shall be mounted on plug-in circuit cards or plug coupled subassemblies to facilitate testing and maintenance.

11. Connections - Connections to external non-electronic signal apparatus shall be on binding posts, plug couplers, or other solderless connectors.

12. Inputs/Outputs (I/O):

a. Inputs - The microprocessor system shall provide vital and non-vital inputs. A visual indication, such as a LED, shall be provided for each input on the input board. It shall illuminate continuously when the input is activated. Vital inputs for the equipment shall have an option to selectively de-bounce each input. Vital inputs shall be electrically and physically vitally isolated from each other.

b. Outputs - The microprocessor shall provide vital and non-vital outputs. A visual indication, such as a LED, shall be provided for each output on the output board. It shall illuminate continuously without use of a pushbutton when the output is activated. Vital outputs shall be electrically and physically isolated from the logic power supply. If output is used to drive double break circuitry, the output shall be physically and electrically isolated from each other. Electrically isolated shall be interpreted to mean a minimum of 2000 V rms.

c. Serial I/O - If the design requires more than one microprocessor per location, the microprocessor system shall provide vital serial links between the processors. Serially transmitted data between subsystems shall be updated every second maximum to ensure integrity of the communication link.

13. Identification - A label shall be provided for each input and output indication which denotes the respective function of each to facilitate troubleshooting and maintenance. Internal Diagnostics - The processor subsystem shall incorporate vital self checking tests to ensure that the equipment and program are functioning as intended. The checks shall be integral parts of both hardware and software to provide for a secure system.

a. A vital processor shall not allow false information to persist long enough to allow an unsafe condition to occur, or allow false information to be transmitted to external devices which will create a hazardous condition. Processor shall use a vital "kill" relay circuit to de-energize all outputs in the event of a safety related I/0 or processor failure. The "kill" circuit shall deenergize all outputs in a time less than the fastest activation time of any external device connected to a vital output. The kill circuit shall use vital circuit design techniques to assure that no false signal that could be generated by any other device in the relay housing i.e. power supplies, audio or coded equipment, or harmonics of these devices shall energize the output power relay.

b. Provide visual indicators, such as LEDS, to demonstrate that the system is functioning as intended; similarly provide failure and diagnostic indications.
Indicators shall isolate a failure to a particular function, or the interface between two functions.

c. Transmission of false information from a non-vital to a vital subsystem shall not affect the safety of the vital subsystem.

d. System outputs shall be positively monitored with independent current/voltage sensors and compared to the requested value. The "kill" circuit shall de-energize all outputs and shutdown the system when the outputs fail to correspond to the required state or a more restrictive state. Diagnostic checks shall act on current (fresh) data only. Memory locations used to determine the proper states of inputs and outputs shall be cleared or overwritten prior to being reused during each cycle of tests to ensure the integrity of the check. The diagnostic checks shall be independent of the application logic for the system. The system shall attempt an automatic restart after executing safety checks.

e. Diagnostics shall check to assure synchronized tasks shall execute correctly in the proper order. Checks shall shutdown the system in the event the processor is overloaded.

14. Power Supply - Each microprocessor unit shall be energized from an uninterruptible power source.

15. Access - A method of security shall be provided to allow only authorized user access. The system shall not interfere with operation of the wayside processor system. A second level of security shall be provided to access to system menus that all configurations and settings of the system to be modified.

16. Timers - Provisions shall be made in the design to adjust the vital and non-vital timer settings associated with the logic without changing the program. The timer configuration menu(s) shall be accessed in the highest security tier. Adjustable vital timers shall include a means of sealing the time setting and recording user, date and time of the change.

a. Event Recording - The Contractor shall provide microprocessor based event recorders containing non-volatile solid-state memory for data storage. Event recorders shall be a multi-channel, multi-speed system containing self-test capability and battery backup. Event recorder memory data storage shall function as a circular queue. When memory storage capacity is reached, the oldest event will be erased and replaced with the event containing the newer information. Event recorders shall have the capability of retaining all of the data for 480 train moves per day for seven consecutive days before recycling. Each event will be date and time stamped. The event recorder shall record the following information:

1) Track Circuits
2) Signal Request
3) Signal Clear
4) Switch Request

5) Switch Position

6) Route Status

7) TWC Code

8) Route selection, Train to Wayside Communication (TWC) or Yard Operations

9) All Alarms

b. The Contractor shall provide a barrier strip terminal block of adequate terminals and ten percent spare terminals to interface with event recorder external circuits.

17. Trouble-Shooting Connection - The microprocessor system shall be capable of interconnection to a portable device that permits interrogation (via keyboard/keypad) and observation (via monitor/display) of internal logic bits during testing and normal operations. This interface shall use English-Text and Arabic numeral nomenclature with explanation of faults in easy to read text.

18. Operator interface shall be via menu driven commands with an on-line HELP feature to describe use of commands. This connection shall also allow access to view the recorded events stored by the system.

19. The microprocessor system shall be designed to operate in the presence of the following noise sources:

a. Lightning surges and voltage surges from external power distribution systems;

b. Transients from nearby power lines, propulsion return currents, back EMF from operating relay coils, arcing contacts, RF noise such as hand-held radios; and

c. I/O wiring from the I/O card file to external terminal strips

20. Parts shall be available for a minimum of ten (10) years after Final Acceptance.

B. Software Application

1. The logic shall be defined in terms of traditional relay logic and shall be converted to Boolean algebraic expressions. The Boolean expressions shall then be submitted to a high level compiler provided by the Contractor that converts Boolean algebra to machine language or application code. The application code shall reside in EPROM that shall be plugged into sockets in the microprocessor. The microprocessor shall execute the application code and perform vital and non-vital interlocking control tasks.
2. Furnish two (2) spare copies of the executive and application logic EPROM for each location.

3. Group application software as follows:
   a. Software defined system control statements;
   b. Software defined system indication statements;
   c. Vital and non-vital input and output definition statements;
   d. Serial communication I/O statements;
   e. Flashing/coding definition statements; and
   f. Application logic statements.

2.11 GROUND DETECTORS

A. Ground detectors for AC and DC buses shall be located on or in the vicinity of the power racks. Product information on ground detectors shall be submitted to the Authority for approval.

1. Ground detectors shall have the sensitivity to detect a minimum ground leakage resistance from either AC or DC supply bus. The ground detectors shall be rack mounted in the train control bungalow. The level of ground detection shall be as approved by the Authority.

2. Each DC ground detector unit shall be provided with three indications and a test control. Two indicators, one each for positive and negative, shall indicate the presence of a ground. The third indicator shall indicate that the ground detector is operating properly and no grounds are present. Separate DC ground detectors shall be provided for each DC voltage supply.

3. One AC ground detector shall be provided for each ungrounded AC power supply in each train control bungalow. Each AC ground detector shall have two indications and a test control. One indicator shall indicate the presence of a ground. The other shall indicate that the ground detector is operating and no grounds are present.

4. Ground detectors in the bungalows shall be provided with alarm contacts for connection to a summary alarm to the SCADA system.

B. Each DC ground detector shall be sensitive enough to detect leakage currents from either terminal of the floating supply to ground through leakage paths having resistance as high as 7,000 ohms.

C. Ground detection scheme shall be immune to transient current flows that may be the result of charging distributed supply-to-ground capacitances. It shall also be immune to induced power line ripple that may exist between the supply leads and ground.

D. Ground detectors shall have a memory capability to provide an indication of a momentary leakage condition. The memory shall be held until reset by a push button provided for that purpose.

E. Operation of ground detectors shall not interfere with operation of power or signal circuits or equipment.
F. Ground detector circuits shall meet the fail-safe design criteria with respect to open circuits. Furthermore, the shorting and opening of any component part of the ground detector circuits shall be detectable.

G. Made ground in the ground detecting part of circuits shall be checked to validate its presence. This check shall be made in a fail-safe manner.

H. Ground detector repeater relays shall be vital relays and shall be energized when no ground is detected.

I. Ground detector circuits shall operate in a stable condition over the specified temperature range and over the voltage range specified for each power supply being monitored as specified within these Specifications.

J. Each ground detector shall be equipped with a three-position, center off, momentary contact test switch to check the operation of that detector, by providing momentary 7,000 ohm-to-ground leakage paths for the DC buses being monitored.

K. It shall be required to manually reset the ground detectors to their normal operating condition after a ground has been detected and eliminated.

L. Each ground detector shall be equipped with indication lights:
   1. To indicate that both buses are clear of grounds
   2. To indicate that a ground has occurred on that bus

M. Each ground detector shall be equipped with one independent isolated contact for remote indication of alarm condition.

2.12 LIGHTNING PROTECTION

A. Provide lightning arresters and other circuit protection devices necessary to protect bungalow and wayside equipment from damage and false operation due to lightning. The lightning arresters shall comply with AREMA C&S Manual, Part 11.2.1, for lightning protection. Product information for all types of lightning protection shall be submitted to the Authority for approval.

B. The Contractor shall provide lightning protection and surge protection that is effective in protecting all power equipment and downstream equipment from damage and operational malfunction. The Contractor shall provide as many applicable types and stages of protection as required to protect each type of circuit and equipment involved.

C. Primary surge arrestors shall have the ability to shunt high current surges to ground with little overshoot.

D. Secondary surge suppressers shall have the ability to shunt-to-ground any surge overshoot from the primary arrester devices.

E. Protection devices shall be wired, mounted and located so that triggering or fault of the device shall not damage the facility or other equipment. If required, protection devices shall be fused to prevent damage.
F. Provide 10 amp fuses in series with each track lead. Provide any additional protective devices that the equipment manufacturer recommends.

2.13 FILTERS

A. Filters for train detection and TWC reception circuits shall be designed for narrow passband and sharp cut-off characteristics. Filters used in fail-safe circuits shall be designed to prevent undesired signals from passing through the filter at levels that could cause unsafe conditions, even in the event of a component failure within the filter.

1. Half power points (3db) shall be a maximum + 13 Hz from the center frequency.
2. Ripple within the passband shall not exceed 1db.
3. Filter output shall be down 60db at maximum + 75 Hz from the center frequency.

2.14 RACKS

A. Equipment Racks:

1. Construct rack frames of minimum 14 gage cold-rolled steel. Design the frame unit for installation on 24 inch centers maximum. Construct panel mounting angles with standard hole spacing.
2. Racks shall be of the same height. Rack construction and final installed assemblies shall be in accordance with CBC and all local codes.
3. Provide chassis supports or guides for auxiliary support of heavy equipment, such as power supply equipment. Provide chassis supports allowing side-to-side guide adjustment.
4. Identify racks in accordance with requirements given in Section 34 42 55 – Marking and Tagging.
5. Cable support bars and hardware shall be provided to protect wiring and cabling from chafing due to vibration, and to relieve stress. Provide grommets and padded edges whenever cable rounds a metal edge.
6. Provide cable ties to keep bundles of internal and external wiring separate. Implement wire harnessing to provide neat and orderly routing, with wires to each device exclusive and together.
7. Provide terminals meeting requirements specified in Section 34 42 60 – Miscellaneous Train Control Products. Identify or tag each terminating wire in accordance with the requirements of Section 34 42 60 – Miscellaneous Train Control Products. Provide insulation caps for terminals with a nominal potential greater than 50 volts.
8. In each equipment rack provide a minimum of 15 percent spare terminals or two spare terminals for each energy type used in the rack, whichever is greater.

B. Relay Racks:
1. Provide and mount relays on racks at least 12 inches from floor of room and no higher than 78 inches from floor.

2. Locate terminal and plug connector panel (if applicable) on upper portion of the rack for connecting wiring and cabling external to the rack.

3. On each relay rack, provide space within the specified usable relay mounting area of the rack for a minimum of 10 percent additional relays or space for two relays, whichever is greater. Also, if utilized, provide space for a minimum of 2 spare cable plug connectors or 10 percent, whichever is greater.

4. Attach no more than two wires to a connector. Each wire shall be of sufficient length to permit it to be moved to any contact on same relay.

5. Mount relays so that the movable contacts move vertically when installed and the movable contact drops when the relay is de-energized.

2.15 FIRE DETECTION SYSTEM

A. Smoke detection, heat detection, and manual pull stations shall be provided and installed in each train control bungalow in accordance with Specification 28 31 00, Interior Fire Alarm System.

B. The fire alarm control panel (FACP) shall be mounted in an equipment rack within the bungalow.

C. Provide wall mounted fire extinguisher suitable for electrical fires.

2.16 INTRUSION DETECTION SYSTEM

A. The intrusion detection system shall be provided and installed in each train control bungalow in accordance with Specification 28 13 00, Electronic Access Control/Alarm Monitoring System.

2.17 COMMUNICATIONS EQUIPMENT

A. Telephones

1. The Contractor shall provide and install two (2) analog telephones in each bungalow as shown in the Contract Drawings. The telephones in each bungalow shall be punched down to share the same phone extension. The Communications Contractor shall supply and install the telephone punch down terminal in the bungalow. The Communications Contractor shall also supply, install and terminate the 25 pair copper telephone cable in the bungalows. This cable will connect the bungalow phones to the Facility telephone system.

B. Data Distribution

1. The Contractor shall provide all converters, panels, cables, terminations, and any other equipment necessary to provide controls and indications, including all alarms, to the yard control panel in the Yard Operations Control room. The Communications Contractor shall install 12 strand, single mode, fiber optic cable and 12 strand, multi-mode, fiber optic cable from the Communications room to
the bungalows. The Communications Contractor will terminate the fiber optic cables at the Communications Contractor provided fiber optic patch panel.

2. The Contractor shall provide all converters, panels, cables, terminations, and any other equipment necessary to provide the data bits required to accommodate the mainline/yard interface as described in these Specifications and shown on the Contract Drawings. The Mainline Contractor shall provide, install and terminate in each bungalow one (1) 19C #14 copper cable and one (1) 12 strand fiber optic cable.

C. Communications Room (Main Building)

1. All data from the bungalows to Yard Operations Control will be terminated in the Communications Room. The Contractor shall connect the communications equipment in the termination racks to the two (2) train control racks provided in the room. The Contractor shall provide all equipment and panels need to convert the data to the format required by the Yard Control Computer (server) in those racks to provide the proper functioning of the Yard Control Panel, located in Yard Operations Control. An under floor cable tray from the train control racks in the communications is being provided for cabling required between the two rooms.

2.18 ELECTRICAL AND ELECTRONIC COMPONENTS

A. Design and construct fusing of all DC power supplies and circuitry according to the following requirements:

1. Circuit breakers and fuses shall be the correct side-band rating for circuit current interruption and shall protect the electrical equipment and circuits from short-term and long-term overloads.

2. Fuses shall be sized to protect the wire.

3. Fuses shall be in the positive leg of the power supply.

4. Fuses shall be of the non-renewable, fiber-case, time-lag, fusion type.

5. Fuses of a correct and rated size shall protect electrical apparatus and circuits.

6. Provide indicating fuses for those circuits as described herein and shown in the approved design drawings. Indications shall be both electrical and visible.

5. All branch feeds for a circuit shall be from the same fuse to prevent fuse cascading due to branch fusing carrying loads for other circuits.

6. Fuses shall be no smaller than 5 amperes unless otherwise shown on the Drawings.

7. Loads shall be divided so that no normal operating current is more than 75 percent of the fuse rating.

8. Fusing shall be functionally oriented to minimize the equipment affected by a blown fuse (i.e., per track, switch control circuits, etc.)
9. Fuse clips shall retain their resilience under installation and service conditions so as to ensure a positive contact between the clips and the fuse. Fuse clips shall be mounted to phenolic or fiber plates for mounting to the top of the rack.

B. Disconnect Switches

1. Disconnect switches shall be wall mounted. Disconnect switches shall not be mounted close to entrance door.

2. Disconnect switches shall be mounted level and plumb.

C. Printed Circuit (PC) Cards and Connectors:

1. The PC cards shall be mounted in 19-inch card files unless otherwise approved by the Authority.

2. The PC wiring shall be organized so that wires serving the same function shall be connected to the same terminal of PC cards. PC cards containing the same circuitry and programming, where applicable, shall be interchangeable between subsystems.

3. The design and construction of PC cards of the same subsystems shall be the same. Cards of different subsystems shall be of the same design and construction wherever practicable.

4. PC cards shall be of glass epoxy construction. Card material shall meet the requirements of NEMA, Type FR-4. Cards shall have sufficient thickness to permit easy insertion and removal without buckling or breaking, and shall be physically keyed to protect against incorrect interchange. Circuits shall be formed by etching. Conductor material shall be copper and shall be protected from exposure to air.

5. PC cards containing components that may be damaged if a plug connector or plug-in unit is removed while the equipment is energized shall be clearly identified in the Operations and Maintenance Manual(s). PC cards shall be marked or labeled with a warning note on the individual board, be conspicuously located on the module, or by an alternate means as approved by the Authority. A means shall be provided to remove power from the module or card file.

6. Components mounted on the PC card, weighing more than 1/2 ounce or with a displacement of more than 1/2 cubic inch, shall have a mechanical supporting attachment to the card separate from all electrical connections.

7. Do not stack or piggyback PC sections in order to accomplish changes or modifications to wiring or components on printed circuit cards.

8. Connectors shall have plating with a minimum thickness of 0.00005 inch.

D. Printed Circuit Card Files:

1. There shall be not more than one type of card file for each size of PC card. The card file plugboards shall be registered to agree with the registry of the
associated PC card. PC cards shall not project beyond the front of the equipment rack when mounted in the card file.

2. Arrange the circuitry in such a manner that terminals assigned to a given power supply, common, or ground shall be the same on each PC board wherever possible.

3. Design the PC boards to bring all LED indicators, potentiometers, and test jack connectors to the card edge where they can be used without use of an extender board.

4. Provide PC boards with pulling handles.

5. Solder components to the board by flow soldering.

6. Provide edge spacers to prevent contact of component on one PC board with adjacent PC board.

7. Card files shall be installed in dust-proof cabinets and protected with dust covers.

8. Insulated cable clamping devices shall be located on the back of the file in such a way that wires terminating in the files shall be installed in a neat and secure bundle, rigidly supported, and protected to prevent chafing of insulation. Cabling provision on the file shall permit wires to enter or leave the file from both the right and left sides. Such cabling shall not restrict access to the card file when the rear covers of the card files are removed.

9. Printed Circuit Board Edge Connectors
   a. Printed circuit board edge connectors shall make contact with terminals on both sides of the PC board and shall be gold plated.
   b. Edge connector shall be rated to remove and insert PC board 50 times minimum without degrading performance.
2.19 TRACK CIRCUITS

A. Track circuits to be furnished and installed shall be low voltage power frequency single rail matching transformer or balancing impedance type.

B. Track circuit shall be as specified in the AREMA C&S Manual, Part 8.1 and meet the following requirements:

1. The track relay shall be a vane relay, normally energized and shall meet the relay requirements of these specifications.

2. Single rail power frequency track circuits shall not share components except for the primary of the transformer.

3. Adjustable resistors conforming to the AREMA C&S Manual, Part 14.2.15 shall allow shunting sensitivity adjustment in conjunction with transformer taps. The track circuit relay shall de-energize whenever a 0.06-ohm shunt is placed across the rails. When adjusted, the relay track coil current shall be less than 75 percent of the minimum drop-away current of the relay whenever the 0.06-ohm shunt is applied. The shunting requirements shall be met for a range of ballast resistance conditions from 5 ohms per thousand feet to 100 ohms per thousand feet.

4. Provide power frequency track transformers rated for 120 VAC input, and 15 VAC output. Secondary windings shall be provided with taps to supply voltages in approximately 1-volt steps from 1 to 15 VAC. Provide taps in primary windings for 110 and 120 VAC. Track transformers shall be capable of carrying track circuit load plus 25 percent overload. Transformers shall be air-cooled, dry type, conforming to AREMA C&S Manual, Part 14.2.10.

5. Track circuit equipment shall operate in an ambient temperature from -20 to +55 degrees Celsius.

6. The track circuits shall be capable of functioning as intended under the EMI/RFI conditions that will be present. Track circuit design shall consider EMI/RFI
conditions that exist in conjunction with 750-volt DC propulsion systems, inverter-controlled light rail vehicles, and adjacent utility company power distribution systems. Track circuit(s) shall be compatible with any other type of track circuit equipment in the right of way and the insulated joint and bonding arrangement. No frequency between 200 Hz. and 725 Hz. shall be permitted.

C. The Contractor shall be responsible for adding any additional equipment at no additional cost to the Authority (i.e., power amplifiers, surge protection, line coupling, and loops) that is required for proper operation of the track circuit equipment.

D. The track circuit equipment for each track circuit shall permit adjustment of each of the operating characteristics including but not limited to:

1. Track transmitter voltage.

E. Receiver sensitivity

1. Switches shall not operate if both track circuits adjoining the switch are occupied.

2.20 Train-to-Wayside Communication (TWC)

A. The Contractor shall provide a TWC system compatible with Hanning & Kahl GmbH & Co’s HCS-V system. TWC loops shall be provided at the locations shown on the Contract Drawings.

B. The TWC shall not take effect unless the TWC track is occupied.

C. The TWC system, when utilized by the Train Operator, shall align the approaching switch to the position requested by the Operator. Each switch must be called by TWC, when not called by the Yard Controller.

PART 3 - EXECUTION

3.01 RELAYS

A. Install relays on relay racks in train control bungalows.

B. Ensure that relay operating characteristics have not been altered due to damage during shipping, relocation or storage procedures.

C. All temporary wiring shall be RED in color.

D. Spares are to be delivered to the Authority 10 days before any portion of any new equipment room or instrument house is put into service.

E. Submit the rack layouts and description of the manner of tracking and locating the next upstream repeater for each relay in a working group for approval by the Authority.

F. The Contractor shall ensure that all DC power buses are open while installing relays and shall not reconnect buses until all relays are installed.

G. Power feeds through switch mechanism control relays shall be closed only during testing, prior to in-service operation.
3.02 PLUGBOARDS

A. Provide relay plugboards that are factory mounted and wired.

B. Use non-corrosive fasteners to mount plugboards.

C. Wires terminating at a relay shall have sufficient length to connect to any terminal on the relay. Provide sufficient slack to enable three re-terminations of the conductor without requiring replacement of cable conductors.

D. The wire on each contact shall carry the same style of tag indicating the same information now on the current tags including:
   1. Destination
   2. Relay position and contact number

3.03 MICROPROCESSORS

A. NOISE MITIGATION

Suppress or prevent noise from entering into the system using the following practices:

1. Use lightning arrestors and secondary surge suppressors to protect against lightning and other voltage surges in accordance with AREMA Signal Manual, Part 11.2.1;

2. Ground all card files, modems and other system components to the cabinet ground stud to earth ground through a capacitor to establish ac ground;

3. Connect shields on serial communication cables to earth ground on one end only;

4. Provide required load to unused outputs;

5. Ensure proper pickup and drop-away relay currents per relay specifications when interfacing relays to I/O card files;

6. Install standard suppression on all relay coils;

7. Use twisted pair wires for all inputs;

8. Shorten wire harnesses from I/O card files to external terminal strips and dress these wires away from the CPU;

9. "Oversize" power supplies and design associated power busses to minimize noise produced by voltage drop of transient currents. External filtering may be used to reduce transient current noise on the power bus;

10. Separate connections to external apparatus from internal wiring carrying processor signals;
11. Keep cabling between card files as short as possible to minimize induced noise; and


3.04 TRACK CIRCUITS

A. Track circuit equipment shall be installed in the racks provided in the train control bungalows.

B. Cable Routing - Connect the track circuit equipment to the rail with wire size as shown on the approved design and installation drawings, via the entrance rack and wayside pull box. The cable shall be installed in PVC coated galvanized rigid steel conduit from the pull box to the rail.

C. Rail Connections - Exothermically weld a stranded bond stub to the web of the rail. The track circuit cable from the pull box shall be exothermically spliced to the stub and the splice covered in heat shrink tubing. Provide a loop in the cable to allow sufficient slack for ten re-terminations.

D. Locations of insulated joints shall be verified by the Contractor. Installation of insulated joints shall be coordinated with the trackwork installation.

E. If the Contractor's design requires additional track circuits, insulated joints, wayside cable, etc., it shall be the Contractor's responsibility to furnish and install the equipment at no additional cost to the Authority.

END OF SECTION 34 42 24
SECTION 34 42 33

YARD CONTROL PANEL

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. American Railway Engineering and Maintenance-of-Way Association (AREMA):

B. Reference Documents:
   1. MIL-STD 1472G - Human Engineering

1.02 SUMMARY

A. Work to be done under this Section consists of design, furnishing, installing, testing and commissioning of circuits, software, and hardware for an operating, computer-based Yard Control Panel system. The Yard Control Panel shall be located in the Yard Operations Center (YOC) as specified herein and as shown on the contract drawings.

B. Work shall include providing the design and equipment required to interface controls and indications between the train control bungalows and the YOC. The Contractor is responsible for providing a list of all controls and indications needed for complete operation of the yard from the YOC. All track circuit indications shall be provided at the YOC. The Contractor shall provide software and hardware for controls and indications data transfer between the Yard Control Computer (YCC), bungalows and the Yard Control Panel (YCP) as approved by the Authority.

1.03 SUBMITTALS

A. All submittals are provided to the Authority for review and approval prior to the manufacturing of the yard control panel and associated equipment. Any work performed prior to submittal approval shall be at the Contractor's risk.

B. Required Submittals:

1. Product Data: Submit the product data including computer hardware and software specifications, wiring details, and plug connector details. When catalog cuts with multiple items are provided, the Contractor shall clearly identify data to be evaluated by the Authority.

2. Screen Design: Submit the screen design, including color scheme for Authority approval.

3. Preliminary Design Package shall include:
a. A preliminary software functional description, to allow the Authority to review the Contractor's theory of the yard control panel operation.

b. Proposed graphical descriptions, including user inputs, local control indications, and alarm indications and required operator responses.

c. Preliminary assembly drawings.

d. Preliminary installation drawings.

e. List of controls and indications on the panel.

4. Final Design Review Package shall include:

a. A complete software functional description that includes operating instructions and graphical descriptions of all user inputs and local control indications.

b. Screen display arrangement drawings showing mounting location of all signal equipment. Drawings shall include comparison of operating track direction to panel orientation.

c. Assembly drawings with a keyed parts list showing ordering numbers for replacement parts for all equipment within the local control and indication panels provided under this Contract.

d. List of controls and indications incorporated into the panel.

5. Test Procedures and Results: Submit detailed factory installation, operational functionality, and system integration test procedures and test results in accordance with these Specifications.

6. Installation and Inspection Procedures: Submit detailed installation and inspection procedures.

7. Any other submittal called out in the Specifications.

1.04 QUALITY ASSURANCE

A. The yard control panel components shall be new and free of defects.

B. All yard control equipment shall be tested before shipping. Factory testing shall be conducted in accordance with the Contractor's Factory Test Procedure as approved by the Authority. Prior to shipment, a copy of the manufacturer's certification of factory tests performed shall be forwarded to the Authority.

C. All electrical components in these Specifications shall be rated to operate at power, voltage, current and temperature levels 20 percent above the level components shall be subject to in normal service unless otherwise specified.

D. The yard control system shall be inspected by the Authority after it has been installed in the YOC. This inspection shall conform to the Installation and Inspection Procedure as approved by the Authority. Installation shall not be considered complete until all installation and operational defects have been corrected to the Authority's
The yard control system shall be tested according to Authority approved test procedures.

The yard control systems shall not be considered complete until all operational defects have been corrected to the Authority’s satisfaction.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Yard Control Interface Panel

1. Above the desk in the operations section of the YOC, the Contractor shall provide a small panel equipped with a reset button, key switch override, audible alarm, and a data connection for a laptop computer.

   a. The reset button shall reboot the Local Control Computer (LCC)
   b. The data connection permits LCC operation with a laptop during an LCC failure

B. Display

1. The yard control panel display shall be LCD based screen or other Authority approved solid-state screen. The screen mounted on the dispatcher’s desk in the YOC.

2. Display shall be sized to comply with the requirements of Mil Standard 1472G.

3. Display Layout

   a. The top portion of the display shall include the track plan. Orientation of the plan shall be so that it is geographically correct, relative to the track and desk location in the YOC. The layout shall be sized to allow the operator to clearly see the status of the equipment and track circuits. The yard layout shall be able to be scrolled to the required section of the yard by waving the mouse to relocate the track position on the screen.
   b. The bottom portion of the display shall have text boxes to reflect user input and alarm status.

C. Computer

1. The local control computer (LCC) and associated equipment as specified herein shall be an industrial grade computer that is rack mounted in the communications room located adjacent to the YOC. The computer and associated equipment as specified herein shall be rated to operate without functional degradation or failure as a result of shock or vibration as manufactured by Mil Tec Equipment and Systems Pvt. LTD, or approved equal.
2. Memory

a. The LCC shall be provided with a minimum of 1 gigabyte of RAM and shall also satisfy the requirement that when the application and operating system are loaded and functioning at the peak performance level, 50% of system RAM shall be unallocated.

b. The LCC shall be provided with a hard drive sized to store the complete and fully installed operating system including its utilities and its support software as well as the approved local control software. The hard drive shall also be sized such that a 75% spare hard drive capacity shall be available following 180 days of continuous operation.

c. Each LCC shall be provided with keyboard and mouse.

2.02 FUNCTIONAL REQUIREMENTS

A. The display shall provide user controls and indication interface as required to effectively and efficiently operate the yard using entrance/exit control.

B. The display shall be ergonomically designed and shall provide logical and unambiguous objects and methods that critically minimize the human man-machine interface interactions required to view indications and perform control functions.

C. Display Objects

1. The track display shall include the following objects:

   a. Track
   b. Switches
   c. Signals
   d. Track Circuits

2. The supervisory portion of the screen shall include:

   a. Execute Button
   b. Cancel Button
   c. Alarm Acknowledge Button
   d. User Input Text Box
   e. Alarm Text Box

D. Indications and Colors

1. The colors specified herein are subject to review and may be modified during the preliminary engineering phase. In the Train Control System preliminary design review, the Contractor shall submit color scheme for Authority approval.

2. Background

   a. Display background shall be black.

3. Track and Track Circuits
a. Unoccupied track shall be indicated with a gray line.
b. White perpendicular lines shall indicate the track circuit boundaries. When a track circuit becomes occupied, the track line corresponding to the occupied circuit shall expand in width to approximately four times that of the unoccupied track and shall be colored orange.
c. Track circuit names shall be indicated in white text. Where space permits, track circuit names should appear between the tracks in double track areas.
d. The display shall include indications of mainline track circuits as shown in the contract drawings and all track circuits that are controlled by the train control bungalows.

4. Switches

a. Track segments that correspond to the indicated switch position shall be solid line type. A section of track in the opposite position shall be a dashed line.
b. When a switch is requested, the section of track corresponding to the requested position shall become a solid flashing line while the switch is out-of-correspondence. When the switch indicates correspondence, the line in the requested position shall stop flashing and become solid and the opposite section of track shall become dashed.
c. When a switch is blocked, the switch shall be outlined by a blue box.

5. Signals

a. Signal symbols shall consist of a single solid circle with a line indicating the mast and base.
b. The circular part of the signal shall be red for signals at STOP. The lines depicting mast and base shall be white.
c. When a signal is selected as an entrance, the circular portion of the signal symbol shall turn steady white. All possible exit signal symbols shall flash white. When the signal is cleared, it will turn solid green.
d. When a signal exit block has been selected, the signal symbol shall be shown in a solid blue box.
e. Signals in time locking shall be indicated by a flashing red signal symbol.

E. Controls

1. Signal and Route Control.

a. Prerequisites for route operation:

1) There are no conflicting or opposing routes aligned and the desired track section is available.
2) The exit is not blocked.
3) Switches in the route are not blocked out-of-position for the desired route.
b. Right-clicking the mouse button with the cursor over the desired entrance signal shall initiate a drop-down menu with the following commands:

<table>
<thead>
<tr>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>N / X</td>
</tr>
<tr>
<td>Signal Cancel</td>
</tr>
<tr>
<td>Call On</td>
</tr>
<tr>
<td>Call On Cancel</td>
</tr>
<tr>
<td>Block</td>
</tr>
<tr>
<td>Block Cancel</td>
</tr>
</tbody>
</table>

c. Selection of “N / X” while the cursor is over a signal will designate that signal as an entrance, provided another entrance has not already been selected. With an entrance designated, selecting “N / X” with the cursor over a signal indicating that it is a valid exit will cause the exit to be selected. When an entrance/exit pair has been selected, the route shall be requested. The requested route will flash until the “Execute” button is clicked, at which time the route request will be implemented.

d. Selecting “Signal Cancel” with the cursor over a signal will cause the signal to be canceled if it is clear. Alternatively, the program shall allow multiple signals to be selected by left-clicking on the signal, and then right-clicking over a selected signal and selecting “Signal Cancel” and the “Execute” button.

e. Signal Exit Blocks shall be requested and canceled in the same manner.

2. Switch Control.

a. Prerequisites for switch operation:

1) There are no conflicting or opposing routes aligned and the desired track section is available.
2) The switch is not in the desired position.
3) Switches in the route are not blocked.
4) Switch is not locked or the route occupied.

b. Right-clicking the mouse button with the cursor over the desired switch shall initiate a drop-down menu with the following commands:

<table>
<thead>
<tr>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set Normal</td>
</tr>
<tr>
<td>Set Reverse</td>
</tr>
<tr>
<td>Block</td>
</tr>
<tr>
<td>Block Cancel</td>
</tr>
</tbody>
</table>

c. The user shall be able to operate switches by placing the cursor over the switch, pressing the right mouse button, selecting the “Set Normal” or “Set Reverse” menu item and clicking the “Execute” button. The user shall be able to select multiple switches using the left mouse button to make the same request for all selected switches.
d. Switch blocks shall be requested and canceled in the same manner.

3. Alarm conditions shall be displayed at the bottom of the screen. New alarms shall be colored red and blink until acknowledged. Each new alarm shall also cause an audible alarm until acknowledged. Alarms conditions shall include, but are not limited to the following (as appropriate):

a. 60 Hz. Power Off  
b. 100 Hz. Power Off  
c. AC GROUND  
d. DC GROUND  
e. AC Blown Fuse  
f. DC Blown Fuse  
g. Data Transmission System Failure  
h. Intrusion Alarm  
i. Fire Alarm  
j. Processor Alarm Non-Vital  
k. Battery Charger Failure

2.03 DELIVERY, STORAGE AND HANDLING

A. Not Used

PART 3 - EXECUTION

3.01 PRODUCTION

A. Not Used

3.02 INSTALLATION

A. Yard Control Panel shall be located in the YOC.

B. Location of panel shall permit convenient use by an operator sitting in front of it.

C. Any damage caused during installation shall be repaired. Restored finish shall be equivalent to factory finish and performed in a manner satisfactory to the Authority.

3.03 TESTING

A. Yard control panel and system shall be tested in accordance with these Specifications.

B. All wayside functions, controls and indications shall be tested and discrepancies shall be corrected.

END OF SECTION 34 42 33
SECTION 34 42 42

SIGNAL LAYOUTS, STRUCTURES AND FOUNDATIONS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS


B. Specification Sections, including, but not limited to:

1. Section 03 30 00 - Cast-in Place Concrete
2. Section 10 14 55 - Railroad Signage
3. Section 34 21 55 - Grounding and Bonding
4. Section 34 42 58 - Train Control Systems Testing
5. Section 34 42 60 - Miscellaneous Train Control Products

1.02 SUMMARY

A. The work to be done under this Section shall include manufacturing, furnishing, installing and testing color light type signal and indicator layouts. Signal layouts shall include junction boxes, lenses, lamps, lamp receptacles, tapped transformers, terminal board, wiring, number plate, foundation, conduit, ladder, and mounting hardware as required for each location.

B. Signal layouts, as specified herein, shall consist of foundations, signal heads and all structures including ground-mounted masts, ladders, platforms, and all mounting hardware required to construct the signals.

C. The signal layouts shall be three (3) aspect transit style signal layouts entering and leaving the yard, and three (3) aspect dwarf signal layouts in the yard.

D. The Contractor shall furnish and install signals as shown on the Contract Drawings.

1.03 SUBMITTALS

A. All submittals shall be provided for Authority review and approval.

B. Required Submittals:

1. Shop Drawings: Submit shop drawings for each type of signal unit and each type of signal layout to the Authority for review and approval. Show all ladders, masts, bases, arms, and required mounting hardware. Show location and method of mounting the signals to the structure.
a. Provide all necessary dimensions, hardware, method of mounting signal structures, and material specifications for all items to be furnished.

2. Structure Foundation Shop Drawings: Submit shop drawings for each structure foundation.

3. Factory Inspection Procedures and Results: Submit Factory Inspection Procedures 60 days prior to factory inspection. Factory Inspection Results shall be provided to the Authority within two weeks of the factory inspection.

4. Installation and Inspection Plans and Procedures: Submit Installation and Inspection Plans and Procedures for each type of signal unit. The plan shall include the overall installation plan for signals and other equipment. The procedures shall include a detailed description of installation activities in sufficient detail to allow the Authority to determine the validity of the installation procedure.

5. Installation and Integration Test Procedures and Results: Submit detailed test procedures and results of tests.

6. The Contractor shall provide manuals describing operation and maintenance of each type of wayside signal in accordance with requirements of Section 01 78 23.

7. Any other submittal required by these Specifications.

1.04 QUALITY ASSURANCE

A. Each lamp unit shall be inspected prior to shipment. Inspection shall conform to the Contractor’s Factory Inspection Procedure as approved by the Authority.

B. Signals shall meet the requirements of the AREMA C&S Manual, Part 7.1.1.

C. Foundations shall meet all requirements of AREMA C&S Manual Parts 14.1.1. A through 14.4.36 inclusive, where requirements of the AREMA Specifications do not conflict with any requirements specified herein.

D. Each signal layout shall be inspected by the Authority after it has been installed in the field. This inspection shall conform to the Contractor’s Installation and Inspection Procedure as approved by the Authority. Installation shall not be considered complete until all installation defects have been corrected to the Authority’s satisfaction.

E. Installation and Integration tests shall be performed to ensure proper operation of each complete signal layout.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Properly crate signal layouts and their component parts at the manufacturer's point of shipment.
B. Ship signal LED’s separately from the signal in which they will be used.

C. All special tools will be turned over to the Authority at the end of the Contract.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Signal Layouts: Provide signal layouts as described herein and as indicated on the Contract Drawings. Signal layouts shall include junction boxes, lenses, lamps, lamp receptacles, tapped transformers, terminal board, wiring, number plate, foundation, conduit, ladder, and mounting hardware as required for each location.

B. Signal Construction: Provide three-aspect cast aluminum signal housings with lockable hinged back doors. Doors shall not be lockable until fully closed. Doors shall have stops to prevent swinging into clearance envelope of train. Ventilate each signal head by two openings covered by fine brass mesh or stainless steel screen and hooded to minimize entrance by moisture. Signal housing shall contain three lamp compartments, separated by partitions that prevent passage of light from one compartment to another. Provide ample space for LED lamp modules and terminals in each compartment.

C. Foundations: Furnish foundations for dwarf and transit style signals as indicated in the Contact Documents.

D. LED Lamp Modules: Provide signals with 5-1/2 inch LED lamp modules conforming to AREMA standards. Equip each mainline transit signal with a red module on top, a middle green module, and a red bottom module.

E. LED Lamp Modules: Provide signals with 5-1/2 inch LED lamp modules conforming to AREMA standards. Equip each dwarf signal with a green module on top, a yellow module in the middle, and a red module on the bottom.

F. LED Module Mounting: Provide LED lamp modules with neoprene gaskets to provide a weatherproof and dustproof seal between the lenses and signal housing.

G. Visibility: When viewed from a height of 7 feet above top of rail, at a distance of 500 ft., LED modules shall present a distinct aspect under the most adverse operating conditions.

H. Hoods: Provide hoods of 6 inches minimum length for each aspect to shield the lenses and to prevent interference from the sun with the display of the aspect. Hood shall not interfere with train operator viewing aspect from 5 ft. in front of signal at 7 ft. above the top of rail.

2.02 SIGNALS

A. Provide an LED lamp module behind each lens. LED modules shall be interchangeable. Rate LEDs for 10 volts AC or DC and with a minimum rated life of 50,000 hours.
B. Transformers mounted within the signal head for each signal LED compartment shall be rated for 60 watts, unless otherwise directed, with a nominal 120-volt, 60Hz primary winding. Equip these transformers with AAR post taps to provide a voltage at the signal LED’s of from 6 to 12 volts in 1-volt steps.

C. Each signal layout shall be provided with split-base junction boxes, signal mast and ladder, as appropriate.

D. Signals shall be internally wired at the factory.

E. Each head shall be wired complete and cable conductors shall be terminated at the junction box and train control bungalow terminal board.

F. Contractor furnished signal assemblies shall include a lamp adjusting resistor in the head.

G. If lenses are necessary for the provided LED lighting unit, the outer lens shall be manufactured from high impact resistant LEXAN or Authority approved equal.

H. Lenses shall be secured to the signal head in a manner such that their removal shall not affect adjustment of lamp receptacles. Lenses shall be provided with neoprene gaskets to provide a weather-proof and dust-proof seal between lenses and signal housing.

I. The Contractor shall provide all equipment and material, including shims and any special tools required to properly focus and align signals both horizontally and vertically to obtain the proper sighting distance.

2.03 SIGNAL FOUNDATIONS

A. Provide cast-in-place foundations in accordance with Section 03 30 00, Cast-in-Place Concrete, or precast concrete foundations as manufactured by Dixie Precast or Authority approved equal.

B. Bolt spacing shall be to manufacturer's standards for the equipment to be supported by the foundation.

PART 3 - EXECUTION

3.01 INSTALLATION - SIGNALS

A. Contractor shall install signal layouts at locations shown on the Contract Drawings and as shown on the approved shop drawings. No part of any signal layout shall conflict with CPUC rules and regulations.

B. Closest edge of the signal shall be 6 feet 0 inches from centerline of track unless a deviation is approved by the Authority.

C. Install signal units level and plumb on their foundations. Leveling nuts shall be used to level signal units.

D. Align signals for a minimum viewing distance of 500 feet before placing in service.
E. Install signals and verify sighting distances. Provide the Authority with written
notification regarding any sighting problems and proposed solution to sighting
problems.

F. Signal nomenclature shall be as shown on the Contract Drawings.

G. The underground cable shall be dressed, potheaded, tagged, and terminated in the
signal junction box as specified in Section 34 42 60, Miscellaneous Train Control
Products. The conductor size of the underground cables shall be at least as large as
that shown in the Contract Drawings.

H. Wiring from the junction box base to the signal heads shall be minimum No. 10 AWG
copper stranded wire or larger as shown on the Contract Drawings.

I. Install identification tags on each wire. These tags shall bear the nomenclature shown on
the approved Shop Drawings.

J. Set lamp voltage between 8.8 volts and 9.2 volts measured at the signal lamp.

3.02 INSTALLATION - FOUNDATIONS

A. Install each foundation in accordance with the approved Contractor's Installation
Procedure for each type of foundation, as herein specified, and as shown on the
Contract Drawings. The absence of a specific task listing herein does not relieve the
Contractor of the responsibility for providing a complete and functional installation.

B. Provide signal foundations, as indicated, and meeting the requirements of AREMA
C&S Manual, Part 14.4 where it does not conflict with these specifications. Mounting
bolts for the signal shall be cast into the concrete foundation.

C. When placing foundations, exercise care and ensure that anchor bolts are not bent or
threads damaged. Protect anchor bolt threads, washers, and nuts by applying friction
tape or other accepted method satisfactory to the Authority, until the unit to be
supported is installed.

D. The Contractor shall provide foundations of sufficient depth to ensure stability. In
areas where the grade slopes, the Contractor shall build up the earth around the
signal installation and, if required to maintain the build-up, shall construct retention
structures of treated lumber such as railroad ties.

3.03 FIELD TESTS

A. Field testing shall be performed on all signal layouts in accordance with approved test
plans and procedures. These tests shall include:

B. Continuity check of field wires and verification of all nomenclature.

C. Application of energy to signal lighting circuits and adjustment of all lamp voltages to
ten percent less than the lamp rating.
D. Break down of signal clearing relay contacts and observation that proper signal aspect is displayed.

E. Sighting of signals for maximum visibility.

3.04 SIGNAL NUMBER PLATES

A. Construction: Provide signal number plates for each signal. Place the signal number plate under the lowest signal lens in the assembly, mounted to the signal assembly using fiber washers next to the enamel. Signal plates shall meet AREMA C&S Manual Part 14.6.1 where they do not conflict with the requirements specified herein. Alphanumeric characters shall be a minimum of 3 inches high.

B. Identification: Signal numbers shall be as shown on the Contract Drawings.

3.05 PAINTING

A. After installation and prior to Contract completion and acceptance, the Contractor shall touch up the exterior of each signal layout as required to cover all scratches, chips, and blemishes in the painted surface. Touch up paint shall be of the same quality, texture, and appearance as manufacturer’s finish coat.

END OF SECTION 34 42 42
PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. American Railway Engineering and Maintenance of Way Association (AREMA):
   1. Communications and Signals Manual of Recommended Practice (C&S Manual)

B. National Fire protection Association (NFPA)
   1. NFPA 70 –National Electrical Code (NEC)

1.02 SUMMARY

A. This Section includes the following:
   1. Requirements for new factory-wired Train Control Bungalows.
   2. Installation and field modification of the new factory-wired equipment bungalows by the Contractor to meet the requirements of the Contract Drawings shall meet or exceed the requirements of this Section.
   3. Design, provide and install transformers as specified on Contract Drawings.

B. Related Sections include, but are not limited to:
   1. Section 34 42 00, General Train Control Requirements
   2. Section 34 42 16, Train Control Wires and Cables
   3. Section 34 42 24, Train Control Bungalow Wayside Equipment
   4. Section 34 42 42, Signal Layout, Structures and Foundations
   5. Section 34 42 48, Switch Layouts
   6. Section 34 42 60, Train Control Miscellaneous Products
   7. Section 34 72 00, Trackwork, for track construction requirements.

1.04 SUBMITTALS

A. All submittals are provided to the Authority for review and approval.

B. Required Submittals:
   1. Detailed Installation Test Procedures and Test Results.
   2. Load calculations, indicating sizes of load center panel, voltage drops, and all other 240/120 VAC equipment.
   3. Contractor’s Inspection and Acceptance Procedure.
   4. Four (4) copies of shop drawings, showing the proposed size and equipment layout including rack, air conditioner, lighting, convenience
outlet arrangement, and exhaust fan mounting and location. Shop drawings shall be submitted within thirty (30) days of NTP.

5. Factory Test Procedures.

6. Factory Test Results.

7. Catalog cuts and descriptive literature for all power system material. For catalog cuts with multiple items, the Contractor shall clearly identify data to be evaluated by the Authority.

8. AC and DC power calculations based on the total peak load that will exist at each train control bungalow. Calculations shall include 25% spare capacity of total peak load at each location for future expansion.

9. Voltage drop calculations for 480 VAC single-phase signal power express cables in accordance with these Specifications.

10. Plans showing layout of a typical train control power distribution center.

11. The Contractor shall include schematic plans showing energy distribution of train control power equipment at each train control bungalow. These plans shall include ratings of protective devices and transformers, as well as required cable and wire sizes.

12. Circuit drawings and drawings showing power layout of feeders, transformer switches, fuses, breakers and buses.

13. Drawings, wiring diagrams and performance data for all transformers to be provided and installed under these Specifications.

14. Calculated size of transformers required to feed loads created by equipment being provided and installed under this Contract. All transformers shall be rated to carry 125% of total load continuously.

15. Provide materials describing operation and maintenance of each type of transformer.

16. Any other submittal called out in the specifications.

1.05 QUALITY ASSURANCE

A. The Contractor shall provide documentation of acceptance regarding the bungalow’s condition before removing and transporting the bungalows to the job site.

B. The Contractor shall provide documentation of Factory Acceptance Testing before transporting the bungalows to the job site.

C. Each bungalow, case, and transformer will be inspected by the Authority after they have been installed and the Contractor shall correct any deficiencies. This inspection will be conducted in conformance with the requirements of the Contractor’s accepted Inspection and Acceptance Procedure.

D. Materials and equipment provided and installed shall conform to the latest edition of the NEC and all applicable state and local ordinances.

E. Performance tests of the equipment and materials provided and installed shall
ensure compliance with these Specifications and Authority approved Field Test Procedure.

F. The Contractor shall inspect and test each transformer prior to shipment. Inspection shall conform to the Contractor’s approved Factory Inspection and Testing Procedure.

G. Transformers shall be in accordance with the AREMA C&S Manual, Part 14.2.10 for Single-Phase Transformers.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Properly fasten and brace equipment shipped within bungalows and cases to prevent damage during transit. Replace any equipment damaged during transit or prior to in-service operation at no cost to the Authority.

B. Package all vital relays, batteries, and electronic plug-in modules in separate containers for shipment and do not install until the bungalow is set at its final location.

C. Batteries shall be stored and delivered in a fully charged state. Batteries shall not be stored for more than 90 days. Batteries shall be shipped separately from housings in which they are to be used.

D. Transformers shall be protected from damage throughout delivery, storage, and handling.

PART 2 – PRODUCTS

2.01 BUNGALOW

A. Furnish and install factory-wired equipment bungalows, as described herein and as shown on the Contract Drawings. These bungalows shall be complete with all the equipment shown on the Contract Drawings. Wiring shall conform to the requirements of the AREMA C&S Manual, NEMA Standard ICS-70, or NEC, as applicable.

B. Equipment bungalows shall be products manufactured by P.T.M.W., Safetran Systems, GETSGS, or equal.

C. Equipment bungalows shall be the size and layout shown on the Contract Drawings.

D. Equipment bungalows shall be rain-tight and dust-tight, NEMA 3R, ventilated, and have hinged doors with three (3) point catch and handle and have welded construction throughout. Welds shall be 1-1/2 inch minimum in length with spacing not to exceed 6-inches where panels meet floor and roof. Spacing on panel welds shall not exceed 18-inches.

E. Equipment bungalows shall be constructed of 12-gauge galvanneal steel for floors, walls, and doors. Roofs shall be no less than 14-gauge galvanneal steel with a minimum of 50 lb/ft loading.

F. The entire structure shall be powder coated on the outside with TGIC Polyester
Powder (or equal polyester powder) with a nominal thickness of four mils, but no less than three mils at any point on the surface of the enclosure in accordance with AREMA C&S Manual Part 1.5.10. The exterior color shall be light gray.

G. The equipment bungalows shall provide access to underground and aerial cable entrance behind the main terminal rack. The top and sides shall be lined with heat and cold insulating material and constructed to prevent sweating. Provide ventilation openings as required for the size of the bungalow proposed. No ventilation opening shall be made in the roof of the bungalow. Provide lift rings to facilitate the movement of the bungalow.

H. Provide ventilation openings in each door. The exterior of the ventilation openings shall be hooded to minimize the entrance of precipitation. Equip the interior of ventilation opening with sliding plate to allow the adjustment of airflow and with a replaceable dust filter. The doors shall be hinged and gasketed so that they will provide a dust tight and weatherproof seal. Provide doors with exterior and interior handles, welded to a three (3) point locking device to ensure that the door cannot be locked until it is in the fully closed position. Provide doors with a two-position retaining device to secure the door when open.

I. Door openings shall be 32 inches wide by 86 inches tall unless otherwise specified on the Contract Drawings.

J. Provide thermostatically controlled exhaust fans, operated from 120 VAC and fused separately, in each bungalow, as shown on the Contract Drawings. The thermostat that activates the fan control shall be adjustable and operate in the range of 70 degrees to 130 degrees Fahrenheit. Locate fans relative to the fresh air inlets to draw air over the equipment and size to renew the air within the bungalow every three (3) minutes. Exhaust fans shall have removable dust filters. Dust filters shall be either replaceable or cleanable.

K. Hinges shall be separate castings, securely fastened to the bungalow and door. The hinges shall be equipped with bronze hinge pins, shall be lubricated by the manufacturer before the case is shipped, and shall have grease fittings for later lubrication.

L. Furnish equipment bungalows with interior lighting and duplex 120 VAC power receptacles. Equip bungalows with double tube fluorescent lights, minimum 40 watts each, as required to provide complete illumination for all passages and sides, and operated from a switch conveniently placed near each entrance door. Furnish convenience outlets as part of each switch.

M. Bungalow lighting and receptacle loads shall be fed from a ground fault interrupt circuit breaker used exclusively for these loads. Train control logic and train control appliance power loads shall be fed from separate circuit breakers. The train control logic power and train control appliance power shall be ungrounded. The Contractor shall size circuit breakers and wiring.

N. Furnish bungalows complete with a 120/240 VAC power distribution panel, circuit protective devices, and all appurtenances necessary to supply the AC power required at each site.

O. All access points in the enclosure shall be sealed for weather protection and
against entry of rodents. All interior and exterior seams shall be caulked with RTV silicone.

P. Enclosure foundations shall be the inner wall type and adjustable from the outside of the enclosure. The range of adjustment shall be from 36-inches to 52-inches in 1/2-inch increments. Located in the wall the foundations shall be galvanized steel, a minimum of 60-inches long, include all hardware, and a 12-inch x 12-inch x 1/4-inch footing pad. All galvanizing shall conform to the AREMA C&S Manual, Part 15.3.1

Q. Permanent vendor name plate, or equivalent, complete with vendor name, address, model number, serial number, and date of manufacture or equivalent shall be located on front.

R. Power feed to train control power distribution equipment shall be obtained from the S&I Building main electrical room. 480 VAC, 3 phase, 60 Hz. shall be provided to each bungalow.

S. Power cables for the distribution of power to train control equipment locations shall be as required in these Specifications.

2.02 BUNGALOWELECTRICAL SPECIFICATIONS

A. All vendor installed electrical products shall be UL listed. All electrical work shall conform to the NEC standards and accepted practices.

B. Conduit and device box sizes shall conform to NEC Article 370.

C. The typical Breaker box shall be Square ‘D’ 100 AMP; Model QO12M100. The breaker box shall be furnished with the following breakers, one- (1) QO120 GFI, one- (1) QO230, one- (1) QO130, and seven- (7) QO120.

D. Bushings shall be installed on all conduits entering or leaving the breaker or device boxes. An SDSA-1175 surge arrestor shall be mounted on the top of the breaker box.

E. The Breaker box ground buss shall be bonded to the breaker box and the nearest keyway using an ERICO ‘VS’ welded connection designed for this purpose. The neutral buss shall not be bonded during manufacture. The field shall bond the neutral at the remote (main) disconnect when used.

F. The neutral bonding screw shall be packaged and shipped in the breaker box for installation in the field if necessary.

G. All conduits shall be installed above the wire chase and secured to enclosure structure. Flex conduit shall not be used except when used as a drop or attached to equipment that maybe removed. All circuits must be routed in separate conduits. The fluorescent lamp fixtures shall not be used for a junction box, raceway or conduit for any circuit other than the one intended for lamp operation.
H. One (1) separate 20 AMP plug circuit shall be provided on the ‘A’ and ‘C’ walls as shown on the Contract Drawings. The end plugs shall be 8-inches from the ‘D’ wall and 18-inches from the ‘B’ wall the remaining plug(s) shall be centered between them.

I. Separate 20 AMP circuits (equipment power drops) shall be provided on the ‘A’ and ‘C’ walls. The junction boxes shall be located, above the wire chase, as shown on the Contract Drawings. The wires from the panel shall be terminated (wire nut and taped) in the junction box. One–(1) piece of aluminum flexible conduit, 48-inches long shall be supplied for each junction box and installed by the wiring shop. The conduit shall be coiled up and shipped along with other house material.

J. Bungalows shall have provisions for connection of an auxiliary generator as shown on the Contract Drawings. Provisions for this arrangement to include the following: 1ea. 125/250V 3-pole 4 wire flange male inlet plug NEMA Type L14-30P with exterior spring loaded weather proof outlet cover (Bryant #71430-MBWP). Main breakers to be 100 AMP (Square ‘D’ #QO2100) for bungalows with 2-pole 30 AMP breaker (Square ‘D’ #QO230) positioned adjacent to main breaker with mechanical interlock (Square ‘D’ # QO2DTI). DO NOT SUBSTITUTE.

K. General color code and wire specifications for all AC wiring are as follows. All wiring shall be THHN or THWN solid copper or as required by the NEC.

- GFI Breaker to Receptacle/Thermostat #10 Black
- GFI Breaker to Receptacle #10 White
- GFI Receptacle Ground #10 Green
- Thermostat to Vent Fan #14 Red
- Fan Neutral #14 White
- Breaker to Light Switch #10 Black
- Light Switch to Light #10 Red
- Light Neutral #10 White
- Breaker to Receptacle A& C walls #10 Black
- Receptacle Neutral #10 White
- Receptacle Ground #10 Green

L. The service entrance shall be a 2-inch EMT conduit, entering the bottom of the breaker box. The conduit shall extend through the floor. Sufficient length shall be left to allow easy coupling. The open end shall be capped and protected while in transit.

M. One (1) 36-inch piece of 2-inch EMT conduit shall be included along with a compression coupling. The conduit and coupling shall be secured and shipped inside the enclosure.
N. A single or 3-way light circuit shall be provided based on house size and door arrangement. One (1) 115/120V-20 AMP duplex receptacle shall be mounted with each light switch, near the main enclosure entrance (D and/or B-wall). The fan thermostat control unit shall be mounted to the light switch/duplex receptacle handy box on ‘D’ wall.

O. A minimum of two (2) double tube, 4-foot fluorescent fixtures, 40 watts each and tube guards shall be installed in each enclosure. The actual quantity and location of lights shall be based on the enclosure size or as shown on the Contract Drawings.

P. An air conditioner, sized for the structure, shall be supplied and located as shown on the typical drawings. A 30 AMP circuit, with a single 30 AMP receptacle, shall be provided.

Q. Bushings shall be installed on all conduits entering or leaving the breaker or device boxes. An SDSA-1175 surge arrestor shall be mounted on the top of the breaker box.

2.03 EQUIPMENT MOUNTING

A. General:
   1. Mount equipment as shown in the Contract Drawings.
   2. Mount all equipment in such a manner that a seismic event within the parameters of Section 34 42 00, General Train Control Requirements, will not cause damage or excessive motion.

2.04 IDENTIFICATION

A. Stencil a white identification number at the top of the front and rear frames of each rack or panel.

B. There shall be an identifying nameplate for each relay, or other instrument mounted on the rack or panel.

C. Equip the back and front of the relay plugboards with a tag, as specified in Section 34 42 60, Train Control Miscellaneous Products. This tag shall indicate the nomenclature of the relay.

D. Identify terminals and both ends of all wires with a wraparound tag printed with the circuit nomenclatures and terminal designations as specified in Section 34 42 60, Train Control Miscellaneous Products.

E. Wire and cable conductor identification tags for terminal board mounting shall be as specified in Section 34 42 60, Train Control Miscellaneous Products.

2.05 CABLE ENTRANCE TERMINAL BOARDS

A. Cable Entrance Terminal Boards shall be 3/4-inch Type AB exterior (five ply) plywood, mounted on a rack and painted with a fire retarding paint.
B. Cable Entrance Terminal Boards shall be located as shown on the Contract Drawings.

C. Multiple-unit terminal blocks for wire and cable conductors shall be in accordance with AREMA C&S Section 14.1.6. Furnish each binding post with two (2) binding nuts, one (1) clamp nut, and three (3) washers.

D. Provide Safetran or equal test links on all terminal pairs where conductors enter bungalows.

E. Equip binding posts and exposed terminals of other apparatus for circuits exceeding 50 volts or greater (AC or DC) with insulating nuts and sleeves.

F. Cable entrance facilities shall be located as shown on the Contract Drawings.

G. Lightning arresters shall be as specified in Section 34 42 60, Train Control Miscellaneous Products.

2.06 CABLE ENTRANCE CONDUIT

A. Supply Cable entrance conduit as specified in Section 34 42 60, Train Control Miscellaneous Products.

2.07 GROUNDING

A. Bungalow shall be fitted with four (4) 48-inch long No. 2 ground wires cadwelded to floor frame of the bungalow at each corner. Cadwelding shall take place prior to powder coating the structure. The pigtails shall be coiled and secured in a manner that prevents damage during construction and while in transit. Cases shall have two (2) 48-inch long No. 2 ground wires cadwelded to floor frame of the bungalow at each end.

B. Supply and install grounding material as specified in Section 34 42 56, Signal Grounding.

C. Each DC ground detector shall be sensitive enough to detect leakage currents from either terminal of the floating supply to ground through leakage paths having resistance as high as 7,000 ohms.

D. Ground detection scheme shall be immune to transient current flows that may be the result of charging distributed supply-to-ground capacitances. It shall also be immune to induced power line ripple that may exist between the supply leads and ground.

E. Ground detectors shall have a memory capability to provide an indication of a momentary leakage condition. The memory shall be held until reset by a push button provided for that purpose.

F. Operation of ground detectors shall not interfere with operation of power or signal circuits or equipment.

G. Ground detector circuits shall meet the fail-safe design criteria with respect to
open circuits. Furthermore, the shorting and opening of any component part of
the ground detector circuits shall be detectable.

H. Made ground in the ground detecting part of circuits shall be checked to validate
its presence. This check shall be made in a fail-safe manner.

I. Ground detector repeater relays shall be vital relays and shall be energized when
no ground is detected.

J. Ground detector circuits shall operate in a stable condition over the specified
temperature range and over the voltage range specified for each power supply
being monitored as specified within these Specifications.

K. Each ground detector shall be equipped with a three-position, center off,
momentary contact test switch to check the operation of that detector, by
providing momentary 7,000 ohm-to-ground leakage paths for the DC buses being
monitored.

L. It shall be required to manually reset the ground detectors to their normal
operating condition after a ground has been detected and eliminated.

M. Each ground detector shall be equipped with indication lights:

1. To indicate that both buses are clear of grounds
2. To indicate that a ground has occurred on that bus

N. Each ground detector shall be equipped with one independent isolated contact
for remote indication of alarm condition.

2.10 BATTERIES

A. Storage Batteries

1. Design

   a. Each cell of the battery assembly shall be hermetically sealed.
   b. Battery shall be leak and spill proof. No electrolyte shall be lost
      when battery is stored or mounted in any position, or if a cell
      container should become ruptured.
   c. Battery shall not be capable of explosion under any condition
      including a short circuit discharge.

2. Operating Characteristics

   a. Battery shall produce the rated capacity when operated in any
      position.
   b. Battery shall be capable of a minimum of 1000 charge-discharge
      cycles to 80% discharge without loss of capacity.
   c. Battery shall not release gas, fumes, or any toxic substances
      when operated under normal conditions, or when charged or
      discharged at a maximum recommended rate.
d. Battery shall be capable of normal operation and suffer no damaged after being frozen and thawed.
e. Battery shall not require charging voltages of more than 2.25 volts per cell to maintain rated capacity and life.

f. Battery shall, if totally discharged, be capable of being recharged to rated capacity with charging voltages of no more than 2.30 volts per cell.

3. Maintenance
   a. Battery shall be “maintenance free,” meaning that no addition of water will be required and no overcharge will be required.

4. Battery Size and Application
   a. The Contractor shall calculate loads based upon the equipment proposed. All batteries shall be sized for a minimum 8-hour standby capacity.

B. Battery Chargers
   1. Battery Charger similar to CraggRailcharger model ETC-12V or Authority approved equal shall be provided.
   2. Charger shall be a panel-chassis combination with a perforated protective cover. The design shall provide natural convection cooling.
   3. Front mounting shall be designed to mount in a standard 19-inch rack space with EIA hole spacing.
   4. Front panel shall contain one voltage failure light, output ammeter and output voltmeter. Meter accuracy shall be plus or minus two percent with nominal voltage readings at center scale.
   5. Terminal binding posts for input, output and alarm circuits shall be provided. Each terminal shall be insulated from the frame of the unit.
   6. All chargers shall be clearly and permanently labeled with manufacturer’s name, serial number, part or model number, and input and output rating.
   7. Battery charging equipment shall be designed for continuous operation.
   8. Battery charging equipment shall be designed to deliver rated outputs with input voltage of 100 to 130 volts AC, with a 60 or 100 Hz, single phase, two wire input.
   9. Battery charging equipment shall have a reserve capacity at least 25% above calculated requirements.
   10. Each charger shall be provided with independently adjustable float and recharge voltages, current limiting and automatic charge control. The battery charger shall have automatic electronically controlled temperature compensation for float voltages.
   11. Terminal markings for AC and DC terminals shall be permanent.
   12. Battery chargers shall be capable of withstanding 600 volts, 60 Hz applied for one minute between both input leads connected together and the case; between both output leads connected together and the case;
and between both input leads connected together and both output leads
connected together.

13. Failure detection circuitry shall include, alarming of failures that affect the
ability of power supply to deliver rated load. A normally closed
independent contact shall be provided for connection of external circuitry
for alarm indication.

14. Battery charging systems shall include a battery eliminator circuit and a
battery elimination switch. Operation of the switch shall not cause any
subsystem to fail. Surge suppression and filtering shall not be eliminated
by operation of the switch.

C. Inverters

1. Inverters shall operate with DC input voltages of 9.0 to 18.0 volts.

2. Output shall be 100 Hz of sufficient voltage and current to operate a
single power frequency track circuit. Alternatively, the inverter may be
used to drive a follower to achieve the required output.

2.11 Lightning and Surge Protection

A. The Contractor shall provide lightning protection and surge protection that is
effective in protecting all power equipment and downstream equipment from
damage and operational malfunction. The Contractor shall provide as many
applicable types and stages of protection as required to protect each type of
circuit and equipment involved.

B. Primary surge arrestors shall have the ability to shunt relatively high current
surges to ground with relatively little overshoot.

C. Secondary surge suppressers shall have the ability to shunt-to-ground any surge
overshoot from the primary arrester devices.

2.12 INTERNAL WIRING

A. Internal wiring shall be in accordance with Section 34 42 16, Train Control Wires
and Cables.

B. Minimum wire conductor sizes shall be as shown on the Contract Drawings
unless otherwise approved by the Engineer.

C. Adhering to minimum wire size specifications does not relieve the Contractor’s
responsibility of using wire sized large enough to safely and effectively provide
power to the circuit it serves.

D. Solderless terminals, for stranded wire, shall be in accordance with Section 34 42
60, Train Control Miscellaneous Products.

E. Solid terminal connectors shall be used for all short terminal jumpers.

F. Wire shall conform to the requirements in Section 34 42 16, Train
Control Wires and Cables.
2.13 PAINTING - INSULATION

A. All instrument enclosures shall be furnished complete with a layer of rigid insulation on the walls, doors, and ceiling. Instrument bungalows shall have a minimum 2-inch thick layer of rigid closed cell foam insulation rated R13. Insulation shall be suitable for residential installation.

B. The interior, including the ceiling, walls, terminal boards, and shelves shall be finished with a primer and two coats of white latex enamel paint.

C. All paint shall be fire-retarding type.

D. Apply typical legend for control point bungalows, highway grade crossing bungalows and cases as indicated on the Metro Engineering Drawings. Consult with manufacturer of bungalow prior to paint application.

2.14 AC POWER EQUIPMENT

A. Circuit Breakers

1. Circuit breakers for power feed to train control bungalows for 480 VAC distributions shall be thermal, magnetic, molded case type, two (2) pole, rated at 480 VAC. Amperes ratings shall be determined by the Contractor for projected loads. Loads shall not exceed 80% of the circuit breaker ampere rating. Ampere ratings shall include 25% spare capacity for future expansions.

2. Circuit breakers shall provide adequate overcurrent protection for connected equipment. Circuit breakers shall be UL listed conforming to the requirements of NEMA AB1-1986.

3. Short circuit rating shall be equal to or greater than the maximum short circuit to which they would be subjected, with a UL listed interrupting rating of not less than 14,000 symmetrical amperes rms.

4. Molded case circuit breakers shall have toggle type mechanisms, providing quick-make, quick-break operation. Circuit breakers shall be calibrated for operation in an ambient temperature of 40 degrees Celsius (C). Each circuit breaker shall have a permanent trip unit containing individual thermal and magnetic trip elements in each pole. Circuit breakers shall have reverse connection capability and be suitable for mounting and operating in any position.

5. Circuit breakers shall be provided with removable lugs. Lugs shall be UL listed for 90 degrees (C) copper wires.

6. Circuit breaker enclosures shall be NEMA Type 12, provided without knockouts. Enclosures shall be fabricated from galvanized steel, with an electrodeposited, gray baked enamel finish. The external operating handle shall be an integral part of the box, not the door. Enclosure shall be UL listed.

B. Train control power isolation transformers shall conform to the requirements of
these Specifications.
2.15 EQUIPMENT RACKS
A. Equipment racks shall be the manufacturer's standard for the type of equipment furnished and shall be sized in conformance to these Specifications.
B. Equipment racks shall include all necessary supports for wire and equipment.
C. Secure equipment racks by bolts attached to a threaded mounting plate structurally secured to the floor of the bungalow. Attach stabilizing straps to the top of the racks as needed. Racks and mounting shall be secure enough to withstand a seismic event as specified in Section 34 42 00, General Train Control Requirements.

2.16 GALVANIZED BUNGALOW FOUNDATIONS
A. All houses shall be equipped with telescoping foundations as described in Part 2.01 Q of this Section complete with galvanized bolts, washers, nuts, and associated hardware. Galvanizing shall conform to Section 34 42 60, Train Control Miscellaneous Products, and AREMA C&S Manual, Part 15.3.1.
B. Bolt spacing shall be to manufacturer's standards for the equipment to be supported by the foundation.

2.17 FUNCTIONAL REQUIREMENTS
A. The Train Control Power System shall be designed to provide normal operations for eight (8) hours using a battery back-up, with the exception of switch machine operation.
B. Power frequency track circuits shall receive power from 12V/100V 100 Hz invertors.
C. Ventilation systems shall be designed to operate on back-up power.

2.18 TRANSFORMERS
A. Contractor shall furnish one transformer of each rating used in the system.
B. All transformers shall be air-cooled unless otherwise Authority approved.
C. Transformers shall be provided for train control power, isolation purposes, 100 Hz AC track circuits and general purpose transformers as required in these Specifications or Contract Drawings.
D. Track transformers shall be provided with sufficient primary and secondary voltage taps to adjust for varying feeder voltages between 100 and 125 volts.
E. Transformers shall not emit audible noise in excess of 75 dB, referenced to 0.0002 dynes/cm² at a distance of two feet at rated voltage and current.
F. Primary and secondary taps shall be brought to terminals mounted inside the transformer case. A connection for each secondary tap and at least two connections for the primary winding shall be brought out of the transformer to
suitable terminals or bushings. All terminals shall be identified in an Authority approved manner.

G. Track feed transformers required for power frequency track circuits shall be equipped with terminal boards containing terminals for primary and secondary leads.
   1. Secondary windings shall be arranged to provide for varying voltage in one-volt steps up to a maximum of 15 volts. Terminal boards shall comply with AREMA C&S Manual Requirements.
   2. Primary excavation shall be 120 VAC, 100 Hertz. All track feed transformers shall have a volt-ampere rating sufficient to handle the operating load. Track transformers shall not be susceptible to DC saturation by propulsion currents.

H. Transformers for train control power shall be single phase with 480 volt, 60/100 hertz, primary windings and 120 volt, 60/100 hertz, secondary windings. Transformer windings shall contain Class H insulation with four, 2-1/2 percent full capacity taps. Two taps shall be above the nominal voltage and two below the nominal voltage. The transformer enclosures shall be of drip-proof construction and provided complete with provisions for wall mounting.
   1. Each train control power transformer required for a bungalow location shall be rated at a minimum of 15kVA.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Mount bungalows level and plumb and secure thereon with the hardware provided. Do not use shims, spacers, or other filler devices to level and plumb bungalows or cases.

B. Install cable entrance pipes through the cable knockout holes provided in the floor of the bungalow behind the terminal board(s) as shown on Contract Drawings. Fill pipes with a substance designed for the purpose that prevents entrance of debris, rodents, and other pests.

C. Ground bungalows as specified in Section 18450, Signal Grounding.

D. Locate bungalow as indicated on the Contract Drawings. If conditions do not allow placement as shown on the Contract Drawings, submit alternate placement for approval.

E. Install relays on the relay plugboards corresponding to the relay nomenclature and identification plate, and securely fasten in place with the hardware provided by the relay manufacturer.

F. Place batteries on rubber matting on the floor of the house. Coat battery posts with approved grease and securely fasten battery connectors to the battery posts. Strap batteries or otherwise secure using a method approved by the manufacturer so that they will not tip or move in the event of an earthquake.
G. Mark each grade crossing warning device case or bungalow with the street name, milepost location, emergency response number, and DOT inventory number per Metro Standards.

H. Install pullboxes and conduits. Provide slotted pullbox covers to accommodate the cable chute at bungalow locations. Place the house so the chute aligns with the slotted cover.

I. Make any modifications to the cable chute required to fit the pullbox and accommodate the cable installation. If it is necessary to cut the cable chute, ensure no rough edges, sharp edges, burrs, or other surfaces exist which have the potential to injure the cable.

J. Install foundations, including telescoping foundations, for bungalows.

3.02 AC POWER

A. Wall mount load center as shown on the Contract Drawings. Mounting height from floor, wire terminations, and clearances shall be in accordance with the NEC.

3.03 Train Control Power Equipment

A. Train Control Power Isolation Transformers
   1. Train control power isolation transformers shall be installed as required by these Specifications.

B. Disconnect Switches
   1. Disconnect switches shall be wall mounted. Disconnect switches shall not be mounted close to entrance door.
   2. Disconnect switches shall be mounted level and plumb.

C. 100 Hz Invertors
   1. 100 Hz invertors shall be installed in the train control bungalows.
   2. Invertors shall be installed in accordance with Authority approved Contractor plans and manufacturer’s installation instructions.

D. Power Cables
   1. All cable entrance to train control bungalows shall be from the bottom.
   2. Cables shall be installed as specified in these Specifications.

E. AC Ground Detectors
   1. AC ground detectors shall be mounted on equipment racks in equipment houses.

F. Batteries
   1. Rectifiers and Battery Chargers
a. The Contractor shall provide all mounting hardware, terminals and terminators, for mounting wall mounted rectifiers and battery charger units in bungalows.

3.04 TRANSFORMERS

A. Transformers shall be installed as shown on Authority approved installation drawings.

B. Mounting

1. Track transformers shall be rack mounted, except in junction boxes wherein they shall be mounted in accordance with Authority approved plans.

2. Train Control power and general power transformers shall be wall mounted.

C. Isolation transformers may be wall mounted.

3.05 FIELD QUALITY CONTROL

A. Test the functioning of the equipment contained within the instrument bungalow in accordance with the requirements of Section 34 42 58, Train Control Systems Testing and AREMA C&S Manual Part 2.4.1.

3.06 TESTING

A. The train control power system shall be tested in accordance with these Specifications.

B. Simulated and load test in accordance with Authority approved train control power system test procedures shall be satisfactory completed prior to final connection of train control facilities at each equipment location.

C. The Contractor shall test each transformer with its associated system in accordance with these Specifications.

END OF SECTION 34 42 46
SECTION 34 42 48
YARD SWITCH MACHINES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS
A. American Railway Engineering and Maintenance-of-Way Association (AREMA)

1.02 SUMMARY
A. The Work specified in this Section consists of furnishing, installing and testing of yard type, dual powered, trailable switch machines and switch circuit controllers as shown on the Contract Drawings.

B. Related Specification Sections include, but are not limited to the following:
   1. Section 34 42 58, Train Control Systems Testing
   2. Section 34 42 60, Train Control Systems Miscellaneous Products
   3. Section 34 72 00, Trackwork

1.03 SUBMITTALS
A. All submittals are provided to the Authority for review and approval.

B. Required Submittals:
   1. Performance data, mechanical and electrical drawings for yard switch movements and layouts, and the switch circuit controller. The submittal shall include a parts list along with the manufacturer's product literature and specifications.

   2. Installation drawings showing the tie straps and the mounting details of the switch and switch circuit controller, including the connections to the track switch points, and the head block tie layouts.

   3. Factory Test procedures and results for each switch and circuit controller prior to shipment.

   4. Detailed installation and inspection procedures for switch layouts, including circuit controller.

   5. Name and type of graphite lubricant proposed for switch tie plate lubrication prior to application.

   6. Detailed field test procedures a minimum of 60 days prior to field testing.
7. All field test results within two weeks of testing completion.

8. Operations and Maintenance manuals as required in Section 01 33 00, Submittal Procedures and Section 01 78 23, Operation and Maintenance Data.

9. Any other submittal called out in the specifications.

1.04 QUALITY ASSURANCE

A. Each switch and circuit controller shall be factory tested before shipping to the job site. The factory testing shall be conducted in accordance with the Authority approved factory test procedure for the switch and circuit controller.

1.05 Deliverables

A. Manuals

B. Submittals

C. All specialized diagnostic equipment and special tools not available at local hardware store

D. Switch tools

E. Spare parts

F. Non-Oxide grease.

1.06 DELIVERY, STORAGE, AND HANDLING

A. The Contractor shall properly identify and crate switches and circuit controllers with all component parts for the complete layout at the manufacturer's point of shipment.

B. Prior to shipment, all unprotected metal parts of the switches and circuit controllers shall be coated with Non-Oxide grease, or approved equal, sufficient to prevent oxidation. Suitably plug or cap all unused threads and threaded outlets.

C. During storage and after installation, switches and circuit controllers shall be properly lubricated and maintained per manufacturer's recommendations until accepted by the Authority. Regular maintenance records shall be kept by the Contractor and shall be made available to the Authority upon request and provided to the Authority prior to final commissioning. If any damage occurs to the switch layout the contractor shall replace all damaged switch components at no cost to the Authority.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Yard Switch Layout: Yard switch layouts shall include switch machines and all appurtenances necessary to provide a complete installation. This shall include, but not be limited to: Switch mechanism and housing, pedestal mounted or direct fixation junction box, throw rod and basket, insulated swivel front rod, point lug, shims, pins, grease fittings, cotter keys, plates, adjustment brackets, insulated gauge plate
extensions, elastomer pads, tie straps, identification hardware, screws, nuts, washers, all hardware necessary to mechanically couple the power switch movement to the track switch points, and circuit controllers. Switch machines shall be Alstom Signaling Model 6, or Authority approved equal.

B. **Switch Circuit Controllers**: Switch Circuit Controllers shall be Alstom Signaling Model 7J or Authority approved equal, complete with rod, lug and associated hardware.

1. Switch circuit controllers shall meet the recommendations of AREMA C&S Manual, Part 12.1.1, for a four front/back contact configuration where they do not conflict with any requirements specified herein.

C. **Junction Box**: Switch Junction Box shall be NEMA 4X rated and sized to accommodate terminal blocks and cables as shown on the Contract Drawings.

D. **Switch Identification Hardware**:

1. Two malleable cast metal letters, “N” and “R”, at least 3 inches high, painted black, shall be provided to denote the switch point normal and reverse position for each layout. Each letter shall have four holes drilled to receive fasteners suitable for securing letters to concrete ties.

2. For each letter, provide four fasteners suitable to affix letters to concrete.

E. **Miscellaneous Fittings**: Furnish all connectors such as threaded nipples, cable clamps, and electrical fittings as required for each switch layout including 18-inch-long, 2-inch-diameter flexible conduit and connectors from switch machine to junction box.

1. Hose connectors shall be a watertight and oil tight compression fitting furnished with a locknut and sealing ring.

2. Hose connectors shall provide insulation between hose and junction box; and hose and switch machine housing.

3. All connectors and clamps shall be zinc-plated steel.

F. **Operating Voltage**

1. Yard switch movements shall operate at 110 volts DC.

2. Switch operation shall be integrated into system design, including power distribution design. On-line power supply operation and simultaneous switch operation shall not compromise the switch operational requirements.

G. **Hand Crank**

1. Each switch machine shall be supplied with a hand-crank mechanism. Motor power, control, operating and switch indication logic shall be disengaged before hand-crank can be inserted mechanically and engaged with switch point moving mechanism by some action necessary to achieve manual operation. A manual
reset action shall be required to return switch machine operation to remote, after removal of crank or lever.

2. It shall take no longer than 20 seconds to manually move switch from FULL NORMAL to FULL REVERSE position or from FULL REVERSE to FULL NORMAL position.

3. Provide a crank or lever with each switch, locked in a separate lockable compartment.

H. Operating Time

1. Switch operating time shall be measured from time of closure of front contact on switch operating relay to closure of front contact on switch repeater relay, while switch machine is operating with load.

2. Switch operating time shall not exceed 5 seconds.

I. Padlock: Equip each switch and circuit controller with Contractor furnished padlocks. Use one padlock each to restrict entry to inside of the switch machine, the opening for hand crank, the storage compartment containing hand crank, and any other lockable locations. Contractor shall install Authority furnished padlocks at final acceptance.

J. Accessories: Provide ten sets of yard switch adjusting wrenches. Provide two vandal-proof lockable boxes to store and lock these accessories within the yard area.

K. U.S. Standards shall apply to all threaded parts of the switch movement layouts that require periodic adjustments or maintenance such as operating rods, lock rods, detector rods, mounting bolts and conduit outlets. Adjustable parts shall be centered during installation to provide maximum maintenance adjustment capabilities. The recommendations of AREMA C&S Manual Part 12.2.1 shall be followed unless indicated otherwise in this Section.

PART 3 - EXECUTION

3.01 GENERAL

A. Mount and adjust the complete switch and circuit controller per Manufacturer’s instructions.

B. Wire control and indication circuits for power-operated switches and circuit controllers per Manufacturer’s instructions.

3.02 INSTALLATION

A. Prior to installation, coat all parts of the switch machine and circuit controller that are not painted, or made of non-corroding material, with approved grease to prevent corrosion. Plug or cap unused threaded outlets.

B. Prior to commencing switch machine installation, the Contractor shall inspect the track layout and accept it as suitable for installation to proceed. The Contractor shall
be responsible for verification that rail is electrically isolated prior to beginning installation.

C. Concrete ties shall be manufactured so that the switch machine and circuit controller is mounted at right angles to the tie at the proper elevation. All mounting holes required in the tie shall be factory installed. The Contractor shall ensure the mounting holes do not expose steel reinforcement.

D. Prior to mounting the switch machine and circuit controller on the concrete ties, align the switch headblock ties at right angles to the straight stock rail, and space the ties in accordance with the switch shop drawings, and condition the switch points to move without binding.

E. Remove any ballast necessary for the installation of each switch and circuit controller. Replace and tamp ballast after the installation has been completed. Spread excess ballast evenly between ties in the vicinity of the switch. Remove ballast from between ties to allow unrestricted movement of switch rods.

F. Install switch machine and circuit controller per approved installation drawings and procedures. Installation of switch machines shall not reduce rail-to-ground resistance by more than 5 percent of the pre-installation reading.

G. The Contractor shall install connectors and electrical fittings for cable installation for each switch and circuit controller as shown on the approved plans.

H. The Contractor shall install all fittings required for connections between switch machines and junction boxes in accordance with the Contract Documents.

I. The Contractor shall make an initial operating adjustment of switch at the time of installation and a final adjustment when placing into service.

J. Do not apply power to the motor until the switch machine has been fully lubricated, thrown, and adjusted in hand throw. There shall be no rubbing or binding of switch rods or points on gauge plates, rails or ties. Follow manufacturer’s adjustment and installation procedure.

K. Switch layouts shall be painted with a finish coat of paint after installation. The color shall be black.

L. Label each switch machine layout per the requirements of Section 34 42 60, Train Control Systems Miscellaneous Products and as shown in the Contract Drawings.

M. The Contractor shall install, for each layout, the letters “N” and “R” for the purpose of identifying the position of the switch points. The “N” shall be placed on the normally closed point side as shown on the Contract Documents.

N. Install one concrete tie for mounting the circuit controllers as shown on the Contract Drawings.

O. Secure the switch circuit controller to the switch ties, according to Manufacturer’s instructions.
P. Make a preliminary adjustment of the controller layout at the time of installation and a final adjustment when placing it in service. Final adjustment shall be made at the time of the functional test. Make final adjustments in conformance with the requirements of AREMA C&S Manual, Parts 12.1.1 and 2.4.1.

Q. Underground cable terminating in the controller junction box shall be dressed and potheaded as specified in Section 34 42 16, Train Control Wire and Cable. Fan the individual conductors in a neat workmanlike manner, properly tagged and terminated. Wiring between switch junction box and switch circuit controller shall be No. 6 AWG, 3 strand and No. 14 AWG, 12 strand insulated flex wire. These wires shall also be tagged and terminated. Install the wires between the controller junction box and the controller mechanism in an approved flexible conduit with a minimum length of 10 inches and a maximum length of 21 inches. Fasten this flexible conduit to the switch junction box and switch mechanism with appropriate connectors as specified in Section 34 42 60.

R. Inspect each switch machine after it has been installed and correct any deficiencies noted. Conduct this inspection in conformance with the requirements of the Contractor’s Installation Inspection Procedure as approved by the Authority.

S. Any switch assembly which is connected to the open point side, or has a reverse switch indication, shall be equipped with an insulated front rod.

T. This work shall not be considered complete until all identified defects have been corrected to the Authority’s satisfaction.

U. The Contractor shall be responsible for any costs incurred by the Authority in restoring track alignment and surface occasioned by the Contractor’s Work on track switches.

END OF SECTION 34 42 48
SECTION 34 42 54

TRACK CONNECTIONS AND RAIL BONDING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Related Specification Sections include, but are not limited to:

1. 34 42 16 – Train Control Wires and Cables

1.02 SUMMARY

A. The Work specified in this Section consists of designing, furnishing, installing, and testing all required track connections including bonding of the track for train control track circuits, special trackwork, and crossbonding.

1.03 SUBMITTALS

A. All submittals shall be provided to the Authority for review and approval.

B. When catalog cuts are supplied, the Contractor shall clearly identify data to be evaluated by the Authority when the catalog cuts contain multiple items.

C. Required Submittals:

1. **Product Data**: Submit product data on each type of bond proposed. Include as a minimum catalog data, exothermic weld material, mold numbers, and manufacturer's installation data and material specifications.

2. **Compression Tools**: Provide mechanical and operating data for the compression tool required for installation of track circuit connectors.

3. **Mechanical Devices**: Provide descriptions of all mechanical devices for securing and protecting rail bonding.

4. **Installation and Inspection Procedures**: Submit detailed Field Installation and Inspection Procedures for each individual type of bonding to be utilized.

5. **Maintenance Instructions**: Provide installation and maintenance instructions, and other data pertinent to the bonding material and circuit connections, specified herein and as shown on the Contract Drawings.

6. **Bonding Cable**: Submit product data on the proposed 500 kcmil cable to be used for crossbonding, and power bonding connections. Include as a minimum cable construction diagrams, materials and their properties, qualification test data, and production test plan.

7. **Terminal Product Data**: Submit product data on proposed 500 kcmil connectors. Include data on any special tools required to complete the installation.
8. **Installation Drawings**: Submit bonding installation drawings.

9. **Detailed Typical Design Plan**: Submit a plan showing detailed typical designs for bonding of special trackwork to assure all pieces of special trackwork are properly connected electrically.

10. **Detailed Test Procedures and Results**: Submit detailed test procedures and results in accordance with these specifications.

D. The Contractor shall show bonding detail on installation drawings.

E. Any other submittal called out in these Specifications.

1.04 QUALITY ASSURANCE

A. The contractor shall install each weld bond and mechanical rail connector in accordance with requirements of these Specifications.

B. Rail bonds shall meet the requirements of AREMA C&S Manual, Part 8.1.20

C. Each rail bond shall be inspected after it has been installed in the field. This inspection shall conform to the Contractor’s Installation and Inspection Procedure as approved by the Authority. Installation shall not be considered complete until all installation defects have been corrected to the Authority’s satisfaction.

1.05 SYSTEM DESCRIPTION

A. Welded bonds and track connections shall be in accordance with the requirements of the Authority’s Engineering Standards and Directive Drawings.

B. Rail track joints shall be bonded with welded railhead bonds per the Authority’s Engineering Standards and Directive Drawings.

C. Track switch, frog fouling bonds, and track connections shall be stranded bonds.

D. Crimped sleeves shall not be used for any fouling or frog bonding unless approved by the Authority.

1.06 DELIVERY, STORAGE, AND HANDLING

A. The Contractor shall provide required special protection for the cables in areas where the cables are unavoidably exposed to hazardous conditions such as vibration or sharp corners on equipment. The Contractor shall be responsible for replacing, at no additional cost to the Authority, any cable installed which is subsequently damaged prior to acceptance as a result of failure to provide such special protection.
A. **General**: Bonding cable used for crossbonding connections shall be 500 kcmil insulated rope-lay cable meeting the requirements of this Section. Use 500 kcmil cables for frog and switch rail bonds where the distance between points of connection are greater than factory made 500 kcmil joint connectors would allow. When required for rail connections, the insulated bonding cable shall connect through an exothermic weld to a stub end bond. Use pre-formed ends designed to assist the exothermic weld process for all rail connections.

B. Provide cable rated 2,000 volts, with copper conductor per ASTM B173, Class G rope-lay stranding. The insulation shall conform to NEMA WC70.

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2.02 SPECIAL TRACKWORK BONDS

A. **General**: Factory pre-form special trackwork bonding rail connection ends to the correct shape for termination in the field. Bonding shall be exothermic welded connections and shall be designed and made for the specific purpose of rail connections.

B. **Standard Joint Bond**: Provide two 250 kcmil type "C" Bonds for connection around each standard rail joint.

C. **Power Bonding**: Provide 500 kcmil power jumpers for each power bond, frog, or switch heel jumper location as indicated on the Contract Drawings. All frogs shall be bonded identically unless otherwise specified. If a longer jumper is necessary, the Contractor may connect 500 kcmil bonding cable to rail using an exothermic splice to a factory made stub end designed for rail connection.

D. **Train Control Rail Bonding**: Provide train control rail transposition jumpers for single rail AC track circuits as indicated on the Contract Drawings. Jumper shall be routed encased in flexible hose and shall use #6 AWG minimum wire size.

2.03 CROSSBOND

A. **Crossbond**: Provide crossbonds per the approved design drawings.

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PART 3 - EXECUTION

3.01 INSTALLATION

A. **General**

1. Grind clean with a vitrified grinding wheel the surfaces of the rails where the bond is to be applied. After grinding, clean surface with an approved non-toxic solvent to remove all traces of grease and dirt. After the surface has been ground and cleaned, it shall be heated to drive out any moisture. The cable bond shall then be welded by the exothermic process in such a manner as to ensure a thorough mechanical and electrical connection.

2. Welding material shall consist of a copper exothermic mixture suitable for connection to load bearing rail, as manufactured by Cadweld (F-80), or Authority
approved equal, and shall meet the requirements of the AREMA C&S Manual, Part 8.1.34.

3. Each rail connection shall be thoroughly welded to the rail web. To ensure quality, the Authority reserves the right to test each weld by hammer and striker or in any other manner which in the opinion of the Authority is reasonable.

4. Before beginning work on bonds, weld in the field, under conditions similar to those of the regular installation, not less than three complete bond connections, and as many more as the Authority considers necessary to determine that the welds are being made satisfactorily. Such welds shall be subject to inspection and testing by the Authority, and acceptance as to the method and quality of workmanship will depend on the results of these inspections and tests.

5. Remove any welded bond installed by the Contractor that is found to be defective prior to placing the system in service, and install a new bond.

B. Welded Bonds

1. Frog, switch jumper, and crossbonding shall be installed at locations shown on Contract Drawings, and as required by these Specifications. All special trackwork shall be bonded in accordance with the Authority approved installation drawings to establish electrical continuity and conductive capacity for traction power return and train control circuits.

2. Install bonding in accordance with approved procedures and installation drawings and in accordance with manufacturer’s recommendations.

3. Prior to installation, inspect the trackwork and area as to suitability and accept it for installation. Provide documentation to the Authority accepting the trackwork and associated area.

4. Install bonds in a manner to reduce tripping hazards to a minimum. If necessary, provide protection, supports, or clamps to achieve the safest routing.

5. All welded bonds shall be installed per manufacturer’s recommended installation procedure.

C. Rail Connections

1. Exothermically weld all track circuit connection bonds and special trackwork bonding connections to the rail. The welding mixture shall consist of a copper exothermic mixture employing tin-metal in an amount to effectively constitute 4.5 to 5.5 percent of the resulting weld metal. The resulting weld metal shall have a minimum tensile strength of 39,000 lb per sq. inch. Weld terminations to the rail at staggered intervals of not less than 4 inches on centerline. Repeat or broken welds due to misfires, poor fusions, or other causes shall be relocated a minimum of 4 inches on centerline from their original weld locations.

2. Bonds designed to weld to the web of the rail shall be centered plus or minus 1/4 inch of the neutral axis.
3. Bonds designed to connect to the rail head shall not extend above the top of the rail. Any weld material extending above top of rail shall be ground level with top of rail and shall not weaken the joint.

4. Install each crossbond with sufficient slack to accommodate rail movement due to expansion and contraction.

5. The plug end of the track circuit connector shall be as specified herein, at a maximum distance of 3 inches from the end of the insulated joint.

6. Strip back underground cable a sufficient distance for the exposed conductor to be fully inserted into the compression sleeve. Then compress sleeve with the type of compression tool designed for that purpose.

7. Track wire installation shall conform to the Authority’s Engineering Standard and Directive Drawings.

8. Remove any track circuit connections found to be defective prior to acceptance, and install a new track circuit connection.

3.02 CROSSBONDS

A. Bury 500 kcmil cable 18 inches minimum deep under rail and between tracks and between track and negative return connectors. In areas beneath ties and rails, protect cable with conduit.

END OF SECTION 34 42 54
SECTION 34 42 58
TRAIN CONTROL SYSTEMS TESTING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. American Railway Engineering and Maintenance-of-Way Association (AREMA):

1.02 SUMMARY

A. This Section includes requirements for tests and inspections to demonstrate that systems, subsystems, assemblies, subassemblies, and components supplied and installed under this Contract are in compliance with these Specifications and operate as a complete system.

B. The work shall include all tests required to ensure proper and safe operation of all systems and subsystems, and to prove the adequacy and acceptability of the total installation specified herein.

1.03 SUBMITTALS

A. All submittals are provided to the Authority for review and approval.

B. General Test Submittal Requirements
   1. Contractor shall provide certified test results for all required tests. The Contractor’s test program manager, the individual performing the test, and all witnesses shall sign all test results.
   2. Test reports shall record each instrument’s calibration date and calibration expiration date. A certified metrology laboratory that maintains National Institute of Standards and Technology (NIST) traceability shall perform instrument calibration. Calibrations shall be maintained as specified by each instrument’s manufacturer. Out-of-calibration instruments will be considered non-certified. Test conducted with non-certified instruments will be summarily rejected.
   3. The Contractor’s engineer shall review all test reports prior to submittal to the Authority.

C. Required submittals include, but are not limited to:
   1. Test Program Plan - The Test Program Plan shall include:
      a. A flow diagram indicating the logical sequence of tests, starting with Qualification Tests and ending with Integrated Testing.
      b. A list of test procedures in test procedure number order and a brief test description.
      c. A preliminary test schedule that shows each test for each location.
with start and finish dates. The schedule portion of the Plan shall be a dynamic document that the Contractor updates monthly as the program progresses.

d. An organization chart and description of the Contractor’s in-house and field test organization.

e. Requirements and recommendations for witnessing by the Authority.

2. Qualification Test Procedures - Either detailed Qualification Test procedures or prior Qualification Test results, as applicable.

3. Qualification Test Results - Completed test results shall be provided for each equipment type.

4. Manufacturing Test Procedures - Detailed procedures for component manufacturing testing.

5. Manufacturing Test Results - Completed component manufacturing test results.

6. Factory Test Procedures - Detailed factory test procedures for each sub-system or control point.

7. Factory Test Results - Completed tested equipment factory test results.

8. Installation Test Procedures - Detailed installation test procedures for each equipment type to be installed.

9. Installation Test Results - Completed installation test results for each installation test performed.

10. Field Test Procedures - Detailed field test procedures for the system to be tested.

11. Field Test Results - Completed field test results for each test performed.

12. Integrated Test Procedures - Detailed integrated test procedures.

13. Integrated Test Results - Completed integrated test results.

14. Final Certification - Prior to placing any section into service, the Contractor shall submit a letter signed by the Contractor’s authorized representative wherein the Contractor shall certify that all tests have been performed and all results and measurements are within the Authority approved engineered values.

15. Submit test reports for any additional tests required by the Contractor to ensure the safe operation of the system to the Authority.

16. Any additional submittals required by these Specifications.

D. In-service testing information (as applicable):

1. Submit, 30 days in advance of any in-service testing, a detailed cutover
and in-service test procedure. This procedure shall indicate the Contractor's personnel involved, their assigned location, and responsibility during the in-service testing. Include the following for cutovers:

a. Test procedures that adequately reflect the tests to be performed and the sequence in which the tests shall be performed. A signal aspect chart indicating the appropriate signal aspect to be displayed as train simulation tests are made shall be included. The signal aspect chart shall reflect the resulting signal aspect displayed as a result of a light-out condition.

2. The test procedure shall include an outline of the tests to be performed on each type of component, unit, or system, together with corresponding samples of test record forms and cards. The outline shall be arranged to indicate the proper sequence of each test to be performed on each component or unit; the numbers of each type of component or unit to be tested to demonstrate adequacy of design and quality control; and a line diagram showing the grouping and sequencing of system and subsystem.

3. Allow 30 days for Authority review and approval process.

4. Record the results of each test, as herein specified, and submit copies of the field test reports to the Authority within seven (7) days of completion of the cut-over testing. Prepare final type-written test reports as indicated herein and submit to the Authority within ten (10) days after the completion of each test. Final Type-written test reports shall include complete details of the test results and corrections or adjustments performed or which remain to be completed. The type-written test reports shall be signed and dated by the Contractor’s Test Program Manager. Furnish certified test results for tests performed by any subcontractors.

1.04 TEST SYSTEM DESCRIPTION

A. Tests and inspections shall be made during the progress of this Contract and after completing equipment installation. These tests and inspections shall consist of, but are not limited to, factory tests of Contractor Furnished equipment, circuit breakdown tests, wiring verification tests, continuity tests, resistance tests, voltage and current tests, applicable locking tests, operating tests, simulation tests, and other electrical and mechanical tests and inspections.

B. Tests performed shall cause each system and subsystem to be sequenced through its required operations, including simulated conditions to prove that the installation complies with all specified fail-safe requirements.
C. Each component and unit of the train control system shall have an inspection performed at its point of manufacture and evidence of this inspection and acceptability shall be indicated on the item where practicable. Inspection documentation shall be provided to the Authority for each component and unit of the train control system upon installation of the component or unit.

D. The Contractor shall utilize test equipment of the proper type, range, and accuracy to perform required tests and inspections.

E. Test equipment used shall be in good working order and properly calibrated. The equipment shall display a sticker indicating its calibration date and the agency that performed the calibration.

1. Calibration of each instrument shall be certified by a recognized testing facility. Instruments with out-of-date calibrations will be considered non-certified. Tests conducted with non-certified instruments will be rejected.

F. In the event that the system does not meet requirements, the Contractor shall make all necessary corrections and perform retesting. Complete all other tests and inspections prior to performing final in-service tests.

G. Work shall include all necessary disconnecting and reconnecting of components and equipment in order to perform the specified tests.

H. Train control systems test work specified elsewhere in these Specifications shall be construed as related to and inclusive with the testing described herein.

I. All tests shall be coordinated with the Authority.

J. Tests and inspections shall conform to the Authority’s Design Criteria and Operating Rules.

K. Testing, including pre-testing, shall include operating all switch machines and lighting all signals. The use of lamp simulators in lieu of, or in parallel with signal lamps will not be allowed in pre-testing. An exception may be approved by the Authority where a signal or switch machine is in service and will be reconfigured for final cutover, or cannot be installed or wired until final cutover.

L. Appropriate test equipment shall be used when testing circuits. Visual observation of a relay is only valid when coil voltage or current or contact voltage, as applicable, is also measured.

M. Test and inspection procedures shall comply with all regulatory requirements and the manufacturer’s recommended test procedures.

N. Notify the Authority in writing at least 48 hours prior to each field test. No part of the train control system shall be placed in service without an authorized representative of the Authority being present and witnessing the in-service tests.

1.05 QUALITY ASSURANCE
A. Inspection documentation shall be provided to the Authority for each component and unit of the train control system upon installation of the component or unit.

B. Test equipment used shall be in good working order and properly calibrated. The equipment shall display a sticker indicating its calibration date and the agency that performed the calibration.

1. Calibration of each instrument shall be certified by a recognized testing facility. Instruments with out-of-date calibrations will be considered non-certified. Tests conducted with non-certified instruments will be rejected.

PART 2 – PRODUCTS

2.01 TEST INSTRUMENTS AND EQUIPMENT

A. Test instruments and equipment necessary to conduct the tests specified herein shall be available and ready for use, not less than one week in advance of test. “Ready for use” shall mean properly matched for test parameters, properly calibrated, and sufficiently supplied with leads, probes, adapters, stands, and similar items necessary to conduct the particular test in a completely professional manner.

2.02 TEST PROCEDURES

A. All test procedures shall be prepared on standard forms that include, as a minimum, fields for the following:

1. Procedure Number and Revision
2. Test Location
3. Test Date
4. Test Objective
5. Test Prerequisites
6. Software Version(s)
7. Test equipment, manufacturer, model number, calibration and calibration expiration dates of each test equipment item that requires National Institute of Standards and Technology (NIST) traceability.
8. Equipment or resources required from other sources outside of the Contractor’s organization.
10. Personnel required performing the test.
11. Test set-up
12. Temporary connections or modification required to perform the test.
14. Anticipated results for each procedure step.
15. Pass/fail criteria for each procedure step.
16. Pass/fail notification and remarks
17. Tester signature
18. Signature of tester certifying that all temporary connections or modifications have been restored.
19. Completion date
20. Tester’s additional comments
21. Witness printed and signature blocks with an appropriate block for the Authority, supplier, and Contractor.
22. Where required, attached results tables.

2.03 TEST RESULTS

A. Submit test results for each test activity.
B. The original test results shall contain the original test forms filled out by the person(s) performing the tests, and original signatures.
C. Unless otherwise specified, submit within seven days of test completion.
D. Blue ink shall be used to complete all test form entries.
E. Errors shall be crossed out with a single line and initialed by the person making the correction.
F. Test results shall include test procedure forms with all fields completed. Fields that are not applicable shall be marked Not Applicable or N/A.
G. Test results shall be submitted with a Test Summary Sheet that includes, as a minimum, the following:
   1. Test Number and Revision
   2. Interim test date if not completed
   3. Test completion date
   4. Narrative summary of the test results
   5. Listing of any procedure failures, observations and procedure field modifications.
   6. Signature of the Contractor’s Testing Manager
   7. Additional comments
H. Unless otherwise approved by the Authority, tests in which one or more procedures have failed shall be repeated in their entirety.
2.04 REGRESSION TESTING

The Contractor shall identify and be responsible for any regression testing required due to software changes after the test program has started.

Prior to commencement of regression testing, the Contractor shall submit a list of tests and/or procedures that require re-testing. The Contractor shall also submit a revised test schedule for Authority approval.

PART 3 - EXECUTION

3.01 QUALIFICATION TESTS

A. The Contractor shall perform Qualification Testing on all equipment to verify that the equipment complies with these Specifications, Contract Drawings, and the approved design.
   1. Qualification tests shall ensure that vital components function in a manner required for fail-safe operation. Testing shall include a full range of interface failures to the tested equipment.
   2. Qualification tests shall ensure proper operation over the temperature, humidity, vibration and shock ranges expected for a rail application in the Southern California region.

B. Qualification tests may not be required for unmodified equipment that has a proven service record in a similar operating environment. In lieu of qualification testing, the Contractor shall submit documentation of prior qualification testing.

3.02 MANUFACTURING TESTS

A. Manufacturing tests shall be performed on each first article equipment type and subsequently at frequencies identified in the Authority approved Test Program Plan.

B. Manufacturing tests shall prove that the product is within acceptable physical and operating tolerances. Where practicable or industry practice, test results shall be affixed to the product.

C. Vital Relay Tests:
   1. Prior to factory test of a location, manufacturing tests shall be completed for all associated DC vital relays in accordance with AREMA C&S Manual, Part 6.4.1 and manufacturer’s recommendations. All associated AC vital relays shall be tested in accordance with AREMA C&S Manual, Part 6.4.5 and manufacturer’s recommendations.

3.03 FACTORY TESTS AND INSPECTIONS

A. The Contractor shall provide written confirmation that all required systems, subsystems, assembly, and sub-assembly factory tests were successfully performed. These tests shall verify design, nameplate ratings and compliant
performance with these Specifications.

B. Bungalows:
Each bungalow shall be wired complete with all equipment installed at the point of assembly. A wiring verification and operational test shall be conducted in accordance with the Authority approved circuit plans. Functions external to the housing shall be simulated where required.

C. Each bungalow shall be tested to verify that it functions properly before it is shipped to the field for installation. These tests shall involve connecting all control systems (excluding signals, switches, and similar equipment) that make up a Train Control Bungalow; applying power; and then exercising each function of the system and verifying proper results.

D. All wiring and equipment shall be checked to verify conformance to the Contract Drawings, the Specifications, and the approved design.

E. Provide confirmation that all required factory tests of Systems, sub-systems, assemblies, sub-assemblies and components supplied under this Contract have been performed. Each component and unit shall be inspected at its point of manufacture and evidence of this inspection and acceptability shall be indicated. Certified test reports shall be furnished.

3.04 FIELD TESTS

A. GENERAL FIELD TESTS AND INSPECTION

1. Perform general field tests including the tests listed herein.
2. Ground verification test.
3. Dielectric Breakdown test of all vital circuitry.
4. Wiring verification of all non-vital circuitry.
5. Vital function tests.
6. Operating tests.
7. All applicable tests prescribed by AREMA C&S Manual Part 2.4.1, where the AREMA inspections and tests do not conflict with the requirements of these Specifications.

B. The field tests performed shall cause each installed system and subsystem to be sequenced through its required operations, including simulated conditions, to demonstrate that the installation complies with all specified fail-safe design requirements and operational functions.

C. Demonstrate the quality of installation by field tests for continuity, insulation resistance, resistance of ground connections, circuit breakdown, visual inspection, and any other tests required by these Specifications. Perform these tests prior to any operational testing of systems or subsystems.
D. Should an error be discovered during field testing due to field wiring and connections that do not agree with the approved circuit plans, the Contractor may correct such errors without prior approval of the Authority. The Contractor shall not, however, make any changes that deviate from the Contract Drawings without prior written approval of the Authority.

E. The Authority will make all final determinations as to whether only a part, or the whole test, shall be rerun when any specific field test does not meet the requirements specified for the test.

F. Any changes made after completion of test procedure shall be re-tested in accordance with the applicable test procedure and regulatory requirement.

3.05 SPECIFIC FIELD TESTS AND INSPECTION

A. Perform specific field tests listed herein.

B. Grounds:
   1. Ground resistance shall be tested and reported as described in Section 34 42 00, General Signal Requirements.
   2. All low voltage dc circuits shall be tested to verify that they are free of grounds.

C. Insulation Resistance:
   1. Insulation resistance tests shall be made between all conductors and ground, and between conductors in each cable in accordance with FRA rule 236.108. The insulation resistance of wires and cables installed by the Contractor shall provide an “infinite” reading when using a direct reading instrument (megger) having a self-contained source of direct current test voltage. The megger scale shall have a minimum range of zero to 20 megohms and be rated at 250 volts minimum and 650 volts maximum.
   2. All insulation tests shall be performed after the equipment and cables are installed in the field.

D. Vital Relays:
   1. All dc vital relays shall be tested for pick-up and drop-away values. These values shall be in accordance with field requirement values stated in Table I of AREMA C&S manual, Part 6.4.1.
   2. These tests shall be performed at the shelter locations after the shelter has been set.

E. Energy Distribution:
   A. Energy-Off Tests: With all power to the train control bungalow off, the following checks and tests shall be performed.
      a. Removing all fuses and opening all breakers.
b. Verifying that circuit breaker size compares to that of the approved circuit plans.

c. Checking all energy distribution using a resistance test instrument acceptable to the Authority, to verify agreement with the approved plans.

d. Comparing wire gauges with those called for on the approved circuit plans. All discrepancies in wire sizes shall be replaced with the proper size wire.

e. During energy distribution breakdown, a wire count on each junction shall be performed to ensure that only the correct wire count shown on the approved circuit plans is present at each junction. Any discrepancies found shall be corrected and additional wires, if found, shall be removed.

f. Tags shall be verified for proper nomenclature and terminal location.

g. Each energy buss shall be tested against all other energy busses to ensure the busses are electrically independent and no crosses exist.

F. Energy-On Tests:

1. Upon completion of energy-off tests, the following checks and tests shall be performed.

   a. Insert fuses for power supply feeds and verify proper size according to Authority approved circuit drawings.

   b. Turn on energy feeds and test operation of power transfer for proper operation.

   c. Each AC voltage input shall be measured and recorded.

   d. Each power supply or charger output voltage shall be measured and recorded.

   e. Verify that designed voltage is present at all distribution points.

   f. Check circuit power failure alarms and all other alarms that indicate to Yard Operations Control.

B. Circuit Continuity Tests

All Contractor installed wire and cable shall be tested to verify continuity of each conductor and that each conductor is connected to the proper terminal as shown on Authority approved drawings. Where parallel circuits exist, each parallel path shall be tested independently to verify path continuity.

C. Vital and Non-vital Circuit Breakdown
All circuits shall be checked for compliance with Authority approved circuit drawings. Tests may be performed with energy on or off and shall verify:

4. Point-to-point wiring:
   A wire count of all field installed wires shall be performed for each junction to ensure that only the correct wire count cited on Authority approved circuit plans is present. Any discrepancies found shall be corrected.

5. Verify tags and nomenclature:
   Verify that all components are the same as on Authority approved circuit drawings and located in proper positions.

G. Breakdown of Control Circuits:
   1. All circuits shall be tested in their entirety for the correct operation and response to each contact on each circuit element, such as relays and contactors. Where parallel paths exist, tests shall validate each path, and circuits shall be opened when required to ensure proper test.
   2. The Contractor shall simulate all operating conditions to verify that each energy circuit operates in accordance with these Specifications and the Authority approved plans.

H. Line Circuits
   This test shall verify the integrity of line circuits between wayside locations. All nomenclature shall be verified and line circuits tested for continuity.

I. Traffic Circuits
   This test shall verify the integrity of traffic circuits between interlocking locations. These tests shall include:
   1. Traffic direction shall be tested by first establishing each direction of traffic and then sequentially de-energizing each individual track circuit from headblock to headblock and observing the traffic cannot be reversed.
   2. Once traffic is established, an attempt shall be made to clear all possible conflicting routes verifying that neither the conflicting routes can be cleared nor can the established direction of traffic be affected.
   3. Each block repeater relay shall be tested to determine that it follows all the proper track relays opened in bungalows.
   4. With an established direction of traffic, the controlled signal governing entrance to that particular route shall be put to stop with the approach track circuit occupied. It shall not be possible to establish traffic in the opposite direction until a predetermined time has passed. This predetermined time shall be as indicated on the Authority approved plans. It shall be determined that approach or time locking is effective for this test.
J. Interlocking Tests
1. Test sequences shall be designed to demonstrate each function for correct performance in accordance with these Specifications and Authority approved plans. Test sequences shall include simulated unusual conditions to determine that interlocking circuits will respond in a predictable, safe and Specification compliant manner.

2. Functions to be tested shall include:
   a. Approach locking
   b. Time locking
   c. Route locking
   d. Verification of timing on time releases
   e. Detector locking
   f. Signal operation in accordance with route and aspect charts.

3. Time tests shall be as follows:
   a. Loss of shunt
   b. Approach and Time Locking
   c. Flashing Rate Time

K. Route Security Locking:
   Each route shall be tested for route security. This test shall be performed by establishing the routes and falsely energizing the route check relay for each opposing or conflicting signal while observing the associated signals stay at STOP and the associated signal clearing relays remain de-energized.

L. Power Tests
   The following power tests shall be performed and recorded:
   1. Main power feeder voltage shall be measured and recorded
   2. A check of all fuses shall be performed for capacity and type.
   3. All power supplies, battery chargers, and batteries shall be checked for correct setting and quantities.
   4. Buss-to-buss checks shall be made to determine that no shorts, crosses, or grounds exist.

G. Electric Switch Movements (when applicable):
   1. Continuity checks of field wires to switch-and-lock movements to verify all nomenclature.
   2. Adjust throw bar so that proper tension is placed on switch points in both directions.
   3. Manually operate switch machine normal and adjust lock rods and point
detector rods to allow switch machine to lock up with no obstruction. Repeat above for switch machine in reverse position.

4. Turn on switch machine power, call switch machine normal and observe in field that switch machine corresponds to position called, and observe in wayside instrument shelter that proper switch correspondence relay is energized.

5. With switch machine called normal, check gaps on circuit controller contacts to see that they meet equipment specifications. Operate machine reverse and repeat.

6. Break each contact in switch circuit controller and observe that proper switch correspondence relay drops. Repeat this procedure for both positions of the switch.

7. Place ammeter in series with motor control energy and adjust clutch such that it causes overload relay to pick up in less than ten seconds with 1/4-inch obstruction in switch point. Record current reading. Repeat for opposite position.

8. Place switch and lock movement in "hand" operation and observe switch mechanism cannot be operated by power. Place back in "motor" and verify that switch mechanism can be powered.

9. Operate switch, then shunt detector track circuit and observe that switch machine is stopped in middle of stroke and not allowed to complete movement. Remove shunt and verify switch completes movement.

10. Contractor shall record test results on the approved test form and submit this completed form to the Authority in order to obtain approval of this test requirement.

H. Switch Circuit Controllers:

1. Each switch circuit controller shall be tested to verify wiring, mechanical connectors, point obstruction, and point detection in accordance with AREMA C&S Manual, Part 12.5.1.

2. Contractor shall record test results on the approved test form and submit this completed form to the Authority in order to obtain approval of this test requirement.

I. Signal Layouts: Tests shall be performed on all signal layouts. These tests shall include the following:

1. Continuity check of field wires and verification of all nomenclature.

2. Apply energy to signal lighting circuits and adjust all lamp voltages to 10 percent less than the lamp rating.

3. Sight signals for maximum visibility.

4. Check that light-out feature, where used, complies with FRA Rule 236.23(f).
J. Line Circuits: The purpose of this test procedure shall be to verify the integrity of line circuits between wayside instrument locations. These tests shall include the following:
   a. All nomenclature shall be verified and line circuits tested for continuity.
   b. Each repeater relay shall be tested to determine that it follows all the proper track relays de-energized in the signal bungalows.

K. Control Office to Wayside Interface: Upon completion of the wayside tests, a system test shall be performed to ensure continuity of operation of wayside equipment by the supervisory control system. This test shall consist of controlling all office wayside functions from the supervisory control console, and the transmission back to the control office of all indications from the field stations. The functions to be tested shall include the following:
   c. Controls from Supervisory Control Console
      i. Control of switch machines.
      ii. Lining of routes.
   d. Indications to Supervisory Control Console
      i. Switch machine positions
      ii. Track circuit occupancy
      iii. Signal indications
      iv. Power-off and alarm indications
   e. All design changes found necessary to obtain proper operation shall be

M. Track Circuits:
   1. Each track circuit shall be tested for shunting sensitivity and polarity in accordance with the AREMA C&S Manual, Part 8.6.1.

N. Insulated joints:
   1. Each insulated joint installed by the Contractor shall be tested with one of the following insulated joint testers: the Harmon 1501A1JC, S&C Model 324 Track Circuit Short Finder, or approved equal, and shall measure no less than 100 ohms across the joint.

END OF SECTION 34 42 58
SECTION 34 42 60
MISCELLANEOUS Train CONTROL PRODUCTS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Reference Standards:

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. Communications and Signals Manual of Standards and Recommended Practice (C&S Manual)

2. Institute of Electrical and Electronics Engineers (IEEE)
   a. IEEE C37.14 – Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

3. National Electrical Manufacturers Association (NEMA)
   a. ST20 – Dry-Type Transformers for General Applications
   b. NEMA 1 – NEMA Standards Publication 250-2003 Enclosures for Electrical Equipment (1000 Volt Maximum)
   c. NEMA 4 – NEMA Standards Publication 250-2003 Enclosures for Electrical Equipment (1000 Volt Maximum)

4. National Fire Protection Association (NFPA)
   a. NFPA 70 – National Electrical Code (NEC)

5. Underwriter’s Laboratories (UL)
   a. UL 489 – Molded-Case Circuit Breakers and Circuit Breaker Enclosures

1.02 SUMMARY

A. The requirements of this Section pertain to junction boxes, electrical and electronic components, marking and tagging, miscellaneous components and products.

1.03 SUBMITTALS

A. All submittals shall be provided to the Authority for review and approval.

B. Required Submittals:

1. Junction Boxes
   a. Submit drawings and product details for each type of junction box required.
   b. Submit drawings of each junction box required, including terminal boards,
terminals, wiring, mounting details, and any other integral parts.

2. Electrical and Electronic Components
   a. Submit data on each type of electrical component and PC board proposed for use in the system. Provide each submittal complete with schematic, physical layout with components identified, edge connector requirements, and component information. The submittal shall be as part of the subsystem submittal in which the PC board is used.

3. Marking and Tagging
   a. Prior to the fabrication or purchase of any device or piece of apparatus requiring marking or tagging, submit a sample of each type of marking or tag. These samples shall show typical nomenclature and lettering arrangement for each type of device, cable, wire or other item to be marked or tagged.
   b. At least 60 days prior to application, submit plans, diagrams, or photographs showing where each type of marking or tagging will be applied.
   c. At least 60 days prior to application, submit detailed procedures for the application of marking or tagging that require special manufacturing or installation techniques.

4. Spare Parts
   a. Submit a complete list of recommended spare parts and consumables for all equipment, appliances, and systems as identified in these Specifications.

5. Maintenance Material
   a. Submit a complete list of maintenance materials as specified in these Specifications.

6. Miscellaneous Components and Products
   a. Submittals shall be in accordance with the requirements of these Specifications.

C. Any additional submittals required by these Specifications.

1.04 QUALITY ASSURANCE

A. Junction Boxes
   1. The Contractor shall inspect each junction box after it has been installed and wired and correct any deficiencies. Inspection shall be conducted in conformance with the requirements of the Contractor’s Installation and Inspection Procedure as Authority approved. Installation shall not be considered complete until all installation defects have been corrected to the Authority’s satisfaction.

   2. Junction boxes shall meet the requirements of the AREMA C&S Manual, Parts 7
and 15.

B. Miscellaneous Components and Products

1. Miscellaneous components and products shall be inspected prior to shipment. Inspection shall conform to the manufacturer’s inspection procedure.

2. Miscellaneous components and products shall be tested according to Authority approved test procedures.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Junction Boxes

1. Junction boxes shall be protected from damage throughout delivery, storage, and handling.

B. Spare Parts

1. All spare parts, maintenance materials, keys, special tools, and test equipment shall be securely packaged in boxes, with the boxes clearly labeled as to the contents. Such labeling shall include: location and description of the equipment and the item, complete listing of all items in the box, and the quantity of each item included in the box.

2. Package and label spare parts and replacement materials in moisture proof containers suitable for shipment and storage. Attach copies of shipping list in package and to exterior of package. Submit procedures for packaging of spare parts for review and approval prior to any delivery of spare parts.

3. Packaging shall consider the reliability of the parts and the normal requirements for inspecting and inventorying (e.g., the packaging selected for highly reliable parts shall be such that the parts can be identified, inspected, stored for long periods, and endure multiple inventories).

4. On scheduled delivery date(s) representative(s) from the Authority will witness inspection of the contents of each item, verify the manufacturer numbers on the delivered material, and match the manufacturer part numbers on the material to the approved spare parts list.

5. To allow adequate inspection time deliveries may be scheduled over a period of one or more days.

6. Spares shall be grouped together by like item, and not by station.

C. Deliver spare parts, maintenance materials, keys, special tools, and test equipment to the warehouse location or locations designated by the Authority. Provide unloading services at the designated storage location for all delivered products.

D. Prepare formal receipts for all delivered products, and have them signed by the Authority once the inspection is completed for the day. A copy of all such receipts
shall be submitted to the Authority for information and record.

E. Spare parts, maintenance materials, keys, special tools, and test equipment may be stored temporarily at the site of the work in suitable storage facilities until time to deliver these products to the locations designated.

F. Unload spare parts and materials in a manner that will prevent damage to packages and contents. The Authority will open packages and inspect spare parts and material for damage. Damaged parts and materials will be returned to contractor for replacement with undamaged parts and materials at no additional cost to the Authority.

PART 2 - PRODUCTS

2.01 JUNCTION BOXES

Junction Boxes – Design, provide, and install junction boxes for use with switch layouts, signals and other signal track equipment as required by these Specifications and Contract Drawings.

A. All junction boxes shall be provided with gaskets to prevent entrance of moisture and dust, in accordance with the AREMA – Communications & Signals Manual, Part 15.2.10.

B. Switch movement layout junction boxes.

1. Junction boxes for switch layouts shall be the manufacturer's standard with adequate space for double post AREMA approved terminals, terminal boards, cable, and other associated apparatus.

2. Each switch movement layout shall include one junction box, designed for use in railroad applications. The box shall have sufficient space for terminals, disconnects, and other components as may be necessary. Terminals and components shall be located in the junction box so that they are accessible and that manipulation of a terminal wrench is not hindered by the structure of the top of the box.

3. For at-grade installations, junction boxes, complete with pedestal, shall be provided. Junction box pedestals shall have a cable entrance near the bottom of the riser section. Pedestals shall be of sufficient length that the box can be securely installed without need for foundation.

4. Knockouts shall be provided on the sides of the junction box to accommodate conduits to switch machine.

5. Junction boxes shall have ventilation breathers with fine wire mesh screen covering the breather holes.

6. Junction box shall be provided complete with double post terminals in accordance with the requirements of these Specifications.
C. Mast-Mounted Equipment

1. Junction boxes for the bases of masts shall be the split base type junction box with AAR terminals.

2. Junction boxes for masts shall be steel or cast metal and be in accordance with AREMA – Communications & Signals Manual, Part 7.2.36A, Part 7.2.36B, Part 7.2.41A, and Part 7.2.41B.

D. Painting

1. Exterior and interior finish and painting requirements shall be in accordance with the requirements of these Specifications.

E. Security

1. Junction boxes shall be equipped with a locking device capable of being secured, upon closure, with a standard signal padlock. Equip each junction box with a Contractor furnished padlock. The Contractor shall install Authority furnished padlocks at final acceptance.

2.02 ELECTRICAL AND ELECTRONIC COMPONENTS

A. General

1. Provide electrical components for this Contract meeting the requirements herein.
   a. Permanently label components with values or type identification.
   b. Components shall meet any applicable codes required by NFPA 70 (NEC) and the authority having jurisdiction.

B. Terminals

1. Terminal strips, unless designated otherwise, shall conform to the requirements of AREMA. Provide double-post terminal strips conforming to AREMA C&S Manual requirements with double nuts per post. Provide test links where required.

C. Electronic Components

1. Provide electronic components for this Contract that are:
   a. Clearly and permanently labeled with values or type identification
   b. Commercially available from at least two suppliers.

2. Provide semiconductors and other electronic components capable of operating with a de-rating of 25 percent minimum at the maximum temperature the component will be subjected to in the microenvironment immediately surrounding the components.

D. Semiconductors
1. Provide semiconductors of the silicon type with JEDEC numbers, except as otherwise specified.

2. Provide Zener diodes used for voltage regulation or reference levels that will not be damaged if the entire load is removed, and that have a Zener voltage tolerance of plus or minus 5% maximum.

3. Integrated Circuits
   a. Mount integrated circuits with more than 24 pins and all microprocessor and memory chips in sockets. They shall not be soldered directly to the printed circuit boards.
   b. Provide integrated circuits capable of operating with the maximum design load while de-rated to 80 percent of their rated operating power.
   c. Provide integrated circuits screened to MIL-STD 883 or an Authority approved equivalent. Provide integrated circuits in ceramic packages. If a circuit is not available in a ceramic package, then identify and request approval to use a plastic package.

2.03 MARKING AND TAGGING

A. General

1. Except as otherwise specified in this Section, both ends of each cable wire and all single wires that terminate in all wayside enclosure and on equipment shall be permanently identified with a tag. Each cable shall be tagged for identification in each manhole/pullbox. Tags shall not obscure connecting links between terminal binding posts. Tags shall be installed so they may be read with a minimum of disturbance of tags and wiring. Each cable conductor shall be identified before applying tag.

2. Tags for wire, cable, transformers identification, resistors, reactors, and other components shall be Authority approved.

B. Material

1. Cast Metal - This type of marker shall be of malleable cast metal and at least 3 inches high and 3/16 inch thick. Paint the identifying lettering white on a black background. The casting shall be free of cracks or voids, and all edges shall be slightly rounded and free of burrs. If holes are required for installation, they are to be predrilled.
   a. Label each switch machine as indicated. Securely fasten the identifying markers to the cover of each machine. If the fasteners penetrate the cover, a suitable and approved sealant shall be utilized to ensure watertight integrity of the unit.
   b. Label each trackside switch point with an "N" denoting the Normal point, and an "R" denoting the Reverse point. The Normal point is the normally closed point. The letters are to be attached securely to the ties on the inside of the switch points, in such a manner as to prevent loosening due to vibration and shall not interfere with the operation of the layout.
2. Sheet Metal - Construct this type of marker of enameled sheet steel covered by a reflectorized sheeting and meeting the following requirements:

   a. Label each signal as required by these Specifications. The lettering shall be white on a black background unless otherwise specified. Bake the enamel on the sheet in such manner as to ensure that every part of the metal has a smooth, durable, and permanent covering, free of any imperfections.

   b. Reflectorized coating shall be flat-top wide-angle reflective sheeting, engineer grade with pressure-sensitive adhesive. Apply the sheeting over the entire front face of each sign blank.

3. Die-Stamped Nameplate - Label cabinets, power supplies, transformers and other similar types of equipment with the manufacturer's standard nameplate. It shall contain pertinent data such as:

   a. Manufacturer’s Name
   b. Serial Number
   c. Model Number
   d. Date of Manufacture (where required)
   e. Drawing Number

4. Printed Plastic - This type of marker shall consist of two types, sleeve tags and flat plastic tags. The following requirements shall apply:

   a. Sleeve tags - Unless otherwise specified, permanently identify both ends of individual cables conductors that terminate in cases, junction boxes, switch mechanisms, entrance racks and any equipment of the train control system outside of such locations. Unless otherwise specified, permanently identify both ends of all interior wire and cable conductors by a tag, with the exception of solid wire utilized for wirewrap applications.

      1) Sleeve tags shall be of the type as manufactured by Raychem Corporation, Thermofit Marker System (TMS), W. H. Brady Co., Bradysleeve (XB-321,-322, -323), or Authority approved equal. Application of conductor nomenclature shall be in accordance with manufacturer's instructions and result in a permanently bonded and legible identification.

      2) Sleeve tags shall conform to the following:

         a) Be white vinyl plastic with Black lettering, protected by a clear 0.005 inch overlaminate;
         b) Have a minimum thickness of 0.020 inch;

      3) Have corners rounded to approximately 0.125 inch radius; Have lettering minimum 0.125 inch high with minimum 0.09375 inch spacing between lines.

   b. Field change wiring tags for identification shall be wrap around and self-adhesive.
c. Flat Plastic Tags - Unless otherwise specified, all relays, resistors, reactors, terminals, fuse blocks, transformers, or other components shall be of the flat laminated type.

1) Tags shall be 1.5 inches long by 0.75 inches wide with one, 0.3125 inch hole located in the center of the width. Distance from the edge of tag to the hole shall be approximately 0.28125 inch. Untreated tag shall be milk white “vinylite” approximately 7/100 of an inch thick, or Authority approved equal.

2) The tag material shall be capable of receiving the typed-on characters by conventional means and the height of the lettering shall not be less than 1/8 of an inch. Identifying nomenclature space shall allow for three rows of lettering.

3) After lettering, both face and tag backside shall be covered with a clear plastic “vinylite” coating or Authority approved equal. The coating shall be 0.01 inch thick.

4) Nomenclature applied to tags on entrance racks and boards shall show terminal post identification on the top line. Functional nomenclature shall appear on the bottom line, or, if required, on the middle and bottom lines. Geometry coordinates, such as rack, row, and post number, shall identify terminal posts.

d. Flag Marker Tags for individual wire identification of shelf-mounted relays and wires and conductors in junction boxes shall be miniature locking type flag marker tags.

e. Identification tags for components not utilizing a preformed slot or other tag space shall be of a sufficient size to clearly and completely label the item.

f. The nomenclature applied to tags on relays, resistors, reactors, terminals, fuse blocks, transformers and other similar components shall indicate, at a minimum, location and functional nomenclature.

g. The nomenclature applied tags on wire and cable conductors shall indicate, at a minimum, location (i.e., rack, row, contact/terminal), functional nomenclature and the location of the other end of the wire.

h. The nomenclature applied to cable tags shall show the cable number, if utilized, and the location of each end of the cable. This tag shall be either of the wraparound type, or have another approved means of securely fastening it to the neck of the cable. The tag shall be clearly visible after installation.

i. The application of the conductor or component nomenclature to the sleeve or flat tags shall be in accordance with the manufacturer's instructions and shall result in permanently bonded and legible identification.

5. Painted Stencil - Utilize this type of marker to identify racks, enclosures, or other items too large to identify otherwise, and which are not subject to field painting.

a. Stencil equipment racks with a white identification number at the top and on both front and rear of the rack. The minimum size of the figures shall be 3/4
inch high and shall be clearly visible after installation.

b. Stencil pull box and junction box enclosures requiring identification with an approved marking paint, unless specified otherwise. Paint shall provide a definite contrast with the surface on which it is being applied. Identify wayside junction boxes by both name and stationing. The minimum size of the figures shall be one inch high.

6. Ink-Stamped or Etched Copper - Utilize this type of marker for the identification of components not otherwise identified. Etching shall not be obscured by any components, and letters shall be large enough so that solder fill-in will not render them illegible. Ink color shall be black or white, whichever provides the greatest contrast with the background color.

7. Engraved Phenolic Anodized Aluminum Plate: Utilize these types of markers for all special purpose panels.

   a. Engraved phenolic markers shall be white phenolic sheet with thin layers of black phenolic laminated to both sides, on which lettering is engraved. Markers shall contain no detectible filled areas resulting from errors or changes. They shall be free of chips or scratches.
   b. Anodized aluminum plate markers shall be brush finished with photo-etched or engraved lettering. Silk-screen lettering shall not be used.
   c. Print size on markers shall be a minimum of 0.75 inch high.
   d. Markers shall be permanently attached to the enclosure. If holes are required for installation, they shall be predrilled.

C. Pressure Sensitive Labels

1. Pressure-sensitive labels bearing the geometric coordinates shall identify the rows and columns on entrance racks.

2. Mark front relay and rear of plug boards.

2.04 MISCELLANEOUS COMPONENTS AND PRODUCTS

A. All miscellaneous components and products used on this Contract shall be:

1. New and free of manufacturing defects

2. Clearly and permanently labeled with value or type identification.

3. All electrical component ratings shall be at least 20 percent greater than the maximum power, voltage, current, and temperature values that are expected for the components in service.

B. Diodes

1. All diodes provided under this Contract shall carry a JEDEC number or be available from more than one manufacturer and be used within the public specifications for such number. All diodes shall be silicon type, unless otherwise Authority approved.
C. Resistors
   1. Provide resistors rated to dissipate a minimum of 1.5 times the maximum design load for the application when operating in the microenvironment immediately surrounding the component.
   2. All resistors, other than those required for electronic circuits, shall be in accordance with AREMA Communications & Signals Manual, Part 14.2.15.

D. Reactors
   1. All reactors, other than those required for electronic circuits, shall be in accordance with AREMA Communications & Signals Manual, Part 14.2.20.

E. Capacitors
   1. Provide capacitors rated at least 1.5 times the maximum operating peak voltage for that application. Capacitors of 10 mfd or less shall have a maximum tolerance of plus or minus 5 percent. Capacitors used only for power filtering shall have a maximum tolerance of plus 75 percent, minus 10 percent.
   2. Capacitors, for electronic circuits, shall be in accordance with the applicable requirements of AREMA Communications & Signals Manual.

F. Inductors
   1. Provide inductors that withstand twice the maximum design voltage for that application and that have impregnated windings.

G. Potentiometers
   Provide potentiometers with lock nuts or other devices to prevent accidental misadjustment of the settings.

H. Terminal Blocks
   1. Terminal blocks shall be in accordance with the applicable requirements of AREMA Communications & Signals Manual, Part 14.1.6.

I. Terminal Binding Posts
   1. Terminal binding posts, other than those required for supervisory control circuits, shall be in accordance with AREMA Communications & Signals Manual, Part 14.1.10.

J. Terminal Post Insulators
   1. All terminal posts, located on terminal boards in the wayside cases and wayside instrument houses used to terminate 50 Volts or greater, shall be provided with a protective insulator.
   2. The type of insulator shall be individual for each terminal post and be fire resistant.
K. Insulated Test Link

1. Insulated test links shall be in accordance with AREMA Communications & Signals Manual, Part 14.1.15.

L. Lightning Arrestors and Equalizers

1. Lightning arresters and equalizers shall be mounted on three-post porcelain or Authority approved type base in accordance with AREMA Communications & Signals Manual, Part 11.3.1.

M. Hardware

1. All mounting hardware exposed to the elements shall be hot-dip galvanized or other Authority approved material.
   
   a. Galvanizing
      
      1) Hot dip galvanizing process shall be used. All parts shall be pickled so that scale and adhering impurities will be removed. The zinc coating shall be of commercially pure zinc, continuous, and thorough. It shall not scale or blister or be removed by handling or installation. Finished surface shall be free from fine line cracks, holes, or other indications of faulty galvanizing. It shall be smooth and free from adhering flux and other impurities. Edges and ends of parts shall be free from lumps and globules. Parts shall be coated with at least 2 ounces of zinc per square foot of galvanized surface, after all bending, cutting, drilling, and final fabrication.

   b. Bolts in Cast Metal
      
      1) Any Bolt installed in a cast metal assembly shall be coated with “Never-seize” prior to assembly.

N. Special Conduit

1. Flexible Conduit and Hose
   
   a. Hose for TWC shall be Braided Cordura Rayon, vari-purpose hose, internal tube neoprene cover, or Authority approved equal. Hose shall be clamped at both ends with stainless steel clamps.

O. Stainless Steel Clamps

1. Hoses shall be clamped at each end using stainless steel clamps.

P. Sealing Compound

1. Sealing compound for use in sealing cable entrances shall be in accordance with AREMA Communications & Signal Manual, Part 15.2.15.

Q. Paint and Finish
1. Signal equipment paint and painting procedures shall be provided and applied in accordance with AREMA Communications & Signals Manual, Part 1.5.10.

R. Cable Entrance Conduits

1. Cable entrance pipes for ground-mounted train control bungalows shall be PVC coated galvanized rigid steel (GRS) conduit running directly between the house and the nearest manhole or as approved by the Authority. Two spare conduits shall be provided and installed within each Train Control Bungalow.

S. Rubber mats

1. Rubber mats shall be provided for installation in the train control bungalow. Rubber mats shall meet the applicable sections of IEEE C-37-14 and NEMA-standard 1CS-1970.

T. Lubrication

1. Switch tie plates lubrication for all switch-and-lock movement layouts shall be an Authority approved graphite lubricant, similar to Dixon’s Graphite “Railroad 60” or Authority approved equal.

U. Environmental Protection

1. Protection for machine-finished surfaces, threaded rods and nuts and other parts that are susceptible to rusting shall be a corroding preventive compound, NO-OX-IDE Number 90918, or Authority approved equal. The product must have sufficient body to resist weather and rusting for at least six months.

2. Two gallons or equivalent weight shall be provided to the Authority as a deliverable.

V. Trench Marker Tape

1. The Contractor shall provide and install a detectable trench marker tape for signal cable, bright yellow, six inches wide and continuously coded in black lettering with the following legend:

   CAUTION   CAUTION   CAUTION
   BURIED     SIGNAL     CABLE

W. Tamper-Proof Bolts

1. Equipment with covers that are not furnished with locks shall have at least one tamper-proof bolt per cover. The Contractor shall provide six tools for each type of bolt keying to the Authority as a deliverable. The Contractor shall provide tamper proof bolts compatible with those used on Authority’s existing system.

X. CONDUIT

1. All conduit installed outside the train control bungalows shall be PVC coated galvanized rigid steel.
2. Conduits and fittings shall be free, within commercial tolerances, of objectionable lines, bubbles, chipped ends, and other manufacturing defects, that would impair the service of the conduit. The bore of the conduit shall be straight and circular in cross section with smooth interior surfaces free from obstructions and rough and flaky areas. The conduit and fittings shall be free from all substances that may injuriously affect any wire or cable covering. The numbers and sizes of the conduits shall be as shown on the Contract Drawings.

3. All conduits shall have a nylon pull-cord installed and secured at each end, with tags referenced the same at both ends on the pull-cord.

4. Field-cut threads and reamed ends in metallic conduit shall be protected from corrosion immediately after cutting, reaming and cleaning by application of a zinc rich coating.

5. Use conductive joint compounds to insure electrical continuity of metallic conduit joints. Manufacturers shall reference the product to ANSI, IEEE, UL, NEMA or any other recognized standards or code.

6. Install manufactured end caps or plugs on all conduit ends immediately after installation to prevent the entrance of liquids or foreign materials.

7. Unless otherwise indicated, minimum bend radius for conduits shall be in accordance with the National Electrical Code. Exceptions to the National Electrical Code shall not be used to determine conduit bend radius, even if permitted by the NEC, for any part of this Contract unless Authority approved.

8. PVC coated GRS conduit and fittings require special installation methods, and shall be installed in strict accordance with the manufacturer's instructions. Provide PVC boot to cover all exposed threads. Touch-up minor slice, nick, or abrasion damage to PVC coating with patching compound approved by the conduit manufacturer. Slices more than 10 mils in depth, and nicks and abrasions more than 10 mils in depth or 0.25 inch in diameter are considered major damage. Patching compound shall not be used to correct major damage. Conduits and fittings with major damage shall be replaced. The Authority shall be the sole judge or whether coating damage is minor or major.

9. End Bells shall be flared, smooth surfaced fittings of same material as conduit.

Y. Spare Parts and Consumables Lists

1. Spare parts shall be new and unused components.

2. The spare parts and consumables lists shall include all spare parts as required to provide for the maintenance and repairs of all Contractor-furnished equipment and appliances for a period of five years after the date of final acceptance.

3. The list of spare parts and consumable material the lists shall be organized by the Specification Section number and title. The spare parts and consumables list shall include the following:
a. Item by item listing
b. Product Name / Description (starting with the appropriate keyword, followed
by keyword modifiers)
c. Manufacturer’s Name, Address and Telephone number
d. Manufacturer’s Part Number
e. Manufacturer's Model Number
f. Unit of Measure (each, feet, and like items.)
g. Unit cost
h. Local Distributor (Name, Address, Federal ID, and Phone Number )
i. Distributor’s Part Number
j. Authorized OEM Rebuild Facility (Name, Address, and Phone Number)
k. Confirmation of whether part is hazardous or not. (Include MSDS sheet if
hazardous)
l. Recommended stocking quantities
m. Alternate vendor sources

4. Spare parts shall be grouped by equipment category. Replacement parts common
to more than one category shall be cross-referenced and indexed. Such common
parts shall have only one part number.

5. Contractor will submit a recommended list of five years’ worth of consumption for
spare parts and replacement material. The list shall follow a “Top Down
Breakdown” starting with the top assembly and proceeding downward through its
various sub-assemblies, components and detail parts to the lowest replaceable
unit.

6. Spares referred to as “sets” (a single part number covering multiple replaceable
units) are unacceptable. Items must be broken down to individual components.

7. Deliver specific spare parts as identified in the Technical Specifications.

8. Spare parts shall be identical to the parts installed in the Work.

Z. Maintenance Materials

1. Provide maintenance materials as specified in these Specifications.

2. Maintenance materials shall be identical to the materials installed in the Work.

3. Provide the quantities of materials as specified in these Specifications.

4. The Contractor shall provide 5 years’ worth of material to support operations of
final installed quantities of all mounted stand alone equipment, including but not
limited to, channel banks, switches, fiber loop converter, multiplexers, and power
supplies. Fiber Optic (FO) receivers, FO transmitters, jumpers, and alarm system.
Yard Operations Control (YOC) panels, record/playback stations, audio control
system, speaker. Spare parts shall be interchangeable with their corresponding
part.

5. The Maintenance Materials List shall be organized in accordance with the
Technical Specifications by Section number and title.
6. Where maintenance materials are specified as a percentage of the materials installed, such percentages shall be translated to actual quantities of materials in the Maintenance Materials List.

7. The Maintenance Materials List shall include, as a minimum, the following:

a. Two rectifiers of each type and rating used in the system, including those normally considered an internal component of any given equipment.
b. Twenty fuses and 10 circuit breakers of each type and rating used in the system, including those normally considered an internal component of any given equipment.
c. Eight terminal strips of each type complete with hardware.
d. Thirty wire connectors of each type and size used in the system, including all multi-conductor connectors with hardware.
e. Two dozen of each type of hardware used, such as nuts washers and screws.
f. One transformer of each rating used in the system.
g. Two of each type Printed Circuit (PC) card used in the train control equipment supplied under this Contract, but not mentioned elsewhere.
h. Three of each type of power supply, inverter, battery, and battery charger supplied under this Contract.
i. Two of each type card extender for each type electronic equipment provided under this Contract.
j. Two complete event recorder units with all required components for installation.
k. One thousand feet of each type of wire and cable used.

AA. Keys, Special Tools, and Test Equipment List:

1. Prepare and submit a complete list of keys, special tools, and test equipment as specified in these Specifications.
2. The Keys, Special Tools, and Test Equipment List shall be organized in accordance with the Technical Specifications by Section number and title.
3. The Contractor shall provide one laptop computer for downloading the existing memory contents of the event recorder. The computer shall be provided with software, interface hardware, and cables for connection to the event recorder.

   a. The computers shall be Pentium processor-based with hard disks of sufficient size for the operating system, application software and downloaded data from the full storage of at least 10 event recorders. The laptop computers shall be provided with Authority approved network cards.
   b. The Contractor shall either provide translation software or ensure that the data file format is such that the data may be printed directly from the laptop, or transferred to a database, or spreadsheet application.

4. Provide sufficient keys, special tools and wrenches, and special test equipment and gages as required to access, start, maintain, and repair all the installed equipment, appliances, systems, and assemblies as specified in the individual Sections of the Technical Specifications.
5. Provide quantities of keys, special tools, and test equipment as specified in the individual Sections of the Technical Specifications.
6. Provide programming tool(s), manuals, and training to allow the Authority to make changes to all software, except proprietary software, in the bungalows, communication room and the Yard Operations Center.

PART 3 - EXECUTION

3.01 JUNCTION BOXES

A. Installation

1. Switch movement layout junction boxes shall be installed to terminate underground cable for the switch layout, as shown on Authority approved installation drawings.

2. Junction boxes for signal layouts shall be installed to terminate signal cables, as shown on Authority approved installation drawings.

3.02 MARKING AND TAGGING

A. Application

1. Apply markings during manufacture whenever possible. Apply the markings in a careful, thorough, and legible manner.

2. During routine field inspections and testing, verify that the field-installed tags and markings are correct and applied in an approved manner. Work shall not considered complete until tags and markings are correct and in place.

3.03 MISCELLANEOUS COMPONENTS AND PRODUCTS

A. All material and apparatus specified shall be installed in accordance as described in these Specifications.

B. Each miscellaneous component and product shall be inspected after it has been installed in the field. This inspection shall conform to the Contractor's Installation and Inspection Procedure as approved by the Authority. Installation shall not be considered complete until all installation defects have been corrected to the Authority's satisfaction.

END OF SECTION 34 42 60
SECTION 34 72 00
TRACKWORK

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Reference Standards:

1. American Railroad Engineering and Maintenance of Way Association (AREMA):

2. Federal Railroad Administration (FRA):

3. Los Angeles County Metropolitan Transportation Authority (MTA):
   a. Metro Rail Design Criteria
   b. Metro Rail Standards and Directive Drawings

1.02 SUMMARY

A. This Section consists of the Contractor, unless otherwise indicated, furnishing all labor, materials, equipment, tools, and incidentals necessary to construct trackwork, slab track, embedded track, turnouts, and crossovers.

1. Work includes ballast, walkways, asphalt, concrete, bar reinforcing steel, ties, rail, tie pads, insulated rail boot, fastening systems, other track material (OTM), turnouts and other special trackwork.

B. Related Specification Sections include, but are not necessarily limited to:

1. Division 00 - Procurement and Contracting Requirements.

2. Division 01 - General Requirements.

3. Section 34 11 26 – Ballast.

4. Section 34 11 27 – Sub-Ballast and Aggregate Base.

5. Section 34 11 33 – Concrete Railroad Ties.

1.03 SUBMITTALS

A. Submit, under the provisions of Division 01:

1. Materials: Submit individual certifications that all materials furnished by the Contractor conform to the specified requirements.
2. Shop Drawings:
   a. Submit Shop Drawing and product data for trackwork items not specifically defined by engineering standards.
   b. Shop Drawings for each size and direction of turnout will be required.
   c. Shop Drawings shall also be submitted in electronic media format on compact discs.
   d. The Authority accepted CADD software shall be either Microstation or AutoCAD, latest release approved by the Authority.

3. Equipment: Provide submittal for all construction equipment proposed to be used as identified in Division 01.

   a. Submit proposed construction and installation procedure for new trackwork as part of the Contractor's approved Construction staging plan for Authority approval and coordination.
   b. Contractor may modify installation procedure stated hereinafter, to produce the most efficient method for track construction, subject to approval by the Engineer.

5. Compliance Record: As-built compilation of actual track geometry produced in construction including curvature, length of reversing tangent, length of spirals, top of rail profile, and super elevation values.

6. Compliance Record: Rail temperature record taken during anchorage and destressing procedures as described in the Articles entitled “Procedures for Placement of CWR” and “Anchoring CWR” herein.

7. Compliance Record: Test results for insulated joints as described in Article entitled “Insulated Joints” in Part 3 of this Section.


10. Procedure: Submit procedure and field welding material technical data for field welding rail.


13. Procedure: Plan for the coordinating and scheduling of a signal track support crew to protect and maintain the operating signal system.

1.04 QUALITY ASSURANCE

   A. Quality Assurance:
1. Perform track construction under the supervision of qualified personnel, as defined in Division 01.

2. Corrections by Contractor: During the installation and testing period, Contractor must make available personnel, equipment, and Materials necessary to make required corrections to the track including such work as replacements, re-ballasting, resurfacing and realigning, or repair of constructed items, as the Authority may require ensuring completion of the Work in accordance with the Contract.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Ties shall be lifted and supported during storage, transportation, and placing in such a manner as to prevent damage.
   1. Ties shall not be dropped to the roadbed.
   2. Refer to Section 34 11 33 – Concrete Railroad Ties for on-site storage requirements.

B. Rail shall be unloaded and distributed in a manner that prevents damage to ties, rails and structures. Do not bump or strike rail.

PART 2 - PRODUCTS

2.01 CONSTRUCTION EQUIPMENT

A. If the Authority determines that Contractor's equipment is not in good working condition or the kind, size, capacity or quantity of equipment is incapable of contributing to the Work progress or to the requirements of the Contract Documents, Contractor must promptly replace the equipment with an improved kind, type, size, capacity, or quantity. Rejection of equipment shall not be considered justification for a delay Claim.

B. Track surfacing and alignment equipment shall be laser guided.
   1. Track surfacing equipment must have all tamping tools in good repair and working order.
   2. As a minimum, at least 70 percent of the original surface area of the tamping tool pad must be available and these tools must closely match adjacent and opposite tamping tool pads in the amount of wear.

C. Equipment shall be compatible with and shall be operated within the clearances indicated in Metro Engineering Standards and Directive Drawings and Design Criteria.

D. Wheel contours of all rail-mounted equipment shall conform to the Association of American Railroads (AAR) wheel standards or AREMA maintenance of way equipment wheel standards.
E. All construction loads borne by equipment shall be applied between gage lines of running rails on each track unless approved by the Authority.

F. Vibratory compaction equipment for compaction of base ballast shall be specifically manufactured for compaction purposes.

1. The self-propelled, pneumatic-tired roller shall have a gross weight of 10 to 15 tons, and the vibratory compactor shall have a weight of not less than 10 tons and shall be capable of applying a dynamic load of not less than 18,000 lbs at 1,300 to 1,500 cycles per minute.

2. The proposed compaction equipment is subject to approval by the Authority.

G. Ballast stabilizer for compacting ballast in crib and shoulder areas shall be approved by the Authority.

2.02 TRACK TOOLS

A. Furnish tools and equipment necessary to construct the track.

B. Track gages, track levels, and other tools shall conform to the AREMA Volume 1, Chapter 5, Part 6, "Specifications and Plans for Tools."

C. Tools and equipment shall be maintained in such a condition as not to endanger personnel nor damage the Work and shall be subject to inspection by the Authority.

D. Tools not conforming to standard shall be repaired to AREMA standards or shall be replaced.

1. Substitution of tools other than AREMA standard will be permitted only with approval of the Authority.

E. Track levels and gages shall be checked for accuracy at the start of every work shift and at any time the tool is dropped or struck.

1. Adjustments shall be performed anytime it is found to have more than 0.050 inch deviation from the nominal measurement value.

2.03 SUB-BALLAST

A. Sub-ballast shall conform to the requirements of Section 34 11 27 – Sub-Ballast and Aggregate Base.

2.04 BALLAST AND WALKWAY ROCK

A. Ballast shall conform to the requirements of Section 34 11 26 – Ballast.

B. Walkway rock shall conform to the requirements of Section 34 11 26 – Ballast.

2.05 TIES
A. Concrete ties, shall conform to the requirements of Section 34 11 33 – Concrete Railroad Ties, Metro Engineering Standard Drawings, Design Criteria and latest AREMA Manual for Railway Engineering. Ties shall be new unless indicated otherwise in the Contract Documents.

2.06 RAIL

A. Rail shall be new 115RE CWR (continuous welded rail) and conform to Metro Rail Design Criteria unless otherwise stated in the Contract Documents.

B. Rails in curves with radii of 300 feet or less shall be precurved using standard shop practices.

2.07 EMERGENCY GUARDRAIL

A. Emergency guardrails shall be installed 60 feet ahead of and behind structural columns supporting second floor office facilities as noted on the Contract Drawings.

B. Guardrails shall be continuously welded and fastened to the supporting tie in accordance with the Contract Drawings.

C. Guardrails shall be electrically insulated.

2.08 OTHER TRACK MATERIAL (OTM)

A. OTM shall be new and conform to Metro Engineering Standards and Directive Drawings and the following requirements:

1. Bolts, Nuts, and Washers shall conform to AREMA Volume 1, Chapter 4, Section 2.9, “Specifications for Heat-Treated Carbon-Steel Track Bolts and Carbon-Steel Nuts”.

2. Joint bars shall be six-hole, 36 inches in length and conform to AREMA Volume 1, Chapter 4, Section 2.8, “Specifications for Quenched Carbon-Steel Joint Bars, Micro-alloyed Joint Bars and Forged Compromise Joint Bars”.


3. Joint bars used to temporarily connect rails that will be field welded in the final configuration shall be bolted with the rails ends drilled in the outer four holes only.

4. Resilient Rail Fastening Systems:

   a. Resilient fastening system for concrete ties shall be a Pandrol Rail fastening system “Pandrol Rail Clip – Type “e” 2055”, consisting of elastic fastener “e-Clip” galvanized type elastic clips, glass reinforced nylon insulator, malleable clip shoulder insert (precast in ties), or substantially equivalent resilient fastening system approved in writing by the Authority, unless indicated otherwise on the Contract Drawings.
b. Rail seat pads shall be 3/8 inch thick elastomer pads per TS-614

c. Resilient fasteners for Insulated Joints shall be type specified in Metro Engineering Standards and Directive Drawings for the type of resilient fasteners to be used.

1) The Contractor must provide suitable fasteners in accordance Relevant Engineering Standards requirements.


2.09 TURNOUTS

A. Turnouts shall be as indicated on the Contract Drawings, fabricated with all new material, 115RE high strength rail, and in conformance with Metro Engineering Standards and Authority approved shop drawings.

2.10 LUBRICANTS

A. Lubricant for special trackwork shall be Whitmore’s Railmaster Curve grease, except Dixon L-5550 graphite, shall be used for switch plate lubricant or approved equal. Approved equals shall be submitted for approval by the Authority.

2.11 INSULATED JOINTS

A. New insulated joints must be furnished by Contractor and shall conform to Metro Engineering Standards and Directive Drawings.

B. Elastic fasteners for ties supporting insulated joints shall be designed to prevent electrical bridging between rails and joint bars.

C. Locations of insulated joints to be installed per the Contract Drawings.

2.12 BUMPING POSTS

A. New bumping posts must be furnished by Contractor and shall be Western Cullen Hayes spring head Type WA Bump Post, modified with all parts above base of rail per Manufacturer’s drawing 10707, or Authority approved equal.

B. Salvaged bumping posts will be H.J. Skelton/Rawie friction element bumping provided by the Authority at a storage site located within the project limits of the Exposition Mainline Rail Construction Project. Contractor shall be responsible for transporting the bumping post to the project site and providing expendables and non-reusable parts per the Manufacturer’s recommendations. Contractor shall also be responsible for providing electric service to and connecting the bumping post beacon.

C. Bolted Bumping Posts shall be placed with at least 18 inches between the last bumping post track bolt and the end of rail.
D. Embedded and Direct Fixation track constructed 18 inches beyond the face of a bumping post shall be constructed without a wheel flangeway (wheel flangeway shall be filled with concrete to the top of rail elevation).

2.13 RAIL BOOTS

A. Provide continuous rubber rail boot as shown in the Contract Plans and as described in this Section.

B. Rail boot material properties shall be as follows:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>ASTM TEST</th>
<th>REQUIRED</th>
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</thead>
<tbody>
<tr>
<td>Tensile Elongation</td>
<td>D412</td>
<td>1,000 psi Minimum</td>
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<tr>
<td>Elongation</td>
<td>D412</td>
<td>300% Minimum</td>
</tr>
<tr>
<td>Durometer, Shore A/Shore D</td>
<td>D2240</td>
<td>70±5/50±5</td>
</tr>
<tr>
<td>Compression Set (70 H @ 212F)</td>
<td>D395 Method B Modified</td>
<td>40% Maximum</td>
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<tr>
<td>Oven Aging (70 H@212F)</td>
<td>D573</td>
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</tr>
<tr>
<td>Tensile Change</td>
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<td>D573</td>
<td>-30%</td>
</tr>
<tr>
<td>Maximum Durometer Change</td>
<td>D573</td>
<td>0 to +10</td>
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<td>Ozone Resistance, 20% Strain, 300 PPM in air (70 H @ 104F)</td>
<td>D1149 Modified</td>
<td>No Cracking</td>
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<tr>
<td>Low Temperature Resistance A, after 3 Minutes</td>
<td>D2137</td>
<td>Non-Brittle @ -40F Method</td>
</tr>
<tr>
<td>Volume Resistivity, Ohms cm (Dry)</td>
<td>D257</td>
<td>1X10^{12} Minimum</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>ASTM TEST</th>
<th>REQUIRED</th>
</tr>
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<tbody>
<tr>
<td>Volume Resistivity, Ohms cm (When saturated with 18% NaCl solution)</td>
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<td>1X10^{12} Minimum</td>
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<tr>
<td>Water Absorption (168 H Maximum@77F)</td>
<td>D570</td>
<td>1% by Weight</td>
</tr>
<tr>
<td>Oil Swell, ASTM #3 Oil (70 H @ 212F)</td>
<td>D47</td>
<td>+60% by Weight Maximum</td>
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</table>

PART 3 - EXECUTION

3.01 GENERAL REQUIREMENTS
A. Work shall be completed in accordance with Authority Engineering Standards and Directive Drawings, AREMA Manual, and as specified herein.

1. Each fully completed segment of track, as approved in the Contractor's construction staging plan, is to be placed into operational service and shall fully comply with the requirements of FRA 49 CFR 213 for the specific classification of train operation.

2. Track must have ballast section full to top of ties, have joints fully bolted or welded, have all anchors or elastic fasteners applied, and the rail shall be fully destressed.

B. Fill, compaction, and subgrade preparation shall conform to the requirements of DIVISION 31 – EARTHWORK. All fill and subgrade within 8 feet of centerline of any track shall be compacted to a minimum of 95 percent relative density per ASTM D1557.

C. Bottom of rail, fastener assemblies, and all bearing surfaces shall be broom cleaned before laying rail.

D. Install track, OTM, rail boots, turnouts, derails and road crossings in accordance with the Contract Drawings, Metro Engineering Standards and Directive Drawings, and CPUC requirements.

3.02 SUB-BALLAST

A. Sub-ballast construction shall conform to typical cross sections as depicted in Metro Engineering Standards and Directive Drawings or as shown on Contract Drawings and must also comply with the requirements of Section 34 11 27 – Sub-Ballast and Aggregate Base.

3.03 CROSS TIES

A. Concrete ties shall be used in all locations of track construction, except where shown in the Contract Drawings to be pedestal track or direct fixation track.

B. Ties damaged as a result of improper handling or installation by Contractor and rejected by the Authority must be removed and replaced with new ties at no additional cost to the Authority.

C. Place concrete crossties as shown in the Contract drawings and Metro Rail Standard Drawings, Metro Engineering Standards and Directive Drawings.

1. Ensure that the proper rail cant is established.

2. Concrete ties shall be spaced 30 inches center to center on tangent, and curved track of a radius greater than or equal to 500 feet. On curves of radii less than 500 feet, concrete ties shall be spaced 24 inches center to center.

3. Concrete crossties shall be 8 feet 3 inch in length conforming to the current Authority-furnished material specifications.
4. Concrete ties shall be 10 feet in length in areas where concrete grade crossing panels have been noted in the Contract Drawings.

3.04 RAIL FASTENING

A. OTM shall be installed in accordance with Metro Engineering Standards and Directive Drawings and where applicable, Manufacturer’s recommendations.

B. Installation of specified resilient fasteners shall be in accordance with Manufacturer’s recommendations, and Metro Engineering Standards and Directive Drawings

3.05 INSTALLING TRACK

A. Installation, laying, raising, lining, tamping and dressing of track over ballast shall be performed as follows:

1. Ballast shall only be installed over sub-ballast, which has been prepared in accordance with Section 34 11 27 – Sub-Ballast and Aggregate Base and approved by the Authority.

2. Place base ballast in lifts not more than 6 inches in thickness before compaction.
   a. Layers shall extend beyond the edge of the ties as shown on the Contract Drawings before compaction.
   b. Compact ballast thoroughly to form a stable section able to support the subsequent layers and loads.

3. Compaction of base ballast shall be by means of vibratory compaction equipment specified in Division 01.
   a. Each lift of ballast within the initial layer shall be uniformly spread and compacted with not less than 4 passes of either a self-propelled, pneumatic-tired roller or vibratory compactor.

4. Ballast surface that exhibits ruts or crowns is not acceptable and shall be regraded and re-compacted prior to the placement of the crossties. Obtain the Authority’s verification of the compacted ballast prior to the installation of track and appurtenant Work over the ballast.

5. The track shall be assembled on the compacted ballast to permit placement of additional ballast for subsequent raising and tamping and to provide the full depth under the ties.

6. The ballast shall be tamped with a 16 tool vibrating squeeze-type mechanical tamper specified in Division 01, making a minimum of one full tamping insertion per tie for each inch of raise.

7. The final track raise shall not exceed 1 inch.

8. The ballast in the crib areas shall be mechanically stabilized by a ballast stabilizer approved by the Authority in accordance with Division 01.
9. The track shall be raised, aligned and tamped to within the specified tolerances.

10. Where track is constructed at a location for placement of a bumping post, the track shall extend at least 18 inches beyond the location of the last rail bolt required for the bumping post.

11. Ballast shall be thoroughly tamped within a space from 15 inches inside either rail to the ends of the ties.
   a. In tamping ties within the above described limits, simultaneous tamping shall be performed under each rail.
   b. Tamping is not permitted at the center of the tie except within limits of turnouts and crossings where the center of the ties shall be tamped unless prevented by trackwork components.

12. Pneumatic or electric tamping tools, either hand held or machine mounted shall be used to perform tamping at portions of turnouts not accessible to a production tamper. Hand tamping with shovels or picks will not be permitted unless authorized by the Authority.

13. Two tamping tools shall always be used opposite each other on the same tie.
   a. Tampers shall be started from a nearly vertical position and worked downward past the bottom of the tie, after which the tool should be slanted downward to force ballast under the tie.
   b. Double tamp every joint tie.

14. Ballast shall be mechanically dressed to provide the section as shown on the Metro Engineering Standards and Directive Drawings and the Contract Drawings.

15. Excess ballast shall be removed.
   a. With the Authority’s permission, excess ballast may be placed as directed by the Authority.
   b. Payment will not be made for ballast in excess of dimensions shown on the Contract Drawings.

16. Ballast damaged by overwork or excessive tamping or fouled by dirt or other deleterious material as determined by the Authority must be removed and replaced at no additional cost to the Authority.

17. Where new track joins existing track, the existing track shall be surfaced for a minimum distance of 500 feet on mainline or siding tracks, or 200 feet on industrial tracks, from the point of connection.
   a. Existing track surfacing may be longer as needed to meet FRA requirements, or as shown on the Contract Drawings.

18. After the track has been raised to its final elevation, ballast consolidation of all tracks shall be performed before the track is placed in service.
a. Each segment of track may be placed in full service, as approved by the Authority, if that segment fully complies with FRA 49 CFR 213 for specific classification of train operation, has ballast section full to top of ties, has joints fully bolted or welded, has all anchors or elastic fasteners applied, and has the rail fully destressed and ballast compacted.

19. When raising track, a spot board or other approved device shall be used to maintain grade, and a level shall be used to keep track to proper crosslevel.

a. Laser guided alignment is required, and horizontal alignment must be maintained during the raising operation.

b. Use of automated controls on tampers will satisfy this requirement.

20. In addition to the other requirements specified herein, all newly constructed track, upon completion of final surfacing operations, shall be mechanically stabilized using a Ballast Stabilizer as specified in Division 01.

3.06 INSTALLING TURNOUTS

A. Installation of turnout with resilient fasteners on concrete ties shall conform to Metro Engineering Standards and Directive Drawings and AREMA trackwork standards.

B. Following the installation of turnouts on the initial layer of ballast, the turnouts shall be lifted, aligned and supported prior to placement of final ballast.

C. Ballast shall be uniformly placed and spread.

1. The turnout shall then be raised and the ballast tamped under both sides of each tie for the full length of the tie.

2. Tamp ballast thoroughly throughout the length of all ties in the turnout or other special trackwork.

3. Final top of ballast shall conform to the ballast section as indicated except in cribs wherein switch operating rods, locking rods or connecting rods are located and between point of switch and heel of switch where the crib ballast shall be 3 inches below the base of the rail.

D. When installing the various components of the turnout, particular attention shall be given to the following:

1. Check that alignment, gage, and surface meet Specifications and Metro Design Criteria.

2. Verify that bolts, nuts, cotter pins, and other fastenings are in place, in good condition, and properly tightened.

3. Verify that switch points are properly aligned and fit tightly against rail when switch is thrown in either position.
4. Verify that connecting rod and switch rod bolts are equipped with cotter pins properly applied.

5. Test-operate the switches for lost motion, difficult throw, or loose connections and adjust as necessary.

6. Examine the rod and fastenings that connect the switch point to the switch machine to see that they are in place and in good condition.

E. Joints within turnouts shall be welded, unless a location for an insulated joint has been specified on the Contract Drawings.

F. Ties beyond the last common tie of the turnout shall be interlaced by the Contractor as necessary to avoid any tie conflicts (ties shall not be cut or modified). Tie spacing shall never exceed 30 inches. Any extra ties required due reduced tie spacing necessary for interlacing shall be considered incidental to track construction.

G. Switch machines shall be installed as to hold the switch point tightly against the stock rail when stand is in normal position, per the Manufacturer's instructions.

1. Switch rods shall be adjusted to hold the opposite point tightly against the rail when machine is in reverse position.

2. Switch machines and associated equipment, shall be mounted on concrete switch ties with insulated precast inserts.

H. Switch machines and associated equipment shall be kept securely fastened to the head block ties, use approved fasteners.

1. The head block ties shall be set square with the track and kept firmly tamped.

2. Correct any walkway deficiencies adjacent to the head block ties that would impact Authority employee or operating personnel access to the operating levers or controls for the switch machine.

I. At the time of installation, sliding surfaces of special trackwork assemblies shall be lubricated with a dry film graphite lubricant in accordance with the Manufacturer's recommendations.

J. Insulated joints for non-interlocked switches shall be installed as shown on the Contract Drawings and in accordance with AREMA (Former AAR) Signal Manual.

1. Install joint using Manufacturer's recommended procedure.

K. Signal System Point Protection:

1. No switch point shall be installed in the main track unless it has the proper signal system point protection in place and tested.

2. No switch protection shall be removed from any normally closed signaled switch point unless the switch point is replaced by a straight rail and signal circuits have been corrected and tested.
3. All rail bonding and fouling circuit protection must be intact at all times on all signaled switches.

4. Contractor will perform installation and testing of signal devices with the oversight of Authority signal inspectors. An Authority representative must be present to approve the completion of all testing.

5. Contractor must coordinate installation or removal of turnout with Authority for required signal testing.

3.07 DRILLING

A. Rail ends for bolted joints shall be drilled in accordance with Metro Engineering Standards and Directive Drawings.

   1. Any additional holes in rail will be sufficient cause for rejection.

B. A variation of 1/32 inch in size and location of bolt holes will be allowed.

C. Holes shall be located with the proper size rail-drilling template and marked with a center punch prior to drilling.

D. Drilling through joint bars is prohibited.

3.08 RAIL ENDS

A. Rail shall be cut with rail saw to a tolerance of 1/32 inch from square.

   1. All burrs shall be removed and ends made smooth.

   2. Torch cut rails will be rejected.

B. Battered or mismatched ends shall be built up or ground off to conform to minimum tolerance of 1/16 inch on top and gage side to adjoining rail.

3.09 RAIL END HARDENING

A. At all rail end locations not eliminated by field welding, rail ends shall be field end hardened in accordance with the AREMA Manual, Volume 1, Chapter 4, Section 2.1.17.1, “Supplementary Requirements” including all insulated joints.

3.10 PROCEDURES FOR PLACEMENT OF CWR

A. Welding of rails into CWR strings shall be either by electric flash butt process or thermite process. Electric flash butt welding shall be used wherever feasible. Thermite welding or mobile electric flush butt welding shall be used to join strips of CWR; where required for rail handling; or where rail requires precurving.

B. Rail welding shall be in accordance with the AREMA recommendations and as modified in the Technical Specifications. Rail shall be laid or adjusted to the Preferred Rail Laying Temperature of 105 degree F using standard AREMA practices and as described herein.
C. Tie cribs shall be filled with ballast immediately after laying rails and after each track raise.

1. Track shall be surfaced, stabilized, and lined and all ties tamped and anchored, prior to returning track to full service.

D. If the rail temperature exceeds 115 degree F, the Authority reserves the right to suspend rail-laying operations, or direct that the rail be cooled.

1. These actions shall not entitle Contractor to any additional compensation or time.

E. Welded rails shall be positioned for installing in a manner to minimize handling and to prevent buckling.

F. The rail base and tie plate or concrete tie rail seat area shall be cleaned to remove foreign material that may interfere with the full bearing contact with the base of the rail.

1. Rails shall be placed base down, parallel with track, avoiding excessive bending or damage, using suitable mechanical equipment.

2. Do not place rails on signal equipment, manhole covers, electrical connections, or near any other installation that could be susceptible to damage.

G. An approved rail thermometer shall be used to determine rail temperature.

1. The thermometer shall be placed on the web or base of rail shaded from the sun and left long enough to record the rail temperature accurately.

2. The temperature shall be checked frequently.

3. All rail thermometers shall be calibrated.

H. Tools used for field cutting rails shall be approved rail saws.

1. Torch-cut rails shall not be installed in the track.

2. Any rail damaged by torches shall be rejected and removed before installation in the track.

I. Rail shall be destressed in accordance with AREMA recommendations and as modified in the Technical Specifications, only after final track line and grade has been achieved and ballast stabilized, or as required by the Authority.

1. Rail shall be re-anchored with elastic fasteners after destressing has been achieved.

2. Rail shall have adequate fasteners installed at all stages of construction.

3.11 ANCHORING CWR
A. As used in this Article the term “rail anchor” or “anchoring of rail” refers to installation of elastic rail fasteners to serve as a rail anchoring device. Install rail-anchoring devices when the rail is within the permissible anchoring temperature.

1. Anchor opposite rail only when its temperature is within 5 degree F of the previously anchored rail’s temperature at the time of its anchoring.

2. Temperatures shall be measured in accordance with AREMA recommendations and as modified in the Technical Specifications.

B. Anchorage for CWR shall be provided by the rail fastening system of the concrete ties to deter expansion and contraction of rail ends, and to prevent rail creep. At critical locations, it may be necessary to relieve expansion and contraction of the rail to prevent damage to the track or to the supporting structure. When the anticipated stresses or movement of the rail cannot be relieved, expansion joints or low restraint rail clips shall be considered.

C. Prior to joining CWR strings, adjust the CWR strings to the Preferred Rail Laying temperature (105 degree F), vibrate to relieve internal rail stresses, and fully anchor.

D. Join CWR strings when the rail gap is at the specified gap.

1. If the rail gap is not within the recommended tolerances for joining CWR strings, and the remainder of the string has been adjusted, un-anchor the CWR strings for 400 feet on each side of the rail gap and readjust each CWR string to within the Preferred Rail Laying Temperature.

2. Re-anchor the CWR strings before installing the rail joint or weld.

3. If the recommended rail gap cannot be obtained in this manner, cut a section of rail from the end of one of the CWR strings and insert a rail plug not less than 19 feet 6 inch long on tangent track and curves less than 2 degree; and not less than 30 feet long on curves of 2 degree or greater to provide the recommended rail gaps, or crop the rail as necessary to provide the recommended gap.

4. If the Contractor elects to use an artificial means of adjusting the rail for anchoring, submit the method and equipment proposed to the Authority and obtain Authority’s acceptance.

5. A rail vibrator shall accompany the rail heating process to assure free expansion of the rail in advance of the heated area.

6. Witness marks shall be made at 4 or more stations on unanchored rail across the base of the rail and tie plates to confirm actual expansion of the rail in accordance with the calculations.

E. Contractor must not make any joints or welds within the body of a curve unless approved by the Authority.

3.12 ADJUSTMENT BY MECHANICAL HEATING
A. Rail shall be adjusted for temperature after it has been laid on tie plates but before it is anchored.

B. Rail gaps shall be provided at the end of each continuous welded rail equal to the amount of the expansion that is required for that rail.

C. Heating shall begin at the end of the rail and be steadily applied moving forward and without reversing direction until the required expansion has been obtained for that rail.

D. Complete application of elastic fasteners shall follow heating as closely as possible.
   1. Any deviation or delay will require reheating the rail.

E. Prevent damage to other work during the heating process.

3.13 THERMAL ADJUSTMENT CALCULATION

A. When it is necessary to adjust the rail already in track, the required increase or decrease may be found by taking the difference between the Preferred Rail Laying Temperature and recorded rail temperatures at each string of CWR and calculating the amount of adjustment as specified herein.

   1. The number of inches by which a CWR segment shall be increased or decreased to adjust its length for a temperature higher or lower than that at which it was anchored or adjusted may be calculated using the following formula

   2. Required adjustment (inches) = 0.0000065 x ΔT (°F) x L (Ft.) x 12, OR

   3. Required adjustment (inches) = 0.000078 x ΔT (°F) x L (Ft.).

B. Example:

   1. To adjust the length (L) of a 400 feet CWR, fastened at a rail temperature of 60 degree, to correspond to the length of this rail at a temperature of 105 degree, subtract 55 from 105 to obtain a difference of 50 degree (?T) and multiply as follows:

      a. 0.000078 x 50 x 400 = 1.56 inch
### Rail Temperature

<table>
<thead>
<tr>
<th>Rail Temperature</th>
<th>Inches of Increase for 400' of rail to 105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2.81</td>
</tr>
<tr>
<td>25</td>
<td>2.50</td>
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<td>35</td>
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</tr>
<tr>
<td>85</td>
<td>0.62</td>
</tr>
<tr>
<td>95</td>
<td>0.31</td>
</tr>
<tr>
<td>105</td>
<td>0.00</td>
</tr>
</tbody>
</table>

#### 3.14 RAIL ANCHORAGE RECORD

**A.** Compliance record shall be kept in the format that includes the following information and provided to the Authority in an acceptable, reproducible form.

1. It shall contain the following data for each end of a CWR and at each 400 feet interval during installation:
   
   a. Date and time.
   b. Track number and rail (East or West, North or South).
   c. Station location.
   d. Weather, air and base of rail temperature.
   e. Type of fastener.
   f. Length of rail being anchored.

#### 3.15 PROCEDURES FOR PLACEMENT OF JOINTED RAIL

**A.** This Article covers both the permanent construction and rehabilitation of jointed rail and the temporary use of rail joints in the CWR pending field welding.

1. When laying jointed rail, each rail shall be carefully placed on the ties with ends square, using standard expansion shims placed between the ends of adjoining rails to ensure proper opening of joint.

2. Shims shall be removed after all joint bolts are tightened.

**B.** Using temperatures taken on the rails when they are being laid or adjusted; the thickness of the shim to be used for 39 feet rails will be determined by the following table:

<table>
<thead>
<tr>
<th>Ranges (deg. F)</th>
<th>Shim (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20 - 0</td>
<td>3/8</td>
</tr>
<tr>
<td>0 - 25</td>
<td>1/4</td>
</tr>
<tr>
<td>25 - 50</td>
<td>3/16</td>
</tr>
<tr>
<td>50 - 75</td>
<td>1/8</td>
</tr>
<tr>
<td>75 - 100</td>
<td>1/16</td>
</tr>
</tbody>
</table>
C. Joint bars shall be well oiled and with full number and correct size of bolts, nuts and spring washers.

D. Joint bolts shall be tightened before spiking rail and the 2 center bolts shall be tightened in advance of the end bolts.

E. Bolts shall be placed with the nuts alternatively on the inside and outside of the rail.
   1. Nuts shall be placed with the flat side toward the rail.
   2. Track bolts, joint bars and finishing surfaces of rails at joint bars shall be swabbed with oil.
   3. Use outer 4 bolt holes only when installing bolted joints that will be eliminated by field welding.
   4. Do not drill inside holes (holes closest to rail ends) at future field weld locations.

3.16 TRACK CRITERIA AND TOLERANCES

A. Track shall be constructed to the alignment and grade prescribed.
   1. Gage shall be 4 feet 8½ inch in tangent track and curves with radius equal to or larger than 500 feet.
   2. Gage shall be 4 feet 8¾ inch in curves with radius from 250 feet to 500 feet.
   3. Gage shall be 4 feet 9 inch in curves with radius larger than 82 feet but less than 250 feet.
   4. Deviation from established gage and crosslevel shall not exceed 1/8 inch, and profile grade and horizontal alignment variation shall not exceed 1/8 inch measured at the center of a 62 feet chord.

B. Provide vertical and horizontal control stakes every 50 feet on curves and every 100 feet on tangents.

C. Tangent and curved track shall be level unless otherwise indicated in the Contract Drawings.

D. Contractor must not cut rail strings except as required to fit rail to turnouts, crossings or limits of work.

E. A thermometer designed to measure rail temperature shall be used in accordance with AREMA recommendations and as modified in the Technical Specifications, during rail installation to assure compliance with the Metro Preferred Rail Laying Temperature.
1. Final installed or Adjusted Rail Temperature shall be within 10 degree below or above the Preferred Rail Laying Temperature.

3.17 WELDING OF CONTINUOUS WELDED RAIL

A. Rail welding shall be in accordance with the approved procedure and Section 34 11 16 – Field Welded Rail.

3.18 WALKWAYS

A. CPUC walkways shall be provided within track work limits in accordance with the Contract Drawings, Metro Design Criteria and CPUC General Order No. 143.

3.19 INSULATED JOINTS

A. Each insulated joint installed by the Contractor must be tested with an insulated joint tester, either the Harmon 1501A1JC or approved equal by the Authority.

1. Test shall measure no less than 100 ohms across the joint.

2. Test results shall be uniquely identified with a specific joint and submitted to the Authority in Compliance Record.

B. The rail ends at each insulated joint shall be beveled and hardened in accordance with the Manufacturer’s procedures as approved by the Authority.

1. Contractor must comply with rail end hardening and beveling requirements specified in this Section.

3.20 RAIL BOOTS

A. The Contractor shall submit for approval the temporary or permanent means to be used to hold gage, line and grade during the installation of Embedded Track. Any material used to maintain the rail boot in place shall be non-conductive.

B. The Contractor shall submit for approval by the Authority concrete tie and rail fastening assembly design that is configured to receive Rail Boot as described in these special provisions.

C. The Contractor shall submit for review and approval the detailed installation process or method he intends to use when constructing the embedded track. This should include preparation of the existing surface, reinforcing steel and provisions for electrical continuity, number of pours, boot installation and splicing details, grinding prevention and flangeway forming, temperature/crack control joints, finishing and drainage.

D. The rail booth shall be installed making sure it is in perfect contact with the rail throughout its entire surface; no bulging, overlaps or gaps will be allowed. Splices shall be made as recommended by the Manufacturer.

E. Reinforcing shall be tied in a way that provides continuous path for possible stray current leaks.
F. Care shall be exercised providing the means to form the flangeway and make provisions for the free rolling of wheels and passage of grinding stones without conflict with the paved track surface.

G. All rail boot lap joints exposed to surface water shall be sealed with a dielectric non-rigid compound as approved by the Authority.

END OF SECTION 34 72 00
PART 1 – GENERAL

1.01 SUMMARY

A. Description:

1. The Work of this Section consists of furnishing, installing, and testing the Remote Terminal Unit (RTU) - for the Traction Electrification System (TES) for the Expo Rail Operations and Maintenance Facility (OMF) as indicated on the Plans and specified herein.

2. Los Angeles County Metropolitan Transportation Authority (Metro) remotely supervises and controls train operations and rail facilities from its Central Control Facility (CCF) with heavy reliance on Supervisory Control and Data Acquisition (SCADA) systems from various vendors. The SCADA systems interface with Remote Terminal Unit (RTU) equipment installed at wayside communications locations to provide interfaces to various subsystems including Train Control, Traction Power and station facilities.

3. The scope of work and specifications herein are specifically for the SCADA Remote Terminal Unit only

4. Actual assemblies to be supplied shall be based on a standard configuration with site specific main and remote I/O.

5. The Contractor shall assemble, factory test, package, store, ship, install and field test all assemblies.

6. The standard RTU design described in these technical provisions shall be reliable and maintainable. The selected technologies shall be based on the latest stable product offerings and have verified vendor support for at least 20 years.

B. Section Includes:

1. Installation

2. Wiring and Conduit Work

3. Field Painting

4. Testing and Acceptance

5. Cleaning

C. Related Sections:

1. Section 26 05 00 – Basic Electrical Materials and Methods
2. Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods
3. Section 34 20 18 – Traction Electrification Grounding Requirements
4. Section 34 20 52 – Traction Electrification System Interface Requirements
5. Section 34 21 40 – Traction Electrification Blue Light - ETS
6. Section 34 30 10 – Traction Electrification Shop DC Distribution System
7. Section 34 30 25 – Traction Electrification Cable and Wire
8. Section 34 30 25 – Traction Electrification Yard DC Distribution Switchboards
9. Section 34 30 35 – Traction Electrification DC Positive and Negative Feeder Cables
10. Section 34 30 40 – Traction Electrification Testing and Commissioning

1.02 SUBMITTALS - SPECIFIC DOCUMENTATION REQUIREMENTS

A. Shop Drawings

1. Drawings shall be provided for the following:
   a. Functional system block diagrams showing Contractor provided equipment and the equipment with which it interfaces.
   b. Enclosure assembly layout
   c. Calculations
   d. Detailed assembly drawings for mechanical and electrical fabrication of Contractor supplied assemblies and their connection terminations for interface equipment.
   e. Parts List
   f. SCADA Point list and interface chart

B. Software Design

1. Documentation shall be provided for all Contractor developed PLC software and shall include:
   a. Software block diagram - a block diagram overview of input/output/program memory maps, functions/algorithms, and data flow.
   b. Overview - description of each major software component contained in the software block diagram.
   c. Program details
      (i) Start/end of each memory map area
(ii) Detailed description of each custom algorithm or program segment (for example, input and output buffering, output pulse duration, PLC execution status, power up and fault routines)

d. Fully commented Source code

C. Operation and Maintenance Manual

The Operation and Maintenance Manual is intended to serve as a system level operation and maintenance document for the RTU and its interfaces to external systems. The following shall be included:

2. System overview - block diagrams, system and component descriptions, theory of operation.

3. Manufacturer Data - The Contractor shall submit Manufacturers Data for each standard product delivered. The data shall include, where applicable:

   a. Product description
   b. Product specifications
   c. Installation Guide
   d. Users Guide
   e. Diagnostics and Troubleshooting Guide
   f. License

4. Drawings - Provide references to applicable Shop Drawings.

5. Maintenance and Operating Procedures - The Contractor shall supplement Manufacturers Documentation with step-by-step procedures for operating and maintaining the RTU system. The Contractor may provide specific references to provided Manufacturers documentation to avoid unnecessary duplication of information wherever clarity of the procedure is not compromised. Procedures shall include but not be limited to:

   a. Initiating Operating Modes: Procedure for properly starting, stopping the RTU as well as for entering and exiting any special modes of operation.
   b. Component removal and replacement: step-by-step procedures for physically removing and replacing components as well loading firmware and other site specific configuration steps. Procedures shall include precautions wherever applicable.
   c. Preventive and Periodic Maintenance (PM): Describe each manufacturer recommended PM and system PM procedure. Indicate recommended frequency.
   d. Troubleshooting and diagnostics: Provide a comprehensive troubleshooting guide using panel indicators and diagnostic
tools to isolate and troubleshoot system problems including appropriate references to manufacture troubleshooting guides.

D. Training Documentation

1. Contractor supplied training documentation shall include components for instructor and students.

2. The level of instruction and detail in the documentation shall be sufficient to develop staff capable of operating and maintaining the RTU subsystem without the need for Contractor or vendor reliance.

3. The following training documentation shall be provided, each as a separate bound package:
   a. Instructor Guide - The instructor guide shall provide a road map for instructors and shall follow industry best practices for technical instruction including but not limited to complete lesson plans and test materials.

E. Student Guide - Student guide shall contain summary lesson plans and appropriate reference material for effective classroom instruction.

F. Factory Test Plan and Procedures

Test plans and procedures shall be prepared in accordance with industry best practices and include but not be limited to:

1. Identification of test items.

2. System risk issues.

3. Features to be tested.

4. Features not to be tested.

5. Approach: roles and responsibilities, testing levels, configuration management/change control, and test tools, schedule requirements, planning risks and contingencies, and approvals.

6. Specific test procedures detailing test objectives, setup/tear-down, test steps, item pass/fail criteria, and test record documentation requirements.

7. Discrepancy reporting and corrective action.

8. Suspension and resumption criteria.

9. Test deliverables.
## 1.03 Definitions and Acronyms

### Definitions

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF1</td>
<td>Allen Bradley serial communications protocol.</td>
</tr>
<tr>
<td>Hazardous operating state</td>
<td>Any system state that may result in hazardous operating conditions.</td>
</tr>
<tr>
<td>Latent Defect</td>
<td>Defect in a product or service provided by the Contractor that is not discoverable by reasonable inspection and which causes service disruptions or harm.</td>
</tr>
<tr>
<td>Metro</td>
<td>Herein refers to the Los Angeles County Metropolitan Transportation Authority.</td>
</tr>
<tr>
<td>Mission Critical Function</td>
<td>A function that is relied upon for safe and efficient system operation.</td>
</tr>
<tr>
<td>Remote Terminal Unit</td>
<td>Wayside equipment that provides the central master station equipment with an interface to field indications and controls. The term &quot;RTU&quot; herein refers to Metro Red Line segment-1 type RTU's except where otherwise noted.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>AWG</td>
<td>American Wire Guage</td>
</tr>
<tr>
<td>CCF</td>
<td>Metro Rail Central Control Facility</td>
</tr>
<tr>
<td>CIR</td>
<td>Communication Interface Rack</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CRC</td>
<td>Cyclical Redundancy Check</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
</tr>
<tr>
<td>DCB</td>
<td>Digital Channel Bank</td>
</tr>
<tr>
<td>DIN</td>
<td>Refers to a mounting rail solution. DIN is an acronym for Deutsche Institute fuer Normung, a German standardization body and member of ISO</td>
</tr>
<tr>
<td>IFM</td>
<td>Interface Module</td>
</tr>
<tr>
<td>I/O</td>
<td>Input and/or Output</td>
</tr>
<tr>
<td>METRO</td>
<td>Los Angeles County Metropolitan Transportation Authority</td>
</tr>
</tbody>
</table>

**Metro**

Herein refers to the Los Angeles County Metropolitan Transportation Authority.

**Mission Critical Function**

A function that is relied upon for safe and efficient system operation.

**Remote Terminal Unit**

Wayside equipment that provides the central master station equipment with an interface to field indications and controls. The term "RTU" herein refers to Metro Red Line segment-1 type RTU's except where otherwise noted.
PART 2 – PRODUCTS

2.01 SCOPE OF WORK SUMMARY

A. The work to be performed by the Contractor shall include procurement, assembly, configuration, documentation, storage, factory testing, delivery, installation, local field acceptance testing and maintenance training for Remote Terminal Unit in accordance with the specifications herein. The Scope of Work shall include all components, subassemblies, equipment, materials, cable, cable management, hardware, software, configuration and appurtenances necessary to provide a complete operational Remote Terminal Unit as described in these Specifications. The contractor shall review existing SCADA system and provide a new RTU compatible with the existing system. The Contractor shall furnish the system equipment, software and the management, labor, data, design, support services, parts, materials, tools, and incidentals necessary to complete the work in accordance with the specification requirements in a timely, proper, thorough, skillful, and professional manner.

2.02 GENERAL RTU ARCHITECTURE

A. The RTU shall be an assembly of readily available components that are integrated together to provide telemetry and logic functions. The major components include: subpanel, assembly power supply and distribution; programmable logic controller, memory, input and outputs, input and output termination facilities; and equipment cabling, and mounting for installation in cases and enclosures.

B. The RTU shall be designed to accept a range of incoming power sources.

C. The RTU shall be constructed as a main assembly with the capability to add an additional expansion I/O assembly.

D. The actual number and types of I/O modules shall be a site specific design responsibility of the Contractor including but not limited to:

   32-point discrete input modules
   32-point discrete output modules
8-point analog current/voltage analog input module
Remote I/O controller module

E. The following shall be the only actions necessary to add new modules (up to the design maximum):

- Install the new PLC I/O module and associated field interface module.
- Install a PLC manufacturer prefabricated cable connection between the module and the field interface module.
- Use the manufacturer provided PLC programming software to configure the new I/O.

F. Discrete input interfaces shall typically be dry contact inputs wetted by the assembly sensing voltage.

G. Discrete control outputs shall utilize high density PLC output modules to drive interposing relays on the assembly. Outputs shall be typically a dry contact closure. However the design shall accommodate fused wetted contacts where necessary.

2.03 ASSEMBLY

A. Components within assemblies shall be neatly arranged and fastened securely to the assembly subpanel with nonflammable fasteners. The use of plastic wire troughs shall be subject to review and approval. Metal wire clamps shall have insulating inserts between the clamps and the wiring. Wiring between stationary and movable components, such as wiring across door hinges or to components mounted on extension slides, shall allow full movement of the component without bending or chafing the wiring.

B. Each assembly shall include suitable signal and safety ground networks. The safety ground shall be isolated from the signal ground and shall connect to the ground (green) wire of the ac power input or to a dedicated ground wire for DC powered assemblies. The signal ground shall terminate at a separate stud connection, sized for connection of a lugged No. 2/0 AWG ground wire. Use of the enclosure frame, skins, or chassis mounting hardware for the ground network will not be considered acceptable. Assembly grounding shall be subject to approval.

C. The assembly shall have four distinct functional areas: power distribution, logic controller, auxiliary equipment and I/O.

D. Cables and wires shall be neatly arranged and secured/fastened to permit maintenance access to all equipment without the need to disturb any wire or cable.
E. Adequate space shall be allocated for routing and management of I/O module cable.

F. Space for routing and management of field interface cable shall be provided at each side of the I/O section. 2”x4" (width x depth) metal vertical cable management brackets shall be installed along each side of the I/O section for securing field cables of up to 1" diameter.

G. The auxiliary equipment area shall have a minimum dimension of 8”x16”.

H. The I/O area shall include reserved space for installation of optional indicating fused feed thru terminal blocks for distribution of wetted contact control outputs. Space for at least 33 terminal blocks shall be provided.

I. The power distribution area shall include reserved space for mounting of an auxiliary power supply and fused load circuit terminal blocks. Incoming power terminal blocks shall have a spare line, neutral and ground terminal block reserved for installation of the auxiliary power supply.

J. All panel indicators shall be visible from the front of the assembly subpanel.

K. All assembly components, cables, and appurtenances shall be accessible from the front of the assembly.

L. Access to the rear of the assembly for any maintenance purpose shall not be required.

M. Provide an appropriately rated breaker for incoming power to serve as a main disconnect.

N. Provide a dedicated terminal block for distribution of incoming power, ground and neutral/return. The use of 120VAC power cords or plug-in transformers shall be prohibited. At least two spare circuits shall be provided.

O. Provide a dedicated terminal block for assembly 24VDC power distribution and return with one indicating fuse for each distribution circuit.

P. Power distribution shall utilize bus bars. No daisy chain wire distribution shall be permitted.

Q. Supply, return and ground shall use physically separated terminal block sections.

R. Provide approved vendor pre-manufactured I/O field interface module (IFM) terminal blocks for all field wiring or other terminal block assemblies. Each IFM or I/O terminal block shall be connected to its associated PLC I/O module using a vendor pre-manufactured cable.

S. All assembly wiring shall be secured with panel mounted guides and or other approved wire management devices.
T. All assembly components shall be professionally labeled in accordance with shop drawings using an approved manner.

U. Any terminal block section greater than 48VDC shall have a warning label.

V. Multi-conductor cables shall be used to interconnect the RTU discrete I/O terminal blocks to the Main Distribution Frame or board (herein referred to as the MDF). Dedicated blocks shall be assigned on the MDF for termination of RTU cables.

W. Each discrete I/O field cable between the RTU and the MDF shall be a minimum of 25-pair and shall be sufficiently rugged for direct routing in overhead cable trays.

X. All field interface connections shall terminate on the MDF. Outside/external cable shall terminate on building entrance protection blocks. Subsystem cables within the RTU communications room/cabinet shall terminate on regular interface blocks. Cross connect wire shall be used to interconnect each field interface to the SCADA interface terminal blocks on the distribution board/frame.

2.04 REMOTE TERMINAL UNIT OPERATION

A. Power-up and Initialization

1. Turning the RTU on or off shall be accomplished by operating a single breaker installed on the assembly. Operating this breaker shall control power to the entire assembly.

2. Upon application of power the RTU shall normally power up, initialize and achieve a normal operating state without the need for any manual intervention.

3. The RTU initialization shall clear all system fault registers before initiating the system diagnostics.

B. Diagnostics

1. The RTU shall perform continuous diagnostics to report the following conditions:
   a. CPU faults
   b. Module faults
   c. Remote I/O link status
   d. Local serial link status for communications based subsystem interfaces

2. The RTU shall increment a health register (RTU Health Register) once per second to indicate to SCADA that the PLC is in a normal
run mode and is executing the ladder logic. The register shall reset to zero when a value of 255 is reached.

3. The RTU shall monitor a health register that is updated by the SCADA system (SCADA Communications Watchdog). If the register fails to update for 30 seconds the RTU shall declare the SCADA system as offline. This status shall be reflected in the first contact of the first discrete output module. The contact shall be closed if SCADA is online and shall be open if SCADA is not online or the PLC is failed.

4. The RTU shall monitor control/wetting voltage in the 1st input point of the first discrete input module.

5. The RTU shall report a chassis summary blown fuse alarm for each fused terminal block starting at the 2nd input point of the first discrete input module.

C. SCADA Communications

1. The Cable Transmission System (CTS) shall provide an Ethernet LAN dedicated for SCADA communications. The LAN shall allow all RTU to be accessed from a single port on the CCF SONET without the need for any external switching. The LAN shall also support RTU peer to peer communications without the need for any external switching.

2. The RTU shall include one Ethernet communications interface integrated directly into the PLC CPU for SCADA communications. It shall be possible to configure a default routing gateway for the interface.

3. The RTU shall include a master/slave serial communications port integrated directly into the PLC CPU for interface to diagnostic/programming software and external communications gateways.

4. In-rack technology shall be used wherever possible to implement local communications between the PLC and external subsystems that require serial interfaces.

D. Safety

1. The power-up initialization shall not unintentionally activate any control output.

2. Sufficient error checking and sparse encoding shall be inherent in the SCADA and remote I/O communications protocols such that it is improbable for normal environmental noise to unintentionally activate control output or incorrectly report the state of a discrete input.

3. Sufficient provisions shall be made in the RTU design and the design of its components such that it is improbable for normal environmental...
noise to unintentionally activate control output, incorrectly report the state of a discrete input, or corrupt a logic calculation.

E. Input/output SCADA Memory Mapping

1. A separate block of CPU memory shall be allocated for each of the following inputs and outputs:
   a. Internal Diagnostics and registers
   b. Analog inputs
   c. Analog outputs
   d. Discrete inputs
   e. Discrete outputs
   f. Remote I/O
   g. Gateway I/O
   h. Special calculations

2. Control memory shall be cleared on PLC startup or reset prior to the enabling of any discrete output or serial protocol.

3. Chassis discrete input and analog input I/O shall be block transferred to the assigned memory maps on each CPU scan cycle.

4. Remote I/O shall be transferred to/from assigned memory maps on data change.

5. Gateway I/O shall be pushed/pulled by external gateway equipment provided to/from the assigned memory maps.

6. A block of memory of at least 20 words shall be reserved for special calculations. This area will store the results of any special calculations that must be performed on field I/O prior to transmission to/from SCADA.

7. The following diagram illustrates the minimum typical SCADA memory map allocations:
### Table 1 - SCADA Memory Map

<table>
<thead>
<tr>
<th>MAIN AND EXPANSION CHASSIS</th>
<th>STATUS REGISTERS</th>
<th>nn words of CPU status registers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal and remote I/O status information</td>
<td>RTU Health Register, SCADA Communications, Watchdog</td>
</tr>
<tr>
<td>DISCRETE INPUT</td>
<td>INPUT-MODULE1 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE2 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE3 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE4 32 bits</td>
<td></td>
</tr>
<tr>
<td>DISCRETE OUTPUT</td>
<td>OUTPUT-MODULE1 32 words</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OUTPUT-MODULE1</td>
<td></td>
</tr>
<tr>
<td>ANALOG INPUT</td>
<td>AINPUT-MODULE1 8 words</td>
<td></td>
</tr>
<tr>
<td>REMOTE I/O - 1</td>
<td>DISCRETE INPUT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE1 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE2 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE3 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE4 32 bits</td>
<td></td>
</tr>
<tr>
<td>DISCRETE OUTPUT</td>
<td>OUTPUT-MODULE1 32 words</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANALOG INPUT</td>
<td>AINPUT-MODULE1 8 words</td>
<td></td>
</tr>
<tr>
<td>REMOTE I/O - 2</td>
<td>DISCRETE INPUT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE1 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE2 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE3 32 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INPUT-MODULE4 32 bits</td>
<td></td>
</tr>
<tr>
<td>DISCRETE OUTPUT</td>
<td>OUTPUT-MODULE1 32 words</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANALOG INPUT</td>
<td>AINPUT-MODULE1 8 words</td>
<td></td>
</tr>
<tr>
<td>GATEWAY INPUT</td>
<td>32 words</td>
<td></td>
</tr>
<tr>
<td>GATEWAY OUTPUT</td>
<td>32 words</td>
<td></td>
</tr>
<tr>
<td>CALCULATIONS</td>
<td>20 words</td>
<td></td>
</tr>
</tbody>
</table>

**F. Discrete Control Processing**

1. The RTU software shall allow each discrete output to act as either a momentary or maintained (latched) contact based on the value of its associated buffered control word.

2. Upon receiving a SCADA control word value of "0" the RTU shall take no action.
3. Upon receiving a SCADA control word value of "1", the RTU shall set the control word to a value of "0", and then activate the associated output relay for a momentary time period.

4. Upon receiving a SCADA control word value of "2" the RTU shall set the control word to a value of "0", and then activate the associated output relay.

5. Upon receiving a SCADA control word value of "4" the RTU shall set the control word to a value of "0", and then deactivate the associated output relay.

6. Receipt of any other SCADA control word value not listed above shall result in no action.

7. Momentary activation time shall be configurable in ladder logic for each individual control down to 250 milliseconds. The Contractor shall determine the value needed for each control output.

G. Remote I/O management

1. The typical RTU program shall accommodate one expansion chassis and up to two remote I/O chassis with a typical configuration as defined in Table 1 - SCADA Memory Map.

2. Adding and enabling remote I/O shall only require the following actions:
   a. Install a remote I/O communications module
   b. Enable the I/O using the manufacturer provided PLC programming software to configure the remote I/O module and I/O and enable memory map transfer as a simple edit to the ladder logic

3. Once enabled, the RTU ladder logic shall monitor the status of the remote I/O link communications and redundancy and report it in the status register area of the SCADA memory map.

2.05 SOFTWARE

A. The Contractor shall provide a base ladder logic and application programming necessary to implement the functional requirements of the RTU as described in these technical provisions.

B. The software shall be designed for simple modification to implement site specific requirements.

C. The Contractor shall be responsible for configuration management of the base software throughout the warranty period and shall make and distribute revisions to address defects and change orders.
D. The Contractor shall be responsible for the site specific programming for each RTU.

2.06 ACCESSORIES

A. The Contractor design shall accommodate the following accessories:
   1. Auxiliary DC power supply and distribution terminal blocks
   2. 4-port Gateway communications server
   3. 10-port Gateway communications server
   4. HMI Panel
   5. Profibus DP-V0 slave
   6. MODBUS master/slave
   7. Fused control output terminal block

2.07 RTU

A. RTU hardware and software shall support all functional requirements contained in these Technical Provisions.

B. Illuminated Panel Indications
   1. Power available shall be indicated on each PLC CPU, PLC module, and power supply.
   2. Status point active shall be indicated for each discrete input point.
   3. Control point active shall be indicated for each discrete output point.
   4. Transmit and receive activity shall be indicated on each external data link and/or remote I/O processor.
   5. PLC CPU mode and status shall be indicated.
   6. Fuse status shall be indicated in a consistent manner for each fuse except where otherwise approved.

C. Circuits
   1. Main Incoming and Supply Circuits
a. A "main" breaker shall be installed to protect the main distribution terminals and to serve as a power disconnect.

b. A fuse shall protect each power feeder circuit.

c. The fuse shall be rated to protect the circuit wiring and permit full load of each distributed circuit.

2. I/O Module Common voltage Supply Circuits

a. Common supply voltage shall be individually fused for each input and output module.

b. Each fuse shall be an indicating type that is sufficiently rated to allow all inputs or outputs on a module to be active simultaneously and be rated lower than the main supply fuse so that a fault on a single point only affects a single module.

3. Control Voltage

a. The power supply shall be 24VDC output, fully enclosed modular unit for panel or DIN rail mount. The PLC chassis power supply may be used for control voltage if the rating is sufficient to drive the maximum PLC chassis configuration and interface module relays for all indicating and control points in their active state.

b. The power supply shall include automatic load current / short circuit protection.

c. The voltage power supply output feeds shall include foldback circuitry such that after a fault is removed from the line the voltage level shall be automatically restored to its proper operating level.

D. RTU Modular Components (general)

1. The RTU components shall be based on a family of processors that are compatible with the existing Metro SCADA system, having at least 10,000 units in service in North America, with local sales and service available within 50 miles of Los Angeles.

2. Module components shall be available from the RTU CPU vendor as well as certified third-party manufacturers to support a wide variety of input, output, and interfacing requirements.

3. Operating temperature 0-50 degrees Celsius with exception of modular communications equipment.

4. Communications equipment operating temperature 0-40 degrees Celsius.

4. Humidity 5-95% non-condensing

5. Noise immunity NEMA Standard ICS 2-230
6. Dielectric withstand 1500VDC (UL 508, CSA C22.2 No. 142)
7. Flammability and Electrical ignition UL94V-0
8. Removable barrier-type terminal blocks or connectors to allow module replacement without the need to disturb wiring
9. Self-locking tabs to permit installation and removal of chassis modules without the need for tools
10. Indexed plugs and connectors to prevent incorrect insertion
11. Continuous overload protection of 200V between any interface terminal and ground.

E. RTU CPU
1. CPU memory shall be of adequate capacity to execute the Contractor provided firmware with at least 25% of the memory unused.
2. Typical scan time 0.9 ms/K
3. Supports online programming and editing
4. The CPU shall include one Ethernet port with a protocol supported by available OLE For Process Control (OPC) vendors.
5. The CPU shall include one master/slave serial port.
6. Local key switch mode selector for run, program, and remote modes.
7. System protection options shall be included for: program files, data tables, input/output forces, CPU run mode (requires insertion of a key).

F. SCADA Communications
1. The RTU shall support Ethernet communications using a protocol compatible with the existing Metro SCADA system.
2. The communications shall support efficient transfer of indication and control information.
3. It shall be possible (and be supported by OPC vendors) to pack discrete indications and controls into word based arrays and subsequently index specific bits out of each register word.

G. RTU Discrete Input Modules
1. The RTU's contact input interface shall be capable of accepting isolated Form C contact inputs and be capable of interfacing to open collector inputs.
2. Filtering to limit effects of transients and contact bounce.
3. Optical isolation to shield logic circuits from possible damage due to transients.

4. LED indicator for each input point status.

5. Each module shall have 32 inputs.

6. The operating voltage range shall be at minimum 21-26 voltage DC.

7. Delay on-to-off and off-to-on time shall be 8ms.

8. Input impedance shall be at least 5KOhm.

H. RTU Discrete Output Modules

1. RTU discrete output modules shall be identical across the system. Interposing relays shall be utilized where necessary to satisfy specific isolation and interfacing requirements.

2. Each module shall have 32 outputs.

3. Optical isolation shall separate module logic from field power.

4. The maximum off-to-on and on-to-off delay shall be 10ms.

I. RTU Analog Input Modules

1. Each module shall support at least 8 differential or single ended inputs.

2. Inputs shall be user selectable to allow voltage or current signals, Voltage: ± 10V dc, 0 to 10V dc, 0 to 5V dc, 1 to 5V dc, Current: 0 to 20 mA, 4 to 20 mA.

3. Full scale analog ranges: Voltage: ± 10.5V dc, 0 to 10.5V dc, 0 to 5.25V dc, 0.5 to 5.25V dc; Current: 0 to 21 mA, 3.2 to 21 mA.

4. Drift Voltage Terminal: ±0.003% per °C, Current Terminal: ±0.0045% per °C.


6. Voltage input impedance >= 220KOhm.

7. User configurable input filtering for desired noise suppression or signal response time.

8. Input signals shall be isolated from the backplane.

9. The A/D converter shall provide a minimum precision of 4096 steps plus one sign bit.

10. Continuous automatic calibration.

11. Common mode rejection shall be at least 50db at 50 and 60Hz.
12. Isolation of 500VAC/VDC withstand for one minute.

2.08 SUBPANEL

A. All materials used in the assembly including cable insulation or sheathing, wire troughs, terminal blocks, shall be made of flame retardant material and shall not produce toxic gasses under fire conditions (see NFPA 75). The use of PVC shall require approval. Each individual device shall be constructed so that by limiting combustible materials, or by use of enclosures, fire is not likely to spread beyond the device in which the source of ignition is located. Assemblies of floor standing equipment having external surfaces of combustible materials of such size that might contribute to the spread of an external fire shall have a flame spread rating of 50 or less (see NFPA 255, Method of Tests of Surface Burning Characteristics of Building Materials). (Note: UL listed equipment or equipment meeting the requirements of UL standard number 478 will be considered as meeting the above requirements.)

B. The subpanel shall be metal, finished on all sides to resist corrosion in a marine environment. The panel thickness shall be such that there is no deformation of the mounted subpanel while performing maintenance and assembly procedures. The panel material shall support drilling and taping of screws for installation of components and fasteners by others.

C. The maximum dimensions of the assembly including subpanel, all components, cables, bending radius and connectors shall require no more than 22" wide x 20" deep x 70" high for installation.

D. The assembly shall be suitable for mounting on a standard 19" telecommunications rack or plywood backboard.

E. Mounting and enclosure shall be site specific adhering to all environmental and other design criteria.

2.09 CABLES WIRES

A. Each cable shall be labeled at both ends in a manner consistent with Contractor drawings.

B. Labels shall use non-fading, permanent marking, and can be read without disruption of any component.

C. Cross-connect wires shall be color-coded, twisted-pair, solid-core 22 AWG.

D. Polarity of cross-connect wires shall utilize a consistent color code scheme.
E. Solid and stranded conductors shall be of annealed copper wire in accordance with ASTM B33, Class B, and Class C stranded conductors conforming to ASTM B8, Table 2.

F. Conductors in multi-conductor cables shall be individually and uniquely color-coded.

2.10 TERMINAL BLOCKS

A. Terminal blocks shall be approved screw or spring clamp type.

B. Terminal blocks shall utilize full-depth insulating barriers or other approved methods to protect exposed conductive wire.

C. Terminal blocks shall accommodate up to two (2) 18 AWG wire for input and output signals.

D. All terminals and blocks shall be clearly labeled.

E. Ring-tongue, compression-type lugs with full length insulating sleeves shall be used for all screw-type terminal block wiring. No more than two wires shall be connected to any terminal.

F. Terminal blocks shall have finger safe terminals and bus bars for signals greater than 48V.

G. Line and supply terminal blocks shall be individually protected by replaceable fuses with visual and electrical indication of status.

H. Indicating fuse terminal blocks shall provide a single summary fuse indication signal.

2.11 INTERFACE MODULES (IFM)

A. All interface modules shall be vendor pre-manufactured, with removable field wiring terminal blocks.

B. Two terminals per point shall be provided for discrete IFMs.

C. One LED indicator lamp shall be provided per point for discrete IFMs.

D. Discrete output IFMs shall include one field replaceable relay per point with form-C contact rating of 6A.

E. Analog IFM shall allow separate configuration of each input for single-ended or differential voltage or current and provide shield grounding terminals. The Contractor may propose an alternative solution consisting of DIN mounted terminal devices with a connection to the analog input modules using a PLC vendor pre-manufactured cable.

F. The Contractor may propose an alternative higher density solution consisting of DIN rail mounted terminal blocks and plug in relays (for outputs) with a connection to the output modules using a PLC vendor pre-manufactured cable.
2.12 ACCESSORIES

A. Auxiliary DC Power Supply
   1. Phoenix Contact QUINT-PS-100-240AC/24DC/ 5 or approved equal.
   2. 24VDC @ 5 amp, DIN mount.

B. 4-Port Gateway communications server
   1. Fieldserver FS-B3510 or approved equal.
   2. 4 serial ports (2 RS323, 2 RS485)
   3. 2 Ethernet ports
   4. Supports a library of protocols including Allen Bradley DF1,
      MODBUS
      ASCII, MODBUS RTU, Hanning & Kahl HCS-V, Notifier FACP protocols,
      Safetran SCS128, Ansaldo/US&S Genisys, Allen Bradley Ethernet/IP,
      GE SRTP, MODBUS TCP, Telnet.
   5. 24VDC with less than 2 AMP power consumption.

C. 10-Port Gateway communications server
   1. Fieldserver FS-B4010-01 or approved equal.
   2. 10 serial ports (8 RS323, 2 RS485)
   3. 2 Ethernet ports
   4. ISA card slot for specialty communications modules supporting
      DH+, Profibus, DeviceNet, LonWorks, and ControlNet.
   5. Supports same library of serial/Ethernet protocols as listed for
      the 4-port communications gateway.
   6. 120VAC operation with less than 1.5A consumption.

D. PROFIBUS DP-V0 Communications Module
   1. In-chassis module compatible Profibus DP-V0 slave communications
   2. Provide access to the Profibus Master input and output images with
      up to 244 bytes of Input and Output data, for a maximum of 400 bytes total.

E. MODBUS Master/Slave Communications Module
   1. In-chassis module compatible MODBUS master or slave communications.
2. One RS232 serial port, 110-38.4 Kbit/sec.
4. RTU or ASCII mode.
5. Supports MODBUS functions 1, 2, 3, 4, 5, 6, 15, and 16.

PART 3 – EXECUTION

3.01 INSTALLATION
A. Install, wire, connect, and test RTU complete and ready for operation in accordance with these Specifications, manufacturer’s instructions, and as shown on the plans. Test interface to Master Station in conjunction with Agency. Agency will perform Master Station Changes.

3.02 WIRING AND CONDUIT WORK
A. Install in accordance with Section 34 05 00 – Traction Electrification Basic Electrical Materials and Methods.

3.03 FIELD PAINTING
A. After installations are complete, thoroughly clean all surfaces where shop paint is missing or abraded, all bare steel, including bolts, nuts, washers, and welds, and paint each item to match the original.
B. Galvanized materials that are scratched, cut, or in other manners have their protective coatings penetrated or damaged, shall be field coated with cold liquid galvanizing to the strength and finish of the original coating.

3.04 TESTING AND ACCEPTANCE
A. Factory Acceptance Test
   1. RTU Factory Acceptance Test - Factory Acceptance Test shall verify that each unit is defect free and ready for shipment. All functional and specification requirements shall be verified including but not limited to:
      a. Firmware execution
      b. Communications interfaces
      c. Each input from RTU terminal block to SCADA memory
d. Each output from SCADA memory to terminal block

2. Factory Acceptance Test Certification of Completion shall include:
   a. Letter from the Contractor indicating that the equipment is ready to ship.
   b. Signed test records for all tests.
   c. Certification for each assembly may be transmitted separately should the Contractor choose a phased delivery.

B. Local Field Acceptance Test

1. An installation test shall verify that each unit has been delivered free of damage and has been properly installed. Tests shall include but not limited to:
   a. Proper mounting and securing of assemblies, racks and enclosures.
   b. Power and safety ground connections
   c. Power-up test
d. Wire pull test for all field wires
e. Each input from RTU terminal block to SCADA memory

2. A local interface test shall utilize RTU programming and diagnostic tools to verify that the RTU properly implements all of its required interfaces:
   a. Each indication from device to RTU memory
   b. Each control function from RTU memory to device
   c. SCADA communications

3.05 TRAINING

1. Training shall be provided in two separate sessions.
2. One session shall be provided during the morning and one session shall be provided in the evening.
3. Each session shall include multi-media classroom instructions that include the use of a fully functional training RTU assembly, based on the typical RTU.
4. Each session shall be single course, with a maximum of 20 students, covering the following topics:
a. System overview - review system block diagram, describe each interface, and provide overview of the system functions and theory of operation.

b. PLC/RTU Assembly overview - describe each component of the PLC/RTU assembly, general functional description, specific function within the assembly, overview of wiring and cabling conventions.

c. System operating modes - Procedure for properly starting and stopping the RTU as well as for entering and exiting any special modes of operation.

d. Hardware maintenance - describe the proper procedure for inspecting, removing and replacing system components and performing preventive and periodic maintenance.

e. System programming and diagnostics - provide instruction on the use of supplied programming and diagnostics tools for upload/download of programs, out-of-box CPU and module configuration, monitoring PLC operation, forcing inputs and outputs and other recommended maintenance and diagnostic procedures.

f. Troubleshooting - using panel indicators and diagnostic tools to isolate and troubleshoot system problems. Review manufacture and Contractor supplied troubleshooting guides.

3.06 CLEANING

A. Comply with the requirements as specified in General Conditions for Cleaning, Closeout Procedures and Section 34 05 00– Traction Electrification Basic Electrical Materials and Methods, and elsewhere on the Contract Documents.
PART 1 - GENERAL

1.01 WORK INCLUDED
   A. Equipment items as listed below by Equipment Identifier:
      1. 5910 System, sanding, LRV (Ref. Part 2.01)
   B. Roughing-in, installation of equipment, and final connection of utilities, with labor, services, and incidentals necessary for complete and operational equipment installation.
   C. Piping, wiring, and switching between equipment and utilities.

1.02 QUALITY ASSURANCE
   A. Experience: Equipment shall be produced by a manufacturer of established reputation with a minimum of five years experience supplying specified equipment.
   B. Manufacturer's Representative:
      1. Installation: Provide a qualified manufacturer's representative at site to supervise work related to equipment installation, check out, and start up.
      2. Training: Provide technical representative to provide training to Authority's maintenance personnel in operation and maintenance of specified equipment.

1.03 SUBMITTALS
   A. Product Data: Submit Product Data in accordance with Division 1 of these specifications.
   B. Operations and Maintenance Manual:
      1. Provide complete parts, operating, and maintenance manual covering equipment at time of installation.
      2. Description of system and components.
      3. Engineered floor plan drawings with a detailed equipment layout.
      4. Schematic diagrams of electrical, plumbing, and compressed air systems.
      5. Manufacturer's printed operating instructions.
      6. Printed listing of periodic preventive maintenance items and recommended frequency required to validate warranties. Failure to provide maintenance information will indicate that preventive maintenance is not a condition for validation of warranties.
7. List of original manufacturer’s parts, including suppliers’ part numbers and cutsheets, recommended spare parts stock quantity, and local parts and service source.

8. Assemble and provide copies of manual in 8-1/2 by 11 inch format. Fold out diagrams and illustrations are acceptable. Manual to be reproducible by dry copy method. Provide copies per provisions of Division 1.

C. Shop Drawings: Submit Shop Drawings in accordance with Division 1.

1.04 PRODUCT SUBSTITUTIONS

A. Follow requirements specified in Division 1 - General Requirements.

B. Additional costs resulting from substitution of products other than those specified, by model number, including drawing changes and construction, will be at the expense of the Contractor.

C. Substitution Approval: Prior to delivery or installation, submittals for each equipment item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by Authority and Architect.

1.05 WARRANTY

A. Warrant work specified herein for one year from substantial completion against defects in materials, functions, and workmanship.

B. Warranty shall include materials and labor necessary to correct defects.

C. Defects shall include, but not be limited to noisy, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer’s recommended preventive maintenance schedule.

D. Submit warranties in accordance with Division 1 - General Requirements of these specifications.

E. All parts shall be readily available locally in the United States.

1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver equipment in manufacturer’s containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.

B. Indelibly label all containers, including those contained in others, on outside with item description(s) per title and Equipment Identifier of this specification.

1.07 LABELING

A. Manufacturer shall securely attach in a prominent location, on each major item of equipment, a non-corrosive nameplate showing manufacturer’s name, address, model number, serial number, and pertinent utility or operating data.
B. All electrical equipment and materials shall be new and shall be listed by Underwriter’s Laboratories, Inc. (UL) in categories for which standards have been set by that agency and labeled as such in the manufacturer’s plant.

PART 2 - PRODUCTS

2.01 SYSTEM, SANDING, LRV

Equipment Identifier: 5910

A. Manufacturer’s Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.

   a. Alb. Klein Technology Group Inc., Plain City, OH (614) 873-8995

   b. Model: Sanding silo with 4 remote sanding stations

2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.

B. General Description:

1. The sand storage silo shall be equipped with all accessories that are necessary for automatic operation. The silo is loaded with sand by a silo truck that is equipped with its own compressor. The silo shall be equipped with level limit switches for maximum, mid-level, and low level. The level limit switches shall be determined with the Authority.

   A dust filter shall be located on top of the silo to filter and return dust-contaminated air generated during the filling process to the silo. Silo shall have dehumidifier unit to ensure dry condition air at all times within silo.

   A low velocity sand transporter shall be installed below the silo. Sand transporter shall supply the brake sand to sand dispensing stations via a steel pipeline.

   Each sanding station shall be equipped with one sand filling hose no longer than 25 feet in length. The optimum hose length shall be determined on site with the Authority. Each hose shall be mounted to a balancer to ensure easy-handling.

C. Capacities/Dimensions:

1. Sand Storage Silo with Sanding Station below and top mounted Silo Dust Vent unit.

   a. Capacity: 30 ton

   b. Diameter: 8 feet

   c. Hopper angle at 50 degrees

   d. Roof angle at 10 degrees
e. Overall Height: 25 feet (from foundation to top of filtration unit)
f. Weight: 8,200 pounds

2. Compressor Module
   a. Length: 13 feet
   b. Width: 8 feet
   c. Height: 10 feet

D. Features/Performance/Construction:
   1. Sand Storage Silo:
      a. Silo shall be a one-piece steel structure with pre-fabricated support skirt. Top of tank shall have a 10 degree sloped roof and be accessible by ladder. Top shall also include a 2 foot diameter manhole with provision for a dust collector bin vent unit.
      b. Silo shall comply with the following requirements:
         1) Seismic Zone 2A
         2) Seismic Importance Factor 1.0
         3) 35 PSF minimum roof load
      c. Silo dust vent unit shall be top mounted to hopper and of the self-discharging cartridge type. Unit shall vent and filter the compressed air used in the pneumatic transport of the sand into the bin. Unit shall have five filters with a combined minimum filtration surface of 500 square feet. Filters shall be self-cleaning on a timed basis by reverse-jet compressed air actuated from a central transporter control panel.

2. Sand Distribution Tank (Transporter)
   a. Transporter shall be pneumatic and installed below sand storage silo.

3. Sanding Stations:
   a. Station shall have one filling hose connection each.
   b. Vessel volume: 3.5 cubic feet
   c. Maximum material temperature 120 degrees
   d. Operating pressure shall be 50 psi
   e. Shall have a filling capacity of 0.88 cubic feet per minute
   f. Filling nozzles shall be vented via separate extraction hose attached to the nozzle and have segmental lock at the discharge end, assuring a dust-tight and complete filing process of the rail vehicle. The segmented lock does not protrude beyond the profile of the sanding nozzle in open or closed position.
   g. Shall provide one nozzle holding device per station.
h. Dust return from each sand filling nozzle is via a common hose connected into the main dust return pipe and into the dust collection system.

i. Shall provide necessary support members to mount vessel tight against roof structure in order to provide maximum clearance beneath vessel.

j. Sanding station components, hoses, and nozzles shall be weather-proofed for wet environment.

k. Shall provide self-balancing carrier beam per station to support hose.

4. Sand System Piping
   a. Shall be 3 inch diameter piping used to transfer sand from transporter to each sanding station.

5. Compressor Module
   a. Shall be a completely engineered and assembled modular unit with all necessary components to ensure proper sanding operation.

E. Controls:
   1. Sand Storage Silo:
      a. Truck unload panel shall be a NEMA 4, wall mounted enclosure with high, medium, and low level indication lights, an alarm horn and beacon, and push button operation for the following:
         1) Operation of emergency un-load valve
         2) System reset
         3) Bin vent start and stop

F. Utility Requirements:
   1. Compressed air:
      a. Silo dust vent unit: 8 SCFM at 90 to 110 PSIG
      b. Sanding stations: 1/2 inch NPT, main connection pressure - 80 PSI, operating pressure - 50 PSI.
   2. Electrical:
      a. Silo dust vent unit: 120 VAC, 1 phase, 60 hertz
      b. Air compressor: 460 VAC, 3 phase, 60 Hz, 25 HP

G. Accessories:
   1. Sand Storage Silo:
      a. Ladder with safety cage (one)
      b. Silo top safety rail (one)
      c. 4 inch diameter filling tube with 90 degree bends as required (one)
d. Tanker truck Pipe Coupling unit (one)
e. Calibration free silo level probe with all connecting hardware (one)
f. Maximum, mid-point, and low level limit switches (one each)
g. 6 inch manual shut-off flap (one)
h. Emergency discharge socket with a manual shut-off flap (one)
i. Overpressure control valve to be installed on top of tank (one)

H. Finish:
1. Finish: Durable enamel in manufacturer's standard color

PART 3 - EXECUTION

3.01 INSPECTION

A. Coordinate location of rough-in work and utility stub-outs to assure match with equipment to be installed.
B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare delivered equipment with packing lists and specifications to assure receipt of all equipment items and specified accessories.
C. Report in writing to the Architect, any damaged, missing or incomplete scheduled equipment and improper rough-in or utility stub-outs.

3.02 INSTALLATION

A. Perform work under direct supervision of Foreman of Construction Superintendent with authority to coordinate installation of scheduled equipment with Architect or designated representative.
B. Install equipment in accordance with plans, shop drawings, and manufacturer’s instructions:
   1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
   2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, professional manner without damaging equipment or adjacent work.
   3. Anchorage: Attach equipment as directed by Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
   4. Upon completion of work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.03 TESTING
A. After final connections are made and prior to authorizing payment, specified equipment shall be tested for compliance with specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.04 CLEANUP

A. Touch-up damage to painted finishes.
B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
C. Clean area around equipment installation and remove packing and installation debris from job site.
D. Notify Architect or designated representative for acceptance inspection.

3.05 TRAINING

A. Direct the technical representative to provide specified hours of training to designated Authority’s maintenance personnel in operation and maintenance of the following equipment. Coordinate, with Authority, training schedule and list of personnel to be trained.
   1. 5910 System, sanding, LRV; 3 hours (minimum)
B. Obtain, from technical representative, a list of Authority’s personnel trained in equipment operations and maintenance.

END OF SECTION 41 12 19
PART 1 - GENERAL

1.01 WORK INCLUDED

A. Equipment items as listed below by Equipment Identifier:
   1. 5006 Crane, bridge, underhung, 1 ton (Ref. Part 2.01)
   2. 5011 Crane, bridge, underhung, 10 ton (Ref. Part 2.02)
   3. 5020 Crane, bridge, top running, 2 ton (Ref. Part 2.03)
   4. 5228 Crane, jib, 2 ton, 20 foot span, column mounted (Ref. Part 2.04)
   5. 5392 Hoist, chain, electric, motorized trolley, 2 ton (Ref. Part 2.05)
   6. 5410 Forklift, electric, 6,000 pounds (Ref. Part 2.05)

B. Roughing-in, installation of equipment, and final connection of utilities, with labor, services, and incidental necessary for complete and operational equipment installation.

C. Wiring, and switching between equipment and utilities.

1.02 QUALITY ASSURANCE

A. Experience: Equipment shall be produced by a manufacturer of established reputation with a minimum of five years experience supplying specified equipment.

B. Manufacturer's Representative:
   1. Installation: Provide a qualified manufacturer's representative at site to supervise work related to equipment installation, check out, and start up.
   2. Training: Provide a technical representative to provide training to Authority's maintenance personnel in operation and maintenance of specified equipment.
   3. Quality standards shall meet or exceed ISO-9001.

1.03 SUBMITTALS

A. Product Data: Submit Product Data in accordance with Division 1 of these specifications.

B. Operations and Maintenance Manual:
   1. Provide complete parts, operating, and maintenance manual covering equipment at time of installation.
   2. Assemble and provide copies of manual in 8-1/2 by 11 inch format. Fold out diagrams and illustrations are acceptable. Manual to be reproducible by dry copy method. Provide copies per provisions of Division 1.

C. Shop Drawings: Submit Shop Drawings in accordance with Division 1.
1.04 PRODUCT SUBSTITUTIONS
A. Follow requirements specified in Division 1 - General Requirements.
B. Additional costs resulting from substitution of products other than those specified, by model number, including drawing changes and construction, will be at the expense of the Contractor.
C. Substitution Approval: Prior to delivery or installation, submittals for each equipment item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by Owner and Architect.

1.05 WARRANTY
A. Warrant work specified herein for one year from substantial completion against defects in materials, functions, and workmanship.
B. Warranty shall include materials and labor necessary to correct defects.
C. Defects shall include, but not be limited to noisy, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
D. Submit warranties in accordance with Division 1 - General Requirements of these specifications.
E. All parts shall be readily available locally in the United States.

1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING
A. Deliver equipment in manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
B. Indelibly label all containers, including those contained in others, on outside with item description(s) per title and Equipment Identifier of this specification.

1.07 LABELING
A. Manufacturer shall securely attach in a prominent location, on each major item of equipment, a non-corrosive nameplate showing manufacturer's name, address, model number, serial number and pertinent utility or operating data.
B. Crane capacity shall be painted with letters and numbers 8 inches high minimum on both sides of the bridge/boom.
C. All electrical equipment and materials shall be new and shall be listed by Underwriter's Laboratories, Inc. (UL) in categories for which standards have been set by that agency and labeled as such in the manufacturer's plant.

PART 2 - PRODUCTS
2.01 CRANE, BRIDGE, UNDERHUNG, 1 TON  
Equipment Identifier: 5006

A. Manufacturer’s Reference:
   1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
      a. Konecranes Inc., Springfield, OH (937) 525-5533
      b. Model: JBR-11-0566
   2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
      a. Ingersoll-Rand, Tool and Hoist, Rochester, MI (800) 347-7047
      b. Mannesman Demag, Cleveland, OH (440) 248-2400

B. Capacities/Dimensions:
   1. Lifting capacity: 2,000 pounds
   2. Crane dimensions:
      a. Span: 23 feet 6 inches (verify exact span in field prior to fabrication)
      b. Runway length: 37 feet 7 inches
      c. Clear hook height: 10 feet 7-1/2 inches
      d. Installation height to bottom of bridge: 11 feet 8-3/4 inches
   3. Rated speeds:
      a. Hoist: Maximum high 19; Minimum low 3.3 FPM
      b. Trolley: 65 FPM
      c. Bridge: 100 FPM
   4. Hoist motor: 1.37 HP and 0.32 HP
   5. Height to bottom of push-button station suspended from hoist: 36 inches
   6. System weight: 2,860 pounds, maximum

C. Features/Performance/Construction:
   1. Bridge: A single girder bridge shall be provided with the system.
      a. Materials: The bridge shall consist of cold-rolled steel members welded together with two inch by two inch square tubing welded on top for reinforcement and strength as required. Three short tubes shall be welded to each end of the bridge for fitting end caps, end stops, and power supplies.
      b. Electrification: The bridge shall have internal electrification consisting of five busbars configured identical to runway sections.
   2. Runways:
a. Materials: Track sections shall consist of cold-rolled steel members welded together. Three short tubes shall be welded to each end of track sections for fitting end caps, end stops, and power supplies.

b. Electrification: The runway shall have internal electrification system in one side of the system consisting of five bus bars configured identical to bridge section.

3. Support trolleys: Bridge and hoist support trolleys shall utilize spacer and load bars for proper bridge and hoist supports and stability. Trolleys shall be fabricated of steel and utilized nylon wheels running on permanently lubricated ball bearings and horizontal guide rollers.

4. Collector trolleys: Collector trolleys shall be provided for safe collection of electrical current through the system and shall travel in unison with support trolleys by means of four plastic wheels mounted on lifetime lubricated anti-friction bearings. Contacts shall be sliding carbon mounted on individually spring-loaded double shoes. Connecting cable shall be provided with maximum load of 15 A at 100 percent duty rating.

5. Hoist: An electric hoist shall be provided for each bridge unit.
   a. Hoist motor shall be squirrel cage brake type having multi-pole stator winding class F insulated with a high-speed to low-speed ratio of 4:1.
   b. Gearing shall be bathed in oil bath and shall incorporate a wear resistant friction coupling. Coupling shall function as an emergency upper and lower limit switch and shall protect against extreme overloads.
   c. Sprocket shall consist of six pockets for smooth even lifts.
   d. Chain shall surface hardening and chrome-alloyed finish to provide protection against shock, bonding stresses, and corrosive atmosphere and shall have minimum safety factor of 6:1.
   e. Chain container shall be provided as part of hoist assembly.

6. Hangers shall be fasten to building structure and adequately spaced to provide proper runway support and stability. Rods shall be high tensile strength and threaded with longitudinal and latitudinal stiffeners at designated points along each runway track to insure rigidity of runway as required. Reference drawings for structural member locations and types determining actual suspension hanger length and quantity.

7. Power supply shall be provided by power feed end cap consisting of rubber end pad and an aluminum terminal box with a twist type cable entry gland. Power feed cap shall be pre-assembled with attached plug connectors and jumper wires.

8. Adhesive PVC foil plates indicating capacity of system shall be attached to both sides of the bridge and equally spaced along runway length. Capacity stated on hoist shall be same as capacity indicated on plates.

9. Ergonomically designed impact resistant housing with electrical and mechanical interlocked contact to prevent misdirection of load movement. Pendent shall have a crane ON/OFF and a two-speed hoist UP/DOWN switch.
D. Controls: All protective circuits and components shall meet National Electrical Code requirements.

E. Utility Requirements:
   1. Motor: 460 VAC, 3 phase, 1.37 HP

F. Finish: Durable, corrosion inhibiting enamel paint with color components and zinc-galvanized components where required.

2.02 CRANE, BRIDGE, UNDERHUNG, 10 TON
   Equipment Identifier: 5011

A. Manufacturer’s Reference:
   1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
      a. Konecranes Inc., Springfield, OH (937) 525-5533
      b. Model: JBR-11-0576
   2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
      a. Ingersoll-Rand, Tool and Hoist, Rochester, MI (800) 347-7047
      b. Mannesman Demag, Cleveland, OH (440) 248-2400

B. Capacities/Dimensions:
   1. Lifting capacity: 20,000 pounds
   2. Crane dimensions:
      a. Span: 22 feet (verify exact span in field prior to fabrication)
      b. Runway length: 200 feet
      c. Clear hook height: 23 feet 7-7/8 inches
      d. Installation height to bottom of bridge: 25 feet 1-1/8 inch
   3. Rated speeds:
      a. Hoist: Maximum high 19; Minimum low 3.3 FPM
      b. Trolley: 65 FPM
      c. Bridge: 100 FPM
   4. Height to bottom of push-button station suspended from hoist: 36 inches
   5. System weight: 5,700 pounds, maximum

C. Features/Performance/Construction:
   1. Bridge: A single girder bridge shall be provided with the system.
      a. Materials: The bridge shall consist of cold-rolled steel members welded together with two inch by two inch square tubing welded on top for
reinforcement and strength as required. Three short tubes shall be welded to each end of the bridge for fitting end caps, end stops, and power supplies.

b. Electrification: The bridge shall have internal electrification consisting of five busbars configured identical to runway sections.

2. Runways:
   a. Materials: Track sections shall consist of cold-rolled steel members welded together. Three short tubes shall be welded to each end of track sections for fitting end caps, end stops, and power supplies.
   b. Electrification: The runway shall have internal electrification system in one side of the system consisting of five busbars configured identical to bridge section.

3. Support trolleys: Bridge and hoist support trolleys shall utilize spacer and load bars for proper bridge and hoist supports and stability. Trolleys shall be fabricated of steel and utilized nylon wheels running on permanently lubricated ball bearings and horizontal guide rollers.

4. Collector trolleys: Collector trolleys shall be provided for safe collection of electrical current through the system and shall travel in unison with support trolleys by means of four plastic wheels mounted on lifetime lubricated anti-friction bearings. Contacts shall be sliding carbon mounted on individually spring-loaded double shoes. Connecting cable shall be provided with maximum load of 15 A at 100 percent duty rating.

5. Hoist: An electric hoist shall be provided for each bridge unit.
   a. Hoist motor shall be squirrel cage brake type having multi-pole stator winding class F insulated with a high-speed to low-speed ratio of 4:1.
   b. Gearing shall be bathed in oil bath and shall incorporate a wear resistant friction coupling. Coupling shall function as an emergency upper and lower limit switch and shall protect against extreme overloads.
   c. Sprocket shall consist of six pockets for smooth even lifts.
   d. Chain shall surface hardening and chrome-alloyed finish to provide protection against shock, bonding stresses, and corrosive atmosphere and shall have minimum safety factor of 6:1.
   e. Chain container shall be provided as part of hoist assembly.

6. Hangers shall be fasten to building structure and adequately spaced to provide proper runway support and stability. Rods shall be high tensile strength and threaded with longitudinal and latitudinal stiffeners at designated points along each runway track to insure rigidity of runway as required. Reference drawings for structural member locations and types determining actual suspension hanger length and quantity.

7. Power supply shall be provided by power feed end cap consisting of rubber end pad and an aluminum terminal box with a twist type cable entry gland. Power feed cap shall be pre-assembled with attached plug connectors and jumper wires.
8. Adhesive PVC foil plates indicating capacity of system shall be attached to both sides of the bridge and equally spaced along runway length. Capacity stated on hoist shall be same as capacity indicated on plates.

9. Ergonomically designed impact resistant housing with electrical and mechanical interlocked contact to prevent misdirection of load movement. Pendent shall have a crane ON/OFF and a two-speed hoist UP/DOWN switch.

D. Controls: All protective circuits and components shall meet National Electrical Code requirements.

E. Utility Requirements:
   1. Motor: 460 VAC, 3 phase, 60 Hz

F. Finish: Durable, corrosion inhibiting enamel paint with color components and zinc-galvanized components where required.

2.03 CRANE, BRIDGE, TOP RUNNING, 2 TON
   Equipment Identifier: 5020

A. Manufacturer's Reference:
   1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
      a. Konecranes Inc., Springfield, OH (937) 525-5533
      b. Model: JBR-12-0601
   2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
      a. Ingersoll-Rand, Tool and Hoist, Rochester, MI (800) 347-7047
      b. Mannesman Demag, Cleveland, OH (440) 248-2400

B. General Requirements:
   1. Top running double girder electric overhead traveling cranes shall be designed, manufactured, and tested as per Crane Manufacturers Association of America (CMAA) Specification #70, Revised 2000.
   2. In addition the crane design and installation shall meet all the applicable local, state, and federal laws and OSHA regulations having jurisdiction.
   3. Cranes shall operate in the given spaces and shall match the runway dimensions and rails indicated. Crane design shall maximize hook coverage, hook vertical travel, and clear hook height.
   4. The crane shall be designed and manufactured to meet the appropriate service conditions based on the particular application. The crane service class shall be clearly indicated by the manufacturer at the time the crane proposal is submitted.

C. Capacities/Dimensions:
   1. Lifting capacity: 4,000 pounds
2. Lower load block or assembly of hook, swivel bearing sheaves, pins and frames suspended by the hoisting ropes shall not be considered part of the rated capacity.

3. CMAA service class: Crane shall be designed and constructed to CMAA Specification #70 (revised 1994) for Class “C” service requirements and operation in a non-hazardous environment.

4. Crane dimensions:
   a. Span: 58 feet 4 inches
   b. Runway length: 120 feet
   c. Clear hook height: 26 feet 8 inches

5. Lift: Hoist design shall maximize hook coverage, hook vertical travel (i.e. end approach), and clear hook height (i.e. headroom). The use of a low headroom hoist is mandatory.

6. Rated speeds (FPM) ±10%:
   a. Hoist: Maximum high 20; Minimum low 3.3 FPM
   b. Trolley: Maximum high 65; Minimum low 65 FPM
   c. Bridge: Maximum high 100; Minimum low 100 FPM

D. Features/Performance/Construction:

1. Hoists and trolleys:
   a. Hoist design shall maximize hook coverage, hook vertical travel (i.e. end approach), and clear hook height (i.e. headroom).
   b. All top running and under-running single girder cranes shall utilize low headroom electric wire rope hoists.
   c. All hoists/ trolleys shall be supplied with two-speed hoisting contractor controls and inverter trolley speed controls (steeples or programmed two-speed) to minimize load swing and ensure accurate load positioning.
   d. Any proposed equivalent must meet or exceed the dimensional and performance specification of the above-mentioned products.
   e. Unless otherwise specified, hoists shall be single revved. Lateral hook drift shall not exceed 1/8 inch per foot of vertical travel, or true vertical lift.
   f. The drum to rope diameter ratio shall be a minimum of 30:1 to minimize rope flex and significantly extend rope life. Drum shall be made from steel and supported on heavy-duty anti-friction bearings; groove depth shall be at least 35 percent of rope diameter. The rope drum shall be equipped with a rope guide and spring loaded roller to help keep the rope aligned in the grooves of the drum at all times.
   g. Gear reducers shall be integral components of standard hoists or hoist/ trolley units of manufacturers regularly engaged in the design and manufacturing of hoists or hoist/ trolley units for Class C cranes. The hoist gearbox must be mounted on angle to the drum to achieve zero gear lash and insure long gear bearing life. The gear reduction units shall be fully enclosed in oil-tight housing. Operation shall be smooth and quiet.
h. Hoisting gears shall be hardened and ground. Gears and pinions shall be spur, helical, or herringbone type only, and shall be forged, steel; open-type gearing is not acceptable. Gears and pinions shall be manufactured to AGMA 2001-B Quality Class 11 or better precision per AGMA 2000-A. Gear reducer shall not incorporate a mechanical load brake; the gear reducer shall not require regular internal maintenance (such as mechanical load brake adjustment) and frequent lubricant changes due to friction material contamination and high running temperatures.

i. If a secondary brake is required the brake shall be installed in such a way as to provide redundant braking at each brake application. Secondary brakes, which are not regularly activated and may become inoperative due to lack of use, are not acceptable.

j. The secondary brake shall be a self adjusting DC disc type rated at a minimum of 150 percent of rated motor torque not including regeneration type braking.

k. Each hoist shall be equipped with an electro-mechanical load-limiting device that shall prevent lifting more than 110 percent of the rated load.

l. Hooks shall be made of forged alloy steel (34rMo4 Class T). Hooks shall be fitted with spring loaded safety latches designed to preclude inadvertent displacement of slings from the hook saddle and have 360 degree rotation on anti-friction bearings. Painting or welding shall not be performed on the hook. Hook nut shall be secured with a removable type set screw or other similar fastener; nut shall not be welded. Hooks shall be designed and commercially rated with safety factors in accordance with CMAA.

m. Bottom block shall be totally enclosed in a steel housing. Rope sheaves shall be supported on heavy-duty anti-friction bearings. Load blocks shall be of steel construction. Load blocks shall be provided with hot-rolled or forged steel fixed crosshead separate from the sheave pin with swivel mounting for forged steel hook. Each lubrication fittings for sheave pins shall be independent type recessed within the sheave pin or adequately guarded to prevent damage.

n. Sheaves shall be of steel or ductile iron (240 to 302 BHN hardness). Sheaves grooves shall be accurately machined, smoothly finished, and free of surface defects. The sheave to rope diameter ratio shall be a minimum of 20:1 to minimize rope flex and extended rope life.

o. Wire rope shall be constructed from galvanized steel having a steel core and a minimum safety factor of 5. (Hoisting ropes shall be the rated capacity load plus the load block weight divided be the number of rope parts, and shall not exceed 20 percent of the certified breaking strength of rope.) Ropes shall be suited to meet the service requirements. Rope socketing or U-bolt clip connections shall be equal to or greater than the rope lengths. Hoisting ropes shall be secured to hoist drum so that no less than two wraps of rope remain at each anchorage of hoist drum at the extreme low position (limit switch stop).

p. Trolley shall be complete with a drive arrangement with a minimum of two-wheel driven by an integral electric motor. Drive mechanism shall run in totally enclosed oil bath. Drive gears shall conform to AGMA 2001-B Quality
Class 11 or better. Stop limit switches must be provided for drive mechanism. Acceleration and deceleration controls shall meet requirements specified in this section. Trolley motor shall be inverter duty motor with minimum class “F” insulation. Motors shall have quick disconnect plugs for easy maintenance. Speed shall be infinitely variable from 0 to 50 FPM.

q. Trolley breaking system shall be automatically set when controls are released or power is interrupted. Brakes shall be sealed, dust proof and shall require no adjustment over a million cycles and last the life of the hoist under normal use.

2. Bridge components:

a. High-strength bolted connections shall utilize SAE Grade 5 bolts with corresponding lockwashers, nuts, etc., conforming to requirements of AISC S329 bolts. Bolts, nuts, and washers shall conform to ASTM 325 bolts. Galvanized bolts are not acceptable.

b. Bridge girders shall be constructed from A36 welded box girders, or A36 Structural beams. Girder shall be notched at ends and bolted to top of end trucks with horizontal connection plate utilizing shear rings to absorb horizontal shear forces and to maintain squareness. No “in shear” connections between girders and trucks will be allowed.

c. Bridge end trucks to be constructed of welded box shapes, formed into a rigid tubular housing. Trucks to be equipped with removable rail sweep on each end as well as energy-absorbing bumper. Wheel assemblies shall consist of flat tread, double-flanged, high-quality nodular iron or forged steel wheels, having anti-friction bearing assemblies with whole wheel assembly readily removed for easy repair. Drive wheels shall have rotating axles; idler wheels may be of fixed axle type. End connections shall be made with high-strength bolts.

d. Bridge drives shall be A-4 drive arrangement as specified in MHI CMAA 70. Bridge drive shall consist of a single electric motor mechanically connected through gear reduction and drive shafts to each drive wheel. Gears shall conform to applicable AGMA standards. Gear reducers shall be oil tight and fully enclosed with pressure or splash type lubrication to reduce maintenance and improve reliability.

e. Bridge braking system shall be provided with a spring-applied and electrically released disc brake for each bridge drive motor. Brakes shall have a torque rating of at least 50 percent of bridge drive motor rated torque. Brakes shall be self-adjusting for wear.

f. Wheels shall be manufactured of steel or nodular iron. Wheel treads and flanges shall be rim toughened to between 220 and 300 Brinell hardness number. Bridge and trolley wheels shall be double-flanged. Trolley wheels shall have straight treads. Bridge wheels shall have straight treads. Wheel shall be equipped with heavy-duty anti-friction bearings - no bushings shall be allowed.

g. Where applicable, cranes shall be designed to preclude leakage of lubricants onto the lifted loads or the floor. Equipment and components, which cannot be made leak-proof, shall be fitted with suitable drip pans. Drip pans shall
be manufactured of stainless steel and designed to permit removal of collected lubricant.

h. Electrically controlled brakes shall be fail-safe spring set when power is interrupted. Brakes shall be released with a mainline contractor POWER-OFF push button or a master switch for the associated drive. Brakes shall automatically stop when there is a power failure.

i. Runway (track-type) limit switches shall be provided for crane bridge motion to stop the bridge motion. Trip mechanisms for bridge motion shall be located on crane runway to trip switch before bumper contacts stop. When the switch is tripped, the switch shall permit opposite travel in the direction of stop and then automatically reset.

3. Welding: Welders, welding operations and welding procedures shall be qualified or pre-qualified in accordance with AWS D14.1. The surface of parts to be welded shall be free from rust, scale, paint, grease or other foreign matter. Minimum preheat and interpass temperatures shall conform to the requirements of AWS D14.1. Welding shall be performed in accordance with written procedures, which specify the Contractor’s standard dimensional tolerances for deviation from camber and sweep. Such tolerances shall not exceed those specified in accordance with AWS D14.1. Allowable stress ranges shall be in accordance with MHI CMAA 70. Welding of girders and beams shall conform to AWS D14.1.

4. Markings, labels, and warnings:
   a. Two capacity plates including the crane capacity in tons are required, one secured to each side of bridge crane. Each capacity plate shall be fabricated of steel or a quality/ fade-resistant stick-on label with letters large enough to be easily read from the floor. Capacity plates shall be placed in a location visible to pendant operator’s position after the crane has been installed.
   b. Readable warning labels shall be affixed to each lift block or control pendant in a readable position in accordance with ASME B30.16, ASME B30.2, and ASME B30.17. The word “Warning” or other legend shall be designed to bring the label to the attention of the following information concerning safe-operating procedures: operating the hoist when the hook is not centered under the hoist; operating hoist with twisted, kinked or damaged rope; with a rope that is not properly seated in its hoist drum groove; lifting people; lifting loads over people; and removing or obscuring the warning label.

5. Crane runway rail: Manufacturer to provide crane runway rail to match end truck wheel assembly with crane stop.

E. Electrical and Control Requirements:
   1. Cranes shall be designed to be operated from a 460 VAC, 3 phase, 60 Hz, alternating current system power source.
   2. The hoist/ trolley shall be CAS (US/ Canada) approved and/ or UL approved to NEMA 3R protection. Hoist control enclosure shall be rated NEMA 4.
   3. Hoisting motors shall be two-speed/ two winding squirrel cage type with a speed ratio of 6:1. Hoisting motors effective duty shall be 60 percent ED (30 minute rated) or higher with minimum class “F” insulation. One thermal sensitive device
embedded in hoist motor windings shall be provided. Thermal-sensitive device
and associated circuits shall be self-restoring (automatic reset). Motors shall be
designed specifically for crane and hoist duty.

4. The hoist motor shall be positioned inside the drum to minimize heat build up by
directing airflow over the motor in close proximity to the motor housing. The
cooling effect of the hoist drum surrounding the motor shall be an acceptable
means of directing this airflow, and keeping damaging motor heat to a minimum.

5. Hoist controls shall be full magnetic type, specifically selected for hoisting
service. The trolley shall be supplied with variable frequency drive (VFD)
controls for two-step or infinitely variable speed control for smooth acceleration
and deceleration; minimal load swing and accurate load placement.

6. Hoist shall be equipped with a geared adjustable upper and lower limit switch to
limit extreme upper and lower travel of the bottom block assembly. Geared limit
switch shall have four positions with the following functions- lower limit, upper
slowdown, upper limit, and phase reversal supervision. The upper-most limit
shall be wired to the down circuit in such manner to prevent hoisting in the event
of a phase reversal.

7. Bridge motors shall be inverter duty motors with minimum class “F” insulation.
Motors shall have quick-disconnect plugs for easy maintenance. Travel motors
shall have a duty of 40 percent or higher. Motor enclosure shall be TENV (totally
enclosed non-ventilated). Provide slow down and stop limit switches at each end
of the bridge to insure safe operation. Speed shall be infinitely variable from 0 to
100 FPM.

8. A main line disconnect consisting of a combination circuit breaker (50,000 AIC)
and non-reversing starter, starter without overloads (mainline contractor) in
NEMA Type 4X enclosure shall be provided. Mainline disconnect shall be
controlled by a control circuit so that all crane motions will be stopped upon
mainline under voltage, overload, control circuit fuse failure, or operation of
POWER-OFF push button. Mainline disconnect shall be equipped with energy
isolating devices designed to accept lockout devices.

9. Pendant control station enclosure shall be NEMA 4X Type. Physical size of
pendant shall be held to a minimum. A separate cable of corrosion-resistant
chain consisting of a minimum 6.4 millimeter (1/4 inch) wire shall be provided.
Cable shall be integral with pendant control wire.

10. Push button control enclosure shall be NEMA 4X. Thermal overloads to be
provided for all motors. Hoist to be equipped with overload cut-off device. Hoist
and trolley control functions to be combined with pushbutton control functions for
crane motions.

11. Reduced voltage at pendant push button.

12. Operation push buttons shall be heavy-duty; type with distinctively felt operation
positions, which meet requirements of NEMA 4X. Pendant control buttons shall
be momentary push buttons. Push buttons (except the POWER-OFF button)
shall be recessed type to avoid accidental operation. Diameter of buttons shall
be a size, which will make operation possible with a thumb while holding the
pendant with the same hand. Nameplates shall be provided adjacent to each
push button. In a multi-speed application, dual-position push buttons shall have
a definite click-indent position for each speed. Pendant shall include a separate set of push buttons for each motion and for POWER-OFF. Push buttons shall be as follows:

a. POWER-OFF
b. POWER-ON
c. Hoist-Up
d. Hoist-Down
e. Bridge-West
f. Bridge-East
g. Trolley-North
h. Trolley-South

13. Bridge span conductor system shall be the rigid conductor/collector type. Cable loops shall not drop below the hook high position. Outdoor crane bridge festoon system hardware shall be corrosion resistant.

14. Pendant festoon system shall consist of a support rail, cables, junction boxes, cable cars, and accessories. Cable loops shall not drop below the hook high position. Pendant control car shall be provided with NEMA Type 12 junction box. Outdoor crane pendant festoon system hardware shall be corrosion resistant.

15. Main power electrification system shall provide power to crane starter/disconnect circuit breakers.

F. Accessories:

1. Crane runway rail to match end truck wheel assembly with crane stop.

2. Crane runway conductor system shall be covered conductor bar system type designed and manufactured to meet UL requirements. Protective covers shall be the rigid or flexible self-closing type designed to cover all live conductors and shall be shaped to prevent accidental contact with conductors. Collectors shall be heavy-duty sliding shoe type compatible with the electrification system. Two tandem designed collector heads shall be provided for each conductor rail to provide redundancy.

3. A solid-waste electronic warning horn shall be provided on the crane. Any bridge or trolley motion shall be accompanied by a continuous series of alternating tones.

4. Control panels shall be provided with a 120 volt lamp fixture with an unbreakable lens and switch. Two floodlights shall be provided to illuminate the work area under the crane. Floodlights shall be metal halide (400 watt) industrial luminaries. Each floodlight shall be totally enclosed, vapor-tight design, gasketed and shall be provided with a heat-resistant glass lens. Floodlights shall be spaced and attached to underside of crane to provide uniform lighting.

G. Utility Requirements: Electrical - 460 VAC, 3 phase, 60 Hz, 8.8 HP

H. Finish: Bridge crane including bridge, trolley, hoist, and all attached items shall be painted in accordance with the manufacturer’s standard practices. Items such as
surfaces in contact with the electrical collector bars in contact with the collector shoes and nameplates shall not be painted.

2.04 CRANE, JIB, 2 TON, 20 FOOT SPAN, COLUMN MOUNTED
Equipment Identifier: 5228

A. Manufacturer’s Reference:
   1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
      a. Gorbel, Fishers, NY (585) 924-6262
      b. Model: WC200-B2-20-W21
   2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
      a. KCI KoneCranes, Santa Fe Springs, CA (949) 248-5496
      b. Abell-Howe Co., Forest Park, IL (708) 366-3475

B. Capacities/Dimensions:
   1. Lifting capacity: 4000 pounds
   2. Dimensions:
      a. Beam height: 20 feet
      b. Hook height: 16 feet 11 inches
      c. Boom reach (center of pivot to boom end): 20 feet
      d. Boom depth: 21 inches
      e. Mast length: 8 feet 6 inches
      f. Flange width: 8.24 inches
   3. Swing: 180 degrees
   4. Weight, hoist/trolley, maximum: 75 pounds
   5. Thrust/pull: 15.84 Kips

C. Features/Performance/Construction:
   1. Two mounting brackets designed to anchor mast to support structure, allow boom rotation and resist drift. Load carrying parts will be double shear and no bolt stress will exceed 10,000 PSI. Brackets with tension welds are not acceptable. Bracket consists of formed channel to be bolted to support structure and equipped with pivot pin and thrust washer. Fabricated I bracket to be welded to mast and joined to formed channel with pivot pin. Provide with oil-impregnated bronze bushings and field lubricated grease fitting.
   2. Boom: Horizontal, wide flange steel beam designed for hoist trolley traveling on bottom flange. Reinforce with cap channel as required for lateral stability and stiffeners at critical stress points. Equip boom with stops to limit movement of trolley per shop drawings.
3. Mast: Vertical, wide flange steel section perpendicular to boom and parallel to crane rotation axis. Mast shall be equipped with stops to ensure beam does not over-swing. Mast shall be reinforced with stiffeners at critical stress points. Provide corner web gusset for mast boom joint. Box-in mast by welding steel plate to mast flanges to provide rigidity.

4. Crane shall have sufficient clearance above the boom.

5. Crane shall be mounted on structural columns as shown on Equipment Layout Drawing EQ-103.

6. Crane shall be equipped with hoist Equipment Identification # 5392 as described in section 2.05.

D. Accessories:

1. Tagline festoon system: Provide system of wire rope tagline, S-hooks, brackets and eyebolts for attachment to boom. System shall support electrical cable supplying trolley hoist moving along boom.

2. Rotation stops: Provide steel plate stops for welding to formed channels of top and bottom brackets in order to limit boom rotation.

E. Finish: Steel frame, primed and painted with baked enamel topcoat in manufacturer’s standard color.

2.05 HOIST, CHAIN, ELECTRIC, MOTORIZED TROLLEY, 2 TON
Equipment Identifier: 5392

A. Manufacturer’s Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
   a. Coffing Hoist, Wadesboro, NC (704) 694-2156
   b. Model: ECMT4008-3-15, 2 ton hoist with low speed trolley and accessories

2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
   b. Yale Hoists, Inc., Forrest City, AR (501) 633-2250

B. Capacities/Dimensions:

1. Hoist:
   a. Lifting capacity: 4,000 pounds
   b. Motor: 1 HP
   c. Lifting speed: 8 FPM
   d. Lifting range: 16 feet
   e. Headroom, with trolley: 20 inches (maximum)

2. Trolley:
a. Capacity: 4,000 pounds
b. Motor: 1/4 HP
c. Travel speed: 35 FPM
d. Control cable length: 16 feet
e. I-beam size range: 6 to 18 inches, American Standard Section

3. Weight: 213 pounds (represents 10 foot lift)

C. Features/Performance/Construction:
1. Hoist shall have needle and ball type bearings with gears running in oil bath.
2. Frame shall be cast aluminum alloy.
3. Load hook and chain: Hook shall be forged steel with safety clip and shall be attached to cadmium plated chain by bearing type swivel.
4. Safety: Safety features shall include ratchets pawl mechanical load brake, overheating, and positive limit switches.
5. Hoist mounting: Hoist shall be lug mounted to trolley for minimum headroom.
7. Hoist shall be mounted on Jib Crane #5228 (as described in section 2.04) as shown on Equipment Layout Drawing EQ-103.

D. Controls: Four push button pendant, with cord strain relief bushings, for hoist UP/DOWN and trolley FORWARD/REVERSE

E. Accessories:
1. Festoon kit: Coffing Hoist No. HER-12-35
2. Chain container: Mounted to hoist, Coffing Hoist No. 927JG18

F. Utility Requirements: 460 VAC, 3 phase, 1-1/4 HP

2.06 FORKLIFT, ELECTRIC, 6,000 POUNDS
Equipment Identifier: 5410

A. Manufacturer’s Reference:
1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer’s name and model to establish minimal acceptable standards of quality, features, performance, and construction.
   a. Clarke Material Handling Company, Lexington, KY (859) 422-6400
   b. Model: ECX30 with Accessories
2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
   a. Hyster Company, Danville, IL (252) 561-7104
   b. Mitsubishi Forklifts, Houston, TX (713) 365-1000

B. Capacities/Dimensions:
1. Rated capacity: 6,000 pounds
2. Maximum fork height: 189 inches
3. Fork length: 48 inches
4. Overall dimensions:
   a. Width: 43-8/10 inches
   b. Length: 86-5/10 inches
   c. Height: 88 to 237 inches
5. Weight: 6,820 pounds
6. Turning radius: 91 inches without load
7. Travel speeds:
   a. Loaded: 6 to 8 MPH
   b. Empty: 7 to 9 MPH
8. Lift/lower speeds:
   a. Loaded: 43 to 61 FPM
   b. Empty: 80 to 103 FPM

C. Features/Performance/Construction:
1. The forklift shall include a triple stage mast for a maximum lifting height of 189 inches.
2. The drive control shall be 36/48 dual voltage.
3. The forklift shall include the following:
   a. Battery compartment
   b. OAH overhead guard
   c. Hydrostatic power steering with tilt wheel
   d. Cowl mounted levers
   e. Vinyl covered safety seat
   f. Foot activated parking brake
   g. Multi-functional diagnostic dash display with hour meter and battery discharge indicator with lift interrupt.
   h. OHG mounted 12-volt headlights, including 12-volt converter
   i. 41 inch, class 3 carriage
   j. Single auxiliary valve
   k. Side shifter
   l. Stop/tail/back-up lights
   m. 12-volt amber strobe light
   n. Back up alarm
o. 24-foot load center

4. Forklift shall be designed for warehouse with warehouse cushioned tires.

5. To recharge unit, unit plugs directly into charger and the charger into a wall receptacle.

6. Battery shall be a Clarke Model No. 18-85P-29, or approved equal

7. Charger shall be a Clarke Model No. MX3-18-1200, or approved equal, with the following dimensions:
   a. Height: 30 inches
   b. Depth: 18 inches
   c. Width: 24 inches

D. Accessories: Wall mounting bracket, No. TSCWB, or approved equal

E. Utility Requirements: 460 VAC, 3 phase, 15.1 A

F. Finish: Durable enamel in Authority’s choice of manufacturer’s standard colors

PART 3 - EXECUTION

3.01 INSPECTION
   A. Coordinate location of rough-in work and utility stub-outs to assure match with equipment to be installed.

   B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare delivered equipment with packing lists and specifications to assure receipt of all equipment items and specified accessories.

   C. Report in writing, to the Architect, any damaged, missing, or incomplete scheduled equipment, and improper rough-in work or utility stub-outs.

3.02 INSTALLATION
   A. Perform work under direct supervision of Foreman of Construction Superintendent with authority to coordinate installation of scheduled equipment with Architect or designated representative.

   B. Reference structural drawings and coordinate length of run and exact span dimensions with shop drawings and construction documents.

   C. Crane shall meet all OSHA design and clearance guidelines.

   D. Install equipment in accordance with plans, shop drawings and manufacturer’s instructions:
      1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb and at right angles to adjacent work.
      2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, professional manner without damaging equipment or adjacent work.
3. Anchorage: Attach equipment as directed by Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.

E. Upon completion of work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.03 TESTING

A. Specification Compliance: After final connections are made and prior to authorizing payment, specified equipment shall be tested for compliance with specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

B. General:

1. Contractor shall provide all personnel necessary to conduct the required testing, which shall include but not be limited to crane operators, riggers, rigging gear and test weights.

2. Contractor shall notify customer seven days prior to testing operations.

3. Contractor shall operate all equipment and make all necessary corrections and adjustments prior to the testing operations witnessed by Contracting Officer.

4. A representative of the Contractor responsible for installing hoist equipment shall be present to direct the field-testing.

5. An OSHA certificate will be provided after the successful completion of the load test.

C. Test Sequence

1. Crane shall be tested in accordance with applicable paragraphs of this procedure in the sequence provided.

2. Improper operation or poor condition of safety devices, electrical components, mechanical equipment and structural assemblies shall be monitored during the load test. Defects observed to be critical during the testing period shall be reported immediately to the Contracting Officer and the testing operations shall be suspended until the defects are corrected. During each load test and immediately following each load test, the following inspections shall be made:

   a. Inspect for bending, warping, permanent deformation, cracking or malfunction of structural components.

   b. Inspect for evidence of slippage in wire rope sockets and fittings.

   c. Check for overheating in brake operation; check for proper stopping. All safety devices including emergency stop switches and POWER-OFF push buttons shall be tested and inspected separately to verify proper operation of the brakes. When provided, safety accessorized including warning horn, lighting, gauges, warning lights and accuracy of wind indicating device and alarm shall be inspected.

   d. Check for abnormal noise or vibration and overheating in machinery drive components.
e. Check wire rope sheaves and run spooling for proper revving and operation, freedom of movement, abnormal noise or vibration.

f. Check electrical drive components for proper operation, freedom from chatter, noise, overheating, and lockout/ tagout devices for energy isolation.

g. Verify that locations of crane capacity plates are visible from pendant operator’s position.

3. Hooks: Hooks shall be measured for hook throat spread before and after load test. Throat dimension base measurements shall be established by installing 2 tram points and measuring the distance between the tram points to within 0.4 millimeters (1/64 inch). This base dimension shall be recorded. Distance between tram points shall be measured before and after load test. An increase in throat opening by more that 1 percent from base measurement shall be cause for rejection.

a. Dynamic Load Test: Test load shall be raised and lowered through the full range operating in each speed. Machinery shall be completely stopped at least once in each direction to ensure proper brake operation.

b. Hoist Loss of Power Test: After raising test load to approximately 2.5 mm (8 feet), slowly lowering the test load, the main power source and control push button shall be released verifying that the test load will not lower and that the brake will set.

4. Trolley and Bridge Loss of Power Test: A test load of 100 to 105 percent of rated load shall be raised clear of any obstructions on operating floor. Starting at a safe distance from walls or other obstructions, a slow speed shall be selected using the trolley and bridge primary drive. While maintaining a safe distance to obstructions, the main power source shall be disconnected and brakes shall be verified to have set and that the equipment stops within the distance recommended by manufacturers.

5. After the operational tests, bridge crane system and all function of bridge crane shall be tested at 125 percent of rated load.

3.04 CLEANUP

A. Touch-up damage to painted finishes.

B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.

C. Clean area around equipment installation and remove packing and installation debris from job site.

D. Notify Architect or designated representative for acceptance inspection.

3.05 TRAINING

A. Direct the technical representative to provide specified hours of training to designated Authority’s maintenance personnel in operation and maintenance of the following equipment. Coordinate, with Metro, training schedule and list of personnel to be trained.

B. Contractor shall conduct a training course for the operating staff. Training period shall start after the system is functionally completed but prior to final acceptance.
Course instructions shall cover pertinent points involved in operating, starting, stopping and servicing the equipment, including all major elements of operation and maintenance manual. Course instructions shall demonstrate all routine maintenance operations such as lubrication, and general inspections. Contracting Officer's Representative shall be given at least 2 weeks advance notice of field training.

1. 5006 Crane, bridge, underhung, 1 ton; 1 hour (minimum)
2. 5011 Crane, bridge, underhung, 10 ton; 1 hour (minimum)
3. 5020 Crane, bridge, top running, 2 ton; 1 hour (minimum)
4. 5228 Crane, jib, compression, 2 ton, 20 foot span, column mounted; 1 hour (minimum)
5. 5392 Hoist, chain, electric, motorized trolley, 2 ton; 1 hour (minimum)
6. 5410 Forklift, electric, 6,000 pounds; 1 hour (minimum)

C. Obtain, from technical representative, a list of Metro's personnel trained in equipment operations and maintenance.

END OF SECTION 41 22 00
STORM WATER POLLUTION PREVENTION PLAN

PART 1 - GENERAL

1.01 SUMMARY

A. A Storm Water Pollution Prevention Plan (SWPPP) has been prepared for this Project and will be furnished to the Contractor. Contractor shall use the SWPPP as reference and develop and submit to the QSD for approval, staging and phasing SWPPP showing the installation of BMPs per Contractor’s construction schedule. Contractor shall implement and monitor the staging and phasing of the SWPPP.

B. The Contractor shall ensure that all Best Management Practices (BMPs) required by the SWPPP Manual, the Construction General Permit (Order 2009-0009-DWQ), and NPDES are supplied and implemented by a Qualified SWPPP Practitioner (QSP).

C. The Contractor will be required to review the Storm Water Pollution Prevention Plan and to identify possible stormwater pollution sources and mitigation measures with all Prime Contractors and subcontractors at their starting of work on site. Each Contractor and their Sub-contractors shall assign a Responsible Person (RP) for BMPs implementation and coordination. Storm Water Pollution Prevention Plan revisions and reporting will be performed by the Prime Contractor.

D. Contractor must comply with all laws and governmental regulations, including but not limited to the requirements of the Clean Water Act, the California State Water Resources Board, the County of Los Angeles, and the City of Santa Monica. The Contractor and their Sub-contractors shall be responsible for installation and maintenance of BMPs (Best Management Practices) as necessary to comply with the SWPPP. Compliance with all regulations shall be the sole responsibility of the Prime Contractors and Sub-contractors.

E. Contractor shall be fully responsible for diligent supervision of all work activities provided by their employees and/or agents to assure that these activities are in full compliance with all applicable General Permit requirements. Contractor must review all SWPPP documents with the QSP prior to commencement of any work. Contractor shall report immediately any discrepancies or conflicts in these documents as they apply to the Contractor’s scope of work.

F. As part of the monitoring program, periodic inspections of all activities will be conducted by the contractor. Contractor’s and Subcontractor’s responsible persons (RPs) will be responsible for meeting weekly with the QSP to evaluate BMP effectiveness and make necessary corrections as indicated on inspection documents. Prime Contractors and Sub-contractors are responsible for making necessary corrections within the time frame indicated. The QSP will conduct pre-storm, interim storm, and post storm inspections to evaluate site readiness for storm activity. Corrective action time frame is as follows:

1. Level A Corrective Action – 72-hour notice
2. Level B Corrective Action – 48-hour notice
3. Level C Corrective Action – Immediate Action
G. Contractor is aware that compliance with SWPPPs and other environmental regulations is mandatory on this Project and any fines / penalties shall be immediately deducted from any contract progress payments payable to Contractor or billed directly to Contractor. In addition to any fines or penalties payable to any enforcing governmental agency, all clean up and/or testing or analysis costs associated with compliance and non-compliance shall be borne by the Contractor.

H. The QSD shall be a representative from the engineer of record.

I. The contractor is responsible for the SWPPP Manual, the Construction General Permit (Order 2009-0009-DWQ), and NPDES compliance. The contractor shall assign a qualified person with the responsibility to ensure full compliance with the permit and to implement all elements of the SWPPP.

J. Contractor shall be responsible for all fees associated with the maintenance of the SWPPP including, but not limited to BMPs, plan preparation, inspections, data submissions, annual reports, and annual fees.

K. Contractor shall update the SWPPP each time after there are significant modifications to the stormwater pollution prevention system or a change of contractors working on the project who disturbs site soil.

1.02 QUALITY ASSURANCE

A. Codes and Standards

3. Construction General Permit (Order 2009-009-DWQ)

B. The discharger shall comply with effluent standards or prohibitions established under Section 307(a) of the CWA for toxic pollutants within the time provided in the regulations that establish these standards or prohibitions.

1.02

1.03 SUBMITTAL

A. LEED Requirements

1. Engage an experienced LEED-Accredited Professional to coordinate LEED requirements. LEED requirements and Construction Waste Management and Disposal requirements are mutually inclusive.

B. The Contractor shall prepare and submit a 24”x36” plan showing the location of the BMPs implemented for each stage and/or phase of the construction to the QSP for approval by the QSD. A template is available in the SWPPP.

C. The Contractor shall provide training documentation for individuals responsible for all activities associated with the General Construction Permit (Order 2009-0009-DWQ) and the SWPPP on a quarterly basis (every three months).

D. The Contractor shall provide training documentation for individuals responsible for BMP installation, inspection, maintenance, and repair on a quarterly basis (every
three months). QSP will inform QSD of any change or additions to the approved staging and phasing plans.

E. The Contractor and Sub-contractors shall furnish and submit a list of all materials to be stored on site. Materials shall be stored in bins or under cover to prevent coming into contact with storm water. Contractor will inform QSP of any changes in activities, or additions to activities such as location of equipment yards, and concrete wash out stations.

F. The Contractor shall assign a Qualified SWPPP Practitioner (QSP) and provide training material and certifications.

G. The Contractor’s QSP shall submit pictures, and the site’s SWPPP with all its attachments, amendments and revisions to the QSD for procession and approval of the site’s Notice of Termination (NOT).

H. The Contractor shall itemize and submit the contractor specific items identified in the SWPPP to update and complete the SWPPP including, but not limited to, construction schedule, BMP Layout Plan, training logs, REAPs, approved laboratory information, weather reports, monitoring records, rain gauge logs, sampling logs, exceedance reports, chain of custody forms, amendment forms, inspection forms, and a list of subcontractors. These submittals shall be on a monthly basis.

I. The Contractor may substitute the forms in the Storm Water Pollution Prevention Plan subject to the approval by the QSD.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 SURFACE CONDITIONS

A. Examine the areas and conditions under which work of this section will be performed. Correct conditions detrimental to timely and proper completion of the work. Do not proceed until unsatisfactory conditions are corrected.

B. The Contractor shall comply with the following Risk Level 2 Requirements as stated on the General Construction Permit Attachment D:

1. Effluent Standards
2. Good Site Management
3. Non-Storm Water Management
4. Non-visible Pollutant Testing
5. Erosion Control
6. Sediment Control
7. Run-on and Run-off Controls
8. Maintenance and Repairs
9. Rain Event Action Plan Implementation

C. The Contractor’s QSP shall comply with Risk Level 2 Monitoring and Reporting Requirements as stated on the General Construction Permit Attachment D. In addition, the Contractor shall follow the Construction Site Monitoring Program developed in Section 7 of the SWPPP.
D. The Contractor shall assign a data submitter to upload documents and/or reports into the State Stormwater Multiple Application and Reporting Tracking System. These documents may include but are not limited to exceedance reports, non-storm water discharge reports, BMP visual inspection reports, sampling test results, change of information requests, pre-rain inspections, rain inspections, post-rain inspections and rain event action plans.

E. The Contractor shall contract the services of a state certified laboratory to conduct non-visible pollutant testing per the Construction Site Monitoring Program included in Section 7 in the SWPPP. Contractor shall submit certificate to the QSD for approval.

PART 2 -
PART 3 -
3.01
3.02 INSTALLATION

A. BMP installation for different trades of the work shall be as indicated on the drawings, as specified herein, as recommended by the QSP and in accordance with regulatory requirements.

B. BMPs shall be maintained until project completion and/or the disturbed area is stabilized.

C. BMP installation shall be in accordance with the SWPPP or CASQA BMP guidelines.

PART 2 -
PART 3 -
3.01
3.02
3.03 CLEANING

A. During and upon completion of the work, Contractor shall comply with the general provisions of the approved SWPPP.

B. Contractor shall maintain BMPs in working order throughout the duration of the entire project or until the disturbed site is stabilized and a Notice of Termination is approved.

PART 4 - TRAINING QUALIFICATIONS AND CERTIFICATION REQUIREMENTS

4.01 GENERAL

A. The Contractor shall ensure that all persons responsible for implementing requirements of this General Permit shall be appropriately trained in accordance with this Section. Training will be both formal and informal, occur on an ongoing basis, and shall include training offered by governmental agencies or recognized professional organizations. The Contractor shall provide documentation of training for persons responsible for implementing the requirements of this General Permit in the Annual Reports.
4.02 SWPPP CERTIFICATION REQUIREMENTS

A. Qualified SWPPP Practitioner: The Contractor shall ensure that the requirements of the General Permit are implemented by a full-time on-site Qualified SWPPP Practitioner (QSP). A QSP is a person responsible for non-storm water and storm water visual observations, sampling and analysis. Effective September 1, 2011, a QSP shall be either a Qualified SWPPP Developer (QSD) or have one of the following certifications:

1. A certified erosion, sediment and storm water inspector registered through Enviro Cert International, Inc.; or
2. Certified inspector of sediment and erosion control registered through Certified Inspector of Sediment and Erosion Control, Inc. Effective two years after the adoption date of this General Permit, a QSP shall have attended a State Water Board-sponsored or approved QSP training course.

In addition to the above requirement, the QSP shall have successfully completed the QSP training required under SWRCB Order No 2009-0009-DWQ. Upon successful completion of the required training, documentation shall be submitted to the Authority and included in the SWPPP.

The QSP shall have the authority and responsibility to fully implement the Authority certified SWPPP in accordance with the Contract Documents and shall be present full time on the project site during construction activity.

PART 5 - PENALTIES

5.01 GENERAL

A. The Contractor shall be responsible for compliance with all aspects of the SWPPP and the NPDES General Construction Permit. The Contractor shall be responsible for the costs and for the liabilities imposed by law as a result of the Contractor’s failure to comply with these provisions. Any penalties levied on the Authority for non-compliance shall be backcharged to the responsible Contractor. Costs and liabilities include, but are not limited to fines, penalties and damages whether assessed against the Authority or Contractor, including those levied under the Federal Clean Water Act and the State Porter Cologne Water Quality Act. In addition, the Authority will deduct, from any monies due to the Contractor, the total amount of any legal fees, staff cost, and consultant fees incurred as a result of the Contractor’s non-compliance with these provisions.

5.02 PENALTIES FOR FALSIFICATION OF REPORTS

A. Section 309(c) (4) of the CWA states that any person who knowingly makes any false material statement, representation, or certification in any record or other document submitted or required to be maintained under this General Permit, including reports of compliance or noncompliance shall upon conviction, be punished by a fine of not more than $10,000 or by imprisonment for not more than two years or by both.

5.03 PENALTIES FOR VIOLATIONS OF PERMIT CONDITIONS

A. Section 309 of the CWA states significant penalties for any person who violates a permit condition implementing Sections 301, 302, 306, 307, 308, 318, or 405 of the CWA or any permit condition or limitation implementing any such section in a permit.
issued under Section 402. Any person who violates any permit condition of this General Permit is subject to a civil penalty not to exceed $10,000 per calendar day of such violation, as well as any other appropriate sanction provided by Section 309 of the CWA.

END OF SECTION
PART 1 - GENERAL

1.01 WORK INCLUDED

A. Equipment items as listed below by Equipment Identifier:
   1. 1860 Workbench, severe use, 6 feet (Ref. Part 2.01)
   2. 1905 Table, steel top, rolling (Ref. Part 2.02)

B. Installation of equipment with labor, services, and incidentals necessary for complete and operational equipment installation.

1.02 QUALITY ASSURANCE

A. Equipment shall be manufactured by a manufacturer of established reputation with a minimum of five years experience performing similar fabrication techniques.

1.03 SUBMITTALS

A. Shop Drawings shall be submitted in accordance with Division 1 - General Requirements of these specifications.

1.04 PRODUCT SUBSTITIONS

A. Follow requirements specified in Division 1 - General Requirements.

B. Additional costs resulting from substitution of products other than those specified, by model number, including drawing changes and construction, will be at the expense of the Contractor.

C. Substitution Approval: Prior to delivery or installation, submittals for each equipment item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by Authority and Architect.

1.05 WARRANTY

A. Warrant work specified herein for one year from substantial completion against defects in materials, functions, and workmanship.

B. Warranty shall include materials and labor necessary to correct defects.

C. Defects shall include, but not be limited to noisy, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer’s recommended preventive maintenance schedule.

D. Submit warranties in accordance with Division 1 - General Requirements of these specifications.
1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver equipment in manufacturer’s containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.

B. Indelibly label all containers, including those contained in others, on outside with item description(s) per title and Equipment Identifier of this specification.

C. Provide equipment and material specified complete in one shipment for each equipment item. Split or partial shipments are not permissible.

PART 2 - PRODUCTS

2.01 WORKBENCH, SEVERE USE, 6 FEET

Equipment Identifier: 1860

A. Manufacturer’s Reference: Fabricated item as shown on Equipment detail 4/EQ-500.

B. Capacities/Dimensions:

1. Load capacity: 2,500 pounds
2. Work surface thickness: 3/8 inch
3. Overall dimensions:
   a. Length: 72 inches
   b. Depth: 32 inches
   c. Height: 34 inches

C. Features/Performance/Construction:

1. Legs: Workbench legs shall be fabricated of 3 inches by 3 inches by 3/16 inch steel tube.
2. Leg braces: Leg braces shall be 3 inches by 1/4 inch steel plate continuously welded to tubing.
3. Top braces: Top braces shall be 3 inches by 3 inches by 1/4 inch steel angle with continuous electrical welds to tubing.
4. Top: Top shall be 3/8 inch steel plate with 50 percent minimum electrical welds to top braces. Corners of top shall have a 2 inch radius for protection of personnel. All edges shall be ground smooth.
5. Skid plate: Skid plate shall be 4 inches by 4 inches by 1/4 inch steel plate with continuous welds to tubing.

D. Finish: Cover all exposed steel surfaces including both sides of top, braces, and legs with one coat of zinc chromate primer and two coats of epoxy per manufacturer’s recommendations in Authority’s choice of color.

2.02 TABLE, STEEL TOP, ROLLING

Equipment Identifier: 1905
A. Manufacturer’s Reference: Fabricated item as shown on Equipment detail 3/EQ-500

B. Capacities/Dimensions:
   1. Load capacity: 2,500 pounds
   2. Work surface thickness: 3/8 inch
   3. Overall dimensions:
      a. Length: 72 inches
      b. Depth: 32 inches
      c. Height: 33 inches

C. Features/Performance/Construction:
   1. Legs: Workbench legs shall be fabricated of 3 inches by 3 inches by 3/16 inch steel tube.
   2. Leg braces: Leg braces shall be 3 inches by 1/4 inch steel plate continuously welded to tubing.
   3. Casters: Four inch phenolic locking casters shall be mounted to the bottom of each leg.
   4. Top braces: Top braces shall be 3 inches by 3 inches by 1/4 inch steel angle with continuous electrical welds to tubing.
   5. Top: Top shall be 3/8 inch steel plate with 50 percent minimum electrical welds to top braces. Corners of top shall have a 2 inch radius for protection of personnel. All edges shall be ground smooth.

D. Finish: Cover all exposed steel surfaces including both sides of top, braces, and legs with one coat of zinc chromate primer and two coats of epoxy per manufacturer’s recommendations in Authority’s choice of color.

PART 3 - EXECUTION

3.01 INSPECTION
   A. Coordinate location of rough-in work and utility stub-outs to assure match with equipment to be installed.
   B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare delivered equipment with packing lists and specifications to assure receipt of all equipment items and specified accessories.

3.02 INSTALLATION
   A. Perform work under direct supervision of Foreman of Construction Superintendent with authority to coordinate installation of scheduled equipment with Architect.
   B. Install equipment in accordance with plans, shop drawings, and manufacturer’s instructions:
1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.

2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, professional manner without damaging equipment or adjacent work.

3. Anchorage: Attach equipment as directed by Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.

   C. Upon completion of work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.03 TESTING

   A. After final connections are made and prior to authorizing payment, specified equipment shall be tested for compliance with specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.04 CLEANUP

   A. Touch-up damage to painted finishes.

   B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.

   C. Clean area around equipment installation and remove packing and installation debris from job site.

   D. Notify Architect or designated representative for acceptance inspection.

   END OF SECTION 45 39 00