

**ATTACHMENT 3**

**TECHNICAL SPECIFICATIONS**

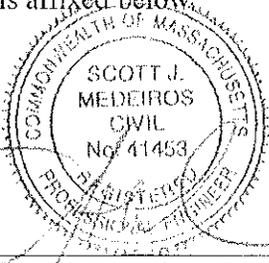
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Pine Hills Communication Tower & Compound  
Plymouth, MA  
Town of Plymouth, MA  
Invitation for Bid 21536-Communication Tower  
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SECTION 00 01 07

SEALS PAGE

The engineering material and data contained in these Contract Documents were prepared under the supervision and direction of the undersigned, whose seal as a registered professional engineer is affixed below.



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Scott J. Medeiros, P.E.  
Associate Principal  
Woodard and Curran, Inc.(Engineer)

July 24, 2015  
Date of Issue

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## SECTION 26 05 00

### COMMON WORK RESULTS FOR ELECTRICAL

#### PART 1 - GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide the labor, tools, equipment, and materials necessary to furnish, install and test all electrical Work in accordance with the Drawings and as specified herein.
- B. Provide the services of the local Data Utility and Electrical Utility companies to provide electrical services and related appurtenances as shown on the Drawings.
- C. In general, electrical Work shall include but not be limited to the following:
  - 1. Power distribution equipment
  - 2. Equipment connections
  - 3. Complete grounding system
  - 4. Standby Generator
  - 5. Service Entrance work
  - 6. Lightning Protection System
  - 7. All support material and hardware for raceway and electrical equipment.
  - 8. Designated branch circuit wiring
  - 9. Underground electrical construction
  - 10. Building wall, floor and roof penetrations for raceways.
  - 11. Start up, acceptance testing test reports and instruction of systems operation to the Owner.
  - 12. Install and wire all electrical equipment and devices for the following items furnished by Owner with the equipment shelter.
    - a. Main Circuit Breaker (MCB)
    - b. 120/240V, 200A Panelboard (MDP)

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**1.02 REQUIREMENTS OF REGULATORY AGENCIES**

**A. Codes and Standards**

1. Electrical equipment, materials, installation and workmanship shall comply with all state and local building codes, safety and fire law regulations at the location of the Work and shall conform to the latest edition of the applicable codes and standards of the organizations listed:
  - a. National Electrical Code (NEC)
  - b. Massachusetts Electrical Code (Amendments)
  - c. Underwriters' Laboratories (UL)
  - d. Institute Of Electrical And Electronics Engineers (IEEE C2)
  - e. American National Standards Institute, INC. (ANSI)
  - f. National Fire Protection Association (NFPA)
  - g. National Electrical Manufacturers Association (NEMA)
  - h. Insulated Power Cable Engineers Association (IPCEA)
  - i. Association of Edison Illuminating Companies (AEIC)
  - j. Occupational Safety Health Act (OSHA).
  - k. Americans with Disabilities Act (ADA).
2. Where the Contract requires the Work or any part of the same, to be above the standards required by applicable laws, ordinances, rules and regulations and other statutory provisions pertaining to the Work, such Work shall be performed and completed in accordance with the Contract requirements.
3. Should any changes in the specifications and Drawings be necessary to conform to the requirements of any of the above mentioned codes or standards, the Contractor shall so notify the Engineer.

**B. Drawings required by governing authorities:** Prepare any detailed diagrams or Drawings which may be required by the governing authorities.

**C. Permits, Certificates, Inspections, Fees and Utility Costs**

1. The Contractor shall obtain and make payments for all permits, licenses, and certificates which are required for the associated Work.
2. Following completion of the Work, the Contractor shall obtain certificates of approval from the responsible agencies concerned with the Work.
3. Arrange for timely inspections required for Work under this section.

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4. All utility company and municipal back charges shall be the responsibility of the Contractor. Cost of electricity shall be borne by the Contractor until substantial completion as determined by the Owner.

**1.03 COORDINATION OF WORK**

- A. The electrical work shall be coordinated with the work of other trades to prevent interferences and so that the progress in construction of the building will in no way be retarded.
- B. Refer to other sections of these specifications and Drawings for related work which may affect the work of this section.
- C. Coordinate with all local utility companies and make all installations for their services in accordance with all utility company requirements.
- D. Where lighting fixtures and other electrical items are shown in conflict with locations of structural members and mechanical or other equipment, furnish and install all required supports and wiring to clear the encroachment for a complete installation.
- E. Any Work installed contrary to or without acceptance by the Engineer shall be subject to change as directed by the Engineer, and no extra compensation will be allowed to the Contractor for making these changes.

**1.04 DRAWINGS**

- A. All electrical equipment such as junction and pull boxes, panelboards, switches, controls and such other apparatus as may require maintenance and operation from time to time shall be made easily accessible and properly labeled.
- B. The Contractor shall examine all contracts and reference Drawings, and verify and properly coordinate the placement of outlets. Contractor shall also check all Drawings including mechanical Drawings and shop drawings for apparatus for which he must rough-in and to which he must connect.

**1.05 SUBMITTALS**

- A. Provide in accordance with Division 01 General Requirements.
- B. Furnish manufacturer's product data, test reports, and materials certifications as required.

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- C. Shop Drawings shall identify the specific equipment and material being supplied; the quantity being supplied; and all accessories, dimensions, descriptions, mounting and connection details, wiring diagrams, elementary control diagrams, equipment interface diagrams and any other information necessary to determine compliance with the plans and specifications. Fabrication and installation shall be in accordance with the approved Shop Drawings.
- D. As-built copies of all Shop Drawings shall be submitted to the Engineer.
- E. Permits and Easements. Submit copies of reports, permits, and easements necessary for installation, use, and operation.
- F. Test Reports. Submit copies of reports of tests, inspections, and meter readings as specified.

**1.06 RECORD DRAWINGS**

- A. Provide in accordance with Division 01 General Requirements.

**1.07 JOB CONDITIONS**

- A. Existing Conditions
  - 1. Existing Utilities: Locate existing underground utilities in excavation areas. If utilities are indicated to remain, support and protect services during excavation operations.
  - 2. Prior to all Work of this section, carefully inspect the installed Work of all other trades and verify that all such Work is complete to the point where this installation may properly commence.
  - 3. Verify that the electrical installation may be made in complete accordance with all pertinent codes and regulations and the original design.
- B. Accuracy of Data
  - 1. The Drawings are diagrammatic and functional only, and are not intended to show exact circuit layouts, number of fittings, components and place in satisfactory operational power, lighting, and other electrical systems shown. Install additional circuits, components and material wherever needed to conform to the specific requirements of the equipment whether or not indicated or specified.
  - 2. Information and components called for in the specification but not shown on plans or vice versa shall apply and shall be provided as though required expressly by both.

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3. The locations of equipment, fixtures, outlets and similar devices shown on the Drawings are approximate only. Field measurements shall take precedence over scaled dimensions from Drawings. Exact locations shall be as accepted by Engineer during construction. Obtain in the field all information relevant to the placing of electrical Work and, in case of any interference with other Work, proceed as directed by the Engineer and furnish all labor and materials necessary to complete the Work in an acceptable manner.
4. In case of difference between building codes, specifications, state laws, industry standards and the Contract Documents, the most stringent shall govern. Should the Contractor perform any Work that does not comply with the requirements of the applicable building codes, state laws, and industry standards, he shall bear all cost arising in correcting these deficiencies.
5. Verify size and ratings of motors and other electrically operated devices supplied by others.
6. Check with Engineer before installation of Work for outlets not specified as to location or for Work that interferes with other trades.

**1.08 FLASHING, CUTTING, FIREPROOFING AND WATERPROOFING**

- A. Flashing around all electrical items penetrating roof or exterior walls shall be the responsibility of the Contractor.
- B. All cutting of surfaces, including core drilling of walls and slabs, shall be done by the Contractor.
- C. Patching shall be done by the Contractor.
- D. The Contractor shall fireproof, waterproof and seal all openings in slabs and walls.

**1.09 PRODUCT DELIVERY, STORAGE, AND HANDLING**

- D. Protection. Use all means necessary to protect electrical system materials before, during and after installation and to protect the installed Work and materials of all other trades.
- B. Replacements. In the event of damage, immediately make all repairs and replacements necessary to the acceptance of the Engineer and at no additional cost to the Owner. If any apparatus has been subject to possible injury by water, it shall be thoroughly dried out and put through such special tests as directed by the Engineer, at the cost and expense of the Contractor, or shall be replaced by the Contractor at his own expense.
- C. Protect the Work of other trades. Restore any damage caused to other trades to the condition existing prior to damage at no additional cost to the Owner.

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- D. Investigate each space in the building through which equipment must pass to reach its final location. If necessary, the manufacture shall be required to ship his material in sections sized to permit passing through such restricted areas in the building.

**1.10 WORK PERFORMANCE**

- A. Electrical work shall be accomplished with all affected circuits or equipment de-energized. When an electrical outage cannot be accomplished in this manner for the required work, the following requirements are mandatory:
  - 1. Electricians must use full protective equipment (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools, etc.) while working on energized systems in accordance with NFPA 70E.
  - 2. Electricians must wear personal protective equipment while working on energized systems in accordance with NFPA 70E.
  - 3. Before initiating any work, a job specific work plan must be developed by the Contractor and the Owner. The work plan must include procedures to be used on and near the live electrical equipment, barriers to be installed, and safety equipment to be used and exit pathways.
  - 4. Work on energized circuits or equipment cannot begin until prior written approval is obtained from the Owner.

**1.11 SPECIAL WARRANTY**

- A. Compile and assemble the warranties specified in Division 26 into a separate set of vinyl covered three ring binders, tabulated and indexed for easy reference.
- B. Provide complete warranty information for each item. Information to include:
  - 1. Product or equipment list
  - 2. Date of beginning of warranty or bond
  - 3. Duration of warranty or bond
  - 4. Names, addresses, and telephone numbers and procedures for filing a claim and obtaining warranty services.

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**1.12 DEFINITIONS**

- A. Finished Areas. In general, areas with carpet or tile floors, lay-in or fixed ceiling tile, special architectural ceiling treatment, or tiled, plastered, or paneled walls shall be considered finished areas.
- B. Interior. For the purposes of this specification, interior is any area within the boundaries of the foundation of any building within the superstructure or other structures not classified as a building.

**1.13 TEMPORARY POWER**

- A. The Contractor shall furnish, install, maintain, and remove the temporary electrical power and lighting systems, including lamps, and pay for all labor, materials, and equipment required therefore. All such temporary electrical Work shall meet the requirements of the National Electrical Code, the local utility company, and OSHA.
- B. The Contractor shall make all necessary arrangements with the local utility company as to where the temporary electric service can be obtained.
- C. The Contractor shall secure and pay for all required permits and back charges for Work performed by others, and other expenses incidental to the installation of the temporary electric service.

**1.14 POSTED OPERATING INSTRUCTIONS**

- A. Provide for each system and principal item of equipment as specified in the technical sections for use by operation and maintenance personnel. The operating instructions shall include the following:
  - 1. Wiring diagrams, control diagrams, and control sequence for each principal system and item of equipment.
  - 2. Start up, proper adjustment, operating, lubrication, and shutdown procedures.
  - 3. Safety precautions.
  - 4. The procedure in the event of equipment failure.
  - 5. Other items of instruction as recommended by the manufacturer of each system or item of equipment.
- B. Print or engrave operating instructions and frame under glass or in approved laminated plastic. Post instructions where directed. For operating instructions exposed to the weather, provide weather-resistant materials or weatherproof enclosures. Operating instructions shall not fade when exposed to sunlight and shall be secured to prevent easy removal or peeling.

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**1.15 MANUFACTURER'S NAMEPLATE**

- A. Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

**1.16 FIELD FABRICATED NAMEPLATES**

- A. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified in the technical sections or as indicated on the Drawings. Each nameplate inscription shall identify the name of the equipment, function and, when applicable, the position. Nameplates shall be melamine plastic, 0.125 inch thick, black with white letters. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be one by 2.5 inches. Lettering shall be a minimum of 0.25 inch high normal block style. All electrical equipment shall be labeled with the following:

1. Panel Name
2. Fed from "Panel Name" & "CKT #"
3. Amps
4. Volts
5. Phase

**1.17 ARC FLASH LABEL**

- A. Provide arc flash labels for all electrical equipment with operating voltages greater than 50 volt per NEC 110.16.

**1.18 WARNING SIGNS**

- A. Exterior warning and caution signs shall be weather resistant, nonfading, preprinted cellulose acetate butyrate signs with 20 gauge, galvanized steel backing, with colors, legend, and size appropriate to the location.
- B. Interior warning and caution signs shall be aluminum signs with preprinted baked enamel finish and punched for fasteners. Colors, legend, and size appropriate to location.

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**1.19 WIRE AND CABLE MARKERS**

- A. Underground line marking tape shall be permanent, bright colored, continuous printed, metal backed, plastic tape compounded for direct burial service not less than 6 inches wide. Printed legend indicative of general type of underground line below.
- B. Wire labels for wires smaller than No. 4, shall be vinyl or vinyl cloth, self-adhesive, wraparound, wire markers with preprinted numbers and letters. Wire sizes No. 4 and larger and multi conductor cables shall be marked with one-piece, nylon locking marker ties equal to Panduit PLM Series.

**PART 2 - PRODUCTS**

**2.01 MATERIALS**

- A. Materials and equipment shall be listed by UL unless it can be demonstrated that no UL standards exist for a specific item or class of equipment.
- B. All other materials, not specifically described but required for a complete and operable electrical installation, shall be new, first quality of their respective kinds, specification grade or better, and as selected by the Contractor subject to the acceptance by the Engineer.
- C. All materials and equipment furnished and installed on this project shall meet the most stringent efficiency standards of the local utility to qualify for the maximum rebate.

**2.02 MATERIAL AND CONSTRUCTION REQUIREMENTS**

- A. Unless otherwise shown or specified, all enclosures, motors, wiring and other materials and all construction methods shall conform to the following:
  - 1. Indoor, Above Ground, Dry Areas - NEMA 12, General Purpose, with gasketing for applications where atmospheric conditions are normal. Enclosures shall be sheet steel, treated to resist corrosion, prime painted and finished with a gray baked-on enamel. Control stations shall have NEMA 13, oil tight and dust-tight enclosures.
  - 2. Outdoors, Moist Areas and Indoor Below Grade Areas - NEMA 4, watertight. Enclosures shall be cast aluminum or stainless steel. Where indicated on electrical plans provide NEMA 4X enclosures of stainless steel or reinforced non-metallic (Krydon) construction. All installations shall utilize only stainless steel fasteners/hardware.
  - 3. Indoor-Outdoor, Subject to Submersion in Liquid - NEMA 6, submersible, liquid tight construction. Enclosures shall be cast aluminum.

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4. Hazardous Areas - NEMA 7 & 9, explosion-proof construction for Class 1, Division 1, Group D areas. Enclosures shall be cast aluminum.
5. Corrosive Atmospheres - All Work located in corrosive atmospheres, such as atmospheres in the filter area and the chemical feed pump areas shall be of such construction that the corrosive agent cannot enter into and damage the electrical Work. All materials in these areas shall be non-corrodible or finished with an inert coating. Stainless steel, or reinforced PVC electrical enclosures and PVC coated rigid conduit and fittings are required. In addition, provide gas tight seals in all conduits passing from or into corrosive areas (similar to Crouse Hinds Type EYS), to minimize migration of corrosive fumes to other building areas.

**2.03 INTERCHANGEABILITY**

- A. In all design and purchasing, interchangeability of items of equipment, subassemblies, parts, motors, starters, relays and other items is essential. All similar items shall be of the same manufacturer, type, model and dimensions.
- B. For ease of maintenance and parts replacement, to the maximum extent possible, use equipment of a single manufacturer.
- C. The Engineer reserves the right to reject any submittal which contains equipment from various manufacturers if suitable materials can be secured from fewer manufacturers and to require that source of materials be unified to the maximum extent possible.

**PART 3 - EXECUTION**

**3.01 COORDINATION**

- A. Prior to all Work of this section, carefully inspect the installed Work of all other trades and verify that all such Work is complete to the point where this installation may properly commence.
- B. Field verify all locations and dimensions to ensure that the equipment will be properly located, readily accessible, and installed in accordance with all pertinent codes and regulations, the Contract Documents, and the referenced standards.
- C. The Work shall be carefully laid out in advance, and where cutting, drilling, etc., of floors, walls, ceilings, or other surfaces is necessary for the proper installation, this Work shall be carefully done, and any damage to building, piping, or equipment shall be repaired by skilled mechanics of the trades involved at no additional cost to the Owner.
- D. In the event any discrepancies are discovered, immediately notify Engineer in writing. Do not proceed with installation in areas of discrepancy until all such discrepancies have been fully resolved.

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**3.02 INSTALLATION**

- A. Install all equipment and fixtures in complete accordance with the manufacturer's recommendations and all pertinent codes and regulations.
- B. Thoroughly inspect all items of equipment and any items dented, scratched, or otherwise damaged in any manner shall be replaced or repaired and painted to match original finish. All items so repaired and refinished shall be brought to the attention of the Engineer for inspection and acceptance.
- C. Coordinate the installation of required supporting devices and sleeves to be set in poured-in-place concrete or supported from or on other structural components, as they are constructed.
- D. Sequence, coordinate, and integrate installations of electrical materials and equipment for efficient flow of the Work. Give particular attention to large equipment requiring positioning prior to closing in the building and equipment which must be placed in service before further construction can take place.
- E. Where mounting heights are not detailed or dimensioned, install systems, materials, and equipment to provide the maximum headroom possible.
- F. The final routing of raceways shall be determined by structural conditions, interferences with other trades and by terminal locations on apparatus. The Engineer reserves the right of a reasonable amount of shifting at no extra cost up until time of roughing in the Work.
- G. Where circuits are shown as "home-runs" all necessary fittings and boxes shall be provided for a complete raceway installation.
- H. In general, wiring and raceway systems for security alarm, fire alarm, telephone and intercommunications systems are not indicated on the Drawings but shall be furnished and installed under this section.
- I. Each lighting and each receptacle circuit shall have its own neutral, dedicated to that circuit. A common neutral for more than one signal phase circuit is not allowed.
- J. Surface mounted panel boxed, junction boxes, conduits, etc., shall be supported by spacers to provide a clearance between wall and equipment.
- K. Upon completion of all installation, lamping, and testing, thoroughly inspect all exposed portions of the electrical installation and completely remove all exposed labels, soils, markings and foreign material.

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**3.03 MARKING AND LABELING**

- A. All panelboards, indoor transformers, cabinets, control panels and other specified equipment shall be labeled with engraved laminated plastic plates with engraved letters. Punch tapes with mastic backings are not acceptable.
- B. All starters, disconnect switches and other specified equipment shall be marked with engraved laminated plastic plates and engraved letters. Where individual switches are circuit breakers in power or distribution panelboards do not have cardholders, they shall be marked with ½" high labels.
- C. All empty conduits shall have labels tied to the pull string at each end of each empty conduit, marked as to identification of each end. Junction boxes with circuits provided for future use shall be labeled with appropriate circuit designation.
- D. All panelboards directories shall be filled out with typewritten identification of each circuit.

**3.04 WIRE AND CABLE MARKERS**

- A. Tag control circuit conductors at both ends and at junction box splices using wire and cable markers with identification numbers as designated on equipment wiring diagrams. Provide typed listing to identify conductors by number and use.
- B. Identify spare conductors, individually, at both ends and at junction box splices with number between 1 and 999. Do not duplicate numbers.
- C. Identify wire numbers on terminal block marking strips.
- D. Provide permanent plastic name tag indicating load for each feeder for all junction boxes, handholes and manholes. Label all process motor wires to yard equipment in handholes and manholes.

**3.05 TESTS & SETTINGS**

- A. Provide the services of an independent Testing Agency to perform the specified tests for the following systems:
  - 1. Ground resistance. The Testing Company shall perform all testing in accordance with National Electrical Testing Association (NETA) standards and procedures. All testing results shall be submitted on NETA forms and the testing data shall be certified by the respective Agency. Test results shall indicate recommended action for a sub-par test results. Results shall list recommended test values that should be obtained for new installation.
- B. Provide necessary material, equipment, labor and technical supervision to perform and complete the Electrical Acceptance Tests as required.

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- C. Acceptance tests as herein specified are defined as those tests and inspections required to determine that the equipment involved is acceptable as delivered to the job Site, that the equipment may be energized for final operational tests and is in accordance with the Specifications.
- D. Final acceptance of the equipment and/or workmanship will depend upon performance characteristics as determined by the subject tests, in addition to complete operation tests, on all electrical equipment to show that it will perform the functions for which it was designed.
- E. If the test and inspection data submitted should indicate deficiencies in the operation of the electrical apparatus or in the manufacturer thereof, the Contractor shall promptly implement the necessary adjustments, corrections, modifications and/or replacements necessary to be made to meet the specified requirements.
- F. Upon completion of the remedial Work, the Testing Agency shall repeat all of the tests on components previously found deficient on the first test or any additional test if they be required. It shall be the responsibility and obligation of the Contractor to have all remedial Work accomplished as may be required by second and/or additional tests.

**3.06 CLEANING**

- A. When all Work is completed and has been tested and accepted by Engineer and Owner, clean all light fixtures, equipment, and exposed surfaces that have been directly affected by this Work.

**END OF SECTION**

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## SECTION 26 05 19

### LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

#### PART 1 – GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide the labor, tools, equipment, and materials necessary to install wires, cables, and connectors for power, lighting, signal, control, communications and related systems rated 600 volts and less.

##### 1.02 RELATED DOCUMENTS

- A. Related Sections
  - 1. Section 26 05 00 Common Work Results For Electrical

##### 1.03 REFERENCE STANDARDS

- A. National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)
- B. Underwriter's Laboratories, INC. (UL) Compliance
  - 1. UL Standard 83 Thermoplastic Insulated Wires and Cables
  - 2. UL Standard 486A Wire Connectors and Soldering Lugs for Use with Copper Conductors
  - 3. UL Standard 854 Service Entrance Cable
- C. National Electrical Manufacturers Association (NEMA) Compliance
  - 1. WC-5 Thermoplastic Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
  - 2. WC-7 Cross Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
  - 3. WC-8 Ethylene Propylene Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- D. Institute Of Electrical And Electronic Engineers (IEEE) Compliance
  - 1. Standard 82 Test Procedure for Impulse Voltage Tests on Insulated Conductors

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**1.04 SUBMITTALS**

- A. Submit the following in accordance with Division 01 General Requirements.
- B. Manufacturer's product data, test reports, and materials certifications as required.
  - 1. Product data for electrical wires, cables, and connectors.
  - 2. Product data for Megger insulation testing instrument.
  - 3. Report sheets for Megger testing.

**1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Deliver wire and cable properly packaged in factory fabricated type containers, or wound on NEMA specified type wire and cable reels.
- B. Store wire and cable in clean dry space in original containers. Protect products from weather, damaging fumes, construction debris, and traffic.

**PART 2 - PRODUCTS**

**2.01 MATERIALS**

- A. General
  - 1. Provide factory-fabricated wires of sizes, ampacity ratings, and materials for applications and services indicated. Where not indicated, provide proper wire selection as determined by Installer to comply with project's installation requirements, NEC and NEMA standards. Select from the following UL types those wires with construction features which fulfill project requirements:
  - 2. Provide color-coding for phase identification as specified herein.
  - 3. Provide factory applied nylon or polyvinyl chloride (PVC) external jackets on wires and cables for pulls in raceways over 100 feet in length, for pulls in raceways with more than three equivalent 90 degree bends, for pulls in conduits underground or under slabs on grade, and where indicated.
- B. Service & Distribution Wiring
  - 1. 98 percent conductivity copper
  - 2. 600 volt insulation, type XHHW
  - 3. U.L. listed for underground use in wet locations at 75 degrees C.

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4. Use XHHW for #4 and larger and THHN/THWN or XHHW for #6 and smaller.

C. Building Wiring

1. 98 percent conductivity copper
2. 600 volt insulation, type, THWN/THHN, or XHHW
3. Stranded conductor: #14 AWG and larger
4. Minimum branch circuit: #12 AWG
5. Minimum #10 AWG for 120 volt circuits more than 100 feet long.
6. Minimum #10 AWG for 277 volt circuits more than 230 feet long.

D. Control Wiring

1. Control wiring for digital/discrete signal wiring, shall be 600V, minimum #14AWG, THHN/THWN, copper stranded, unless specifically indicated otherwise.
2. Instrument cable for analog signal wiring (4-20mA DC) shall be shielded, 2-conductor, 300 volt rated, minimum #18 AWG, Belden No. 8760, Alpha Wire, or approved equal. Provide 600 volt rated cable where cable occupies the same enclosure and/or raceway with voltages greater than 300 volt as specified below.
3. Single Shielded Pair Instrument Cable
  - a. Tinned copper, XLPE insulated stranded conductors, No. 18 AWG minimum, twisted pair with overall shield, stranded tinned No. 18 AWG copper drain wire and overall PVC jacket. Rated for 600 volts minimum and conforming to UL 1581. Cables shall be rated for tray cable "TC" use where installed within a cable tray.
4. Multi-paired Shielded Instrument Cable
  - a. Tinned copper, XLPE insulated stranded conductors, No. 16 AWG minimum, twisted pairs with shield over each pair, stranded tinned No. 18 AWG copper drain wire, and overall PVC outer jacket. Rated for 600 volts minimum and conforming to UL 1581 or UL 13. Cables shall be rated for tray cable "TC" use where installed within a cable tray.

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E. VFD Cable

1. VFD load-side power cable shall be shielded type specifically listed for use with Variable Frequency Drives.
2. VFD cable shall be UL listed with 600V black XLPE insulation.
3. Cable shall be equipped with 100% foil shield.
4. Cables shall be stranded type with number and sizes of conductors as indicated on the Drawings.
5. Cable shall be equal to Belden Series 295XX, Alpha Wire or approved equal.

F. Splices

1. #10 AWG and smaller with 600-volt pressure type insulated connector of wire-nut type, or equal; soldered and crimped type not allowed. Ideal type "wire nut" Buchanan type "B-Cap" and Minnesota Mining (3M) type "Scotchlok".
2. #8 AWG and larger with solderless lugs or solderless connectors of Lock-tite or similar type properly taped with plastic insulating tape, Minnesota Mining (3M) #33, or equal, then two half-lap servings of friction tape, Manson, or equal.
3. Wire connector systems for use with underground conductors shall be UL listed specifically for such use.
4. Service entrance conductors shall be installed without splices. Electrical equipment feeders shall be spliced only where shown or specifically approved. Control and metering conductors shall be installed without splices.
5. All splices shall be made only by specific permission of the Engineer and then only in manholes or pull boxes and shall be sealed watertight with a heat-shrunk insulation.
6. Tighten electrical connectors and terminals in accordance with manufacturer's published torque tightening values. Where manufacturer's torquing requirements are not indicated, tighten connectors and terminals to comply with tightening torques specified in UL Standards 486A and 486B.
7. Use UL listed splice for all underground wires, ducts buried, in conduit and in ducts. Connectors and splices shall be waterproof.

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**PART 3 – EXECUTION**

**3.01 WIRE AND CABLE INSTALLATION**

- A. All wire and cables shall be installed in conduit of size and type indicated on the drawing and specifications.
- B. Install electrical cables, wires, and connectors in compliance with NEC.
- C. Pull conductors simultaneously where more than one is being installed in same raceway. Use UL listed pulling compound or lubricant, where necessary.
- D. Use pulling means including, fish tape, cable, rope, and basket weave wire/cable grips which will not damage cables or raceways. Do not use rope hitches for pulling attachment to wire or cable.
- E. Conceal all cable in finished spaces.
- F. Install exposed cable parallel and perpendicular to surfaces or exposed structural members, and follow surface contours, where possible.
- G. Conductors shall be sized such that voltage drop does not exceed 3 percent for branch circuits or 5 percent for feeder/branch circuit combination.
- H. Provide adequate length of conductors within electrical enclosures and train the conductors to terminal points with no excess. Bundle multiple conductors, with conductors larger than #10 AWG cabled in individual circuits. Make terminations so there is no bare conductor at the terminal.
- I. All feeder and branch circuit wiring shall be color coded at all termination and splice locations. System neutrals shall be designated in addition to phase conductors. Equipment grounds shall be green.
- J. The number of conductors shown on the Drawings is not necessarily the correct number required. As many conductors as are required in each case shall be installed. In general, grounding conductors are not scheduled.
- K. In general, wiring for the following systems shall be installed in separate conduits. Do not mix categories in a single raceway.
  - 1. 120 volt power wiring.
  - 2. 120 volt control wiring, including, digital input and output signals.
  - 3. 24 volt DC control wiring, including, digital input and output signals.
  - 4. 24 volt DC analog control wiring (4-20mA).

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5. Communications wiring.
  6. Special & Emergency Systems
- L. Conductors 600 volts and below shall be color coded in accordance with the following:

CONDUCTOR	120/208 COLOR	480 / 277 COLOR
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	White / Gray
Equipment Grounds	Green	Green

**3.02 FIELD QUALITY CONTROL**

- A. Test each electrical circuit after permanent cables are in place with terminators installed, but before cable or wire is connected to equipment or devices to demonstrate that each circuit is free from improper grounds and short circuits.
- B. Megger Test, the insulation resistance between phases and from each phase to ground for each of the following feeder and motor branch circuits:
  1. Secondary Service Entrance
  2. Electrical Distribution Equipment (Main Circuit Breaker, Motor Control Center, Panelboards, etc.)
  3. Generator and Automatic Transfer Switch
  4. Transformers
- C. The Megger Testing shall be witnessed by the Engineer. The Engineer shall be notified at least 48 hours in advance of testing.
- D. Measure the insulation resistance with a digital "Megger" insulation testing instrument in accordance with manufacturer's recommendations. All test instruments are to be provided by the Contractor.
- E. If any insulation resistance measures less than 50 megohms, the cable shall be considered faulty with the cable failing the insulation test. In moist environments, bag the ends of the cable to prevent a faulty Megger test.

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- F. Any cable which fails the insulation tests or which fails when tested under full load conditions shall be replaced with new cable for the full length and retested at no additional cost to Owner.
- G. The below grade service or feeder splice shall be water immersion Megger tested in the presence of the Engineer. Each splice shall be immersed in a grounded water immersion bath for 24 continuous hours prior to and during the test. Criteria for failure shall be as described for cable above.

**END OF SECTION**

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## SECTION 26 05 26

### GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

#### PART 1 – GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide all labor, tools, equipment, materials and appurtenances necessary to furnish and install grounding materials in accordance with the Drawings and as specified herein. This section includes solid grounding of electrical systems and equipment.

##### 1.02 REFERENCES

- A. National Electrical Code (NEC), as applicable to electrical grounding and Bonding, Art. 250.
- B. Underwriters' Laboratories, INC. (UL)
  - 1. UL 467 Electrical Grounding and Bonding Equipment
- C. Institute Of Electrical And Electronic Engineers (IEEE) IEEE 81 AND 142
  - 1. 81-2012 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounded System (Part 1)
  - 2. 141-1993 IEEE Recommended Practice for Electric Power Distribution for Industrial Plants
  - 3. 142-2007 IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

##### 1.03 SUBMITTALS

- A. Submit in accordance with Division 01 General Requirements. All submittals shall have pertinent numerical data and information specified in the "English" language using "English" units.
- B. Product Data
  - 1. Provide product data for all grounding equipment and appurtenances, including but not limited to; wires, connectors, lugs, clamps, ground rods, bonding jumpers and accessories.

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**PART 2 – PRODUCTS**

**2.01 GENERAL**

- A. Provide each electrical grounding system with assembly of materials required for complete installation including wires/cables, connectors, lugs, clamps, ground rods, bonding jumpers and accessories.
- B. Provide electrical grounding conductors for grounding connections matched to power supply wiring materials and sized according to NEC.
- C. Provide electrical connectors, lugs, clamps, bonding jumpers and accessories as recommended by the respective manufacturer for the particular application, unless other indicated.
- D. Ground Rods: Solid copper clad, 3/4-inch diameter by 10 feet long.
- E. Insulated Conductors: Green in color.
- F. Ground Bus. Bare annealed copper bars of rectangular cross section, 1/4-inch x 3-inch x length as required, with 98 percent conductivity, rigidly attached to structure.
- G. Bonding Strap Conductor/Connectors: Soft copper, 0.05 inch thick and 2-inches wide, except as indicated.
- H. Pressure Connectors: High conductivity plated units.
- I. Bolted Clamps: Heavy-duty units listed for the application.
- J. Exothermic Welded Connections: Provided in kit form and selected for the specific types, sizes, and combinations of conductors and other items to be connected.

**PART 3 – EXECUTION**

**3.01 GROUNDING & BONDING**

- A. Ground main service entrance ground bus or lug to neutral of incoming service, to enclosure, to building steel, to ground rods/grounding ring and to rebar in concrete footing. Install grounding bushings or service conduits. Use exothermic style ground connections to the ground rods and building steel. Bond building ground ring to lightning protection system in accordance with NEC and as specified in Section 26 41 00 – Lightning Protection System.
- B. Use of conduit system for ground conductor shall not be allowed.

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- C. Provide and install 600 volt insulated bonding conductors throughout the distribution system with connection to bonding (or grounding) terminal on each panel and panel board with connections to other equipment where specifically indicated and noted.
- D. Bonding conductors shall be continuous where possible. Where splices are required, provide compression connectors of approved pattern. Insulate connectors to equivalent thickness of conductors.
- E. Provide grounding system for grounded circuit conductors of dry type transformer secondaries in accordance with NEC. Use exothermic style ground connections to building steel. Enclose grounding conductors in schedule 80 PVC conduit.
- F. Provide equipment grounding conductors in all conduits containing power, control, or instrumentation conductors on the load side of the service equipment or on the load side of a separately derived system.
- G. Comply with NEC Article 250 for sizes and quantities of equipment grounding conductors, except that larger sizes indicated or shown on the Contract Documents shall take precedence. Use of metallic conduit systems for equipment grounding as recognized by the NEC shall not be permitted under this specification.
- H. Install grounding bushings on conduits at both primary and secondary entrances to transformers. Ground transformer enclosures to bushings.
- I. Install bonding jumper for flexible metal conduit unless fittings are approved for grounding or otherwise comply with NEC.
  - 1. Size jumper to match over-current device.
  - 2. Green insulation.
  - 3. Connect to grounding bushing at each end.
- J. Ensure that entire electrical system is electrically continuous and permanently and effectively grounded, including all electrical equipment and structures.
  - 1. Locate ground rods with a minimum of two rod length from each other and at least the same distance from any other grounding electrode. Connect ground conductors to ground rods by means of exothermic welds. Drive rods until tops are 24 inches below finished floor or final grade except as otherwise indicated.
- K. Route grounding electrode conductors along the shortest and straightest paths possible without obstructing access or placing conductors where they may be subjected to strain, impact, or damage, except as indicated.

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- L. Ensure that grounding electrode conductor connections to interior piping, structural members, and the like are accessible for periodic inspection during the life of the structure.

**3.02 BONDING FOR OTHER TRADES**

- A. Signal raceways, water piping, heating piping and metallic air ducts shall be bonded together and to the grounding conductor with No. 8 soft drawn bare solid conductors. Connections to pipes shall be made with cast clamps of like material as the pipes to which attached, to ducting terminated in a secure manner by best practical means, bonding across any flexible or insulated connections.
- B. All bonding conductors shall be installed in a neat manner properly shaped for contour of surface involved and properly supported. At locations remote from the main service entrance panel boards, bond to the largest raceway nearby.

**3.03 FIELD TESTING**

- A. Measure ground resistance without the soil being moistened by any means other than natural precipitation or natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance. Perform tests by the three-point fall of potential method in accordance with Section 9.03 of IEEE 81. Simple moisture addition is not acceptable.
  - 1. Ground/resistance maximum values shall be as follows:
    - a. Equipment rated 500 kva and less: 10 ohms.
    - b. Equipment rated 500 kVA to 1000 Kva: 5 ohms.
    - c. Equipment rated over 1000 kVA: 3 ohms.
    - d. Unfenced substations and pad mounted equipment: 5 ohms.
    - e. Fence Grounds: 10 ohms.
    - f. Structures or Towers: 10 ohms.
- B. Where ground resistances exceed specified values, and if directed, modify the grounding system to reduce resistance values.

**END OF SECTION**

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## SECTION 26 05 34

### RACEWAYS, BOXES AND SUPPORTING DEVICES

#### PART 1 - GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide the labor, tools, equipment, and materials necessary to furnish and install raceways, boxes and supporting devices in accordance with the Drawings and as specified herein.
- B. Products specified include:
  - 1. Conduit, Raceways & Fittings
  - 2. Supporting Devices
  - 3. Boxes and fittings

##### 1.02 RELATED DOCUMENTS

- A. Related Sections
  - 1. Section 26 05 00 Common Work Results For Electrical
  - 2. Section 26 05 19 Low-Voltage Electrical Power Conductors And Cables

##### 1.03 QUALITY ASSURANCE

- A. Reference Standards.
- B. Underwriter's Laboratories, INC. (UL) Listing And Labeling
  - 1. Items provided under this section shall be listed and labeled by UL.
- C. National Electrical Code (NEC)
- D. National Electrical Manufacturers Association (NEMA)

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**1.04 SUBMITTALS**

- A. Provide in accordance with Division 01 General Requirements.
- B. Furnish manufacturer's product data, test reports, and material certifications as required.
  - 1. Product data for cabinets and enclosures with classification higher than NEMA 1.
  - 2. Shop drawings for floor boxes and boxes, enclosures and cabinets that are to be shop fabricated (non-stock items).

**PART 2 - PRODUCTS**

**2.01 CONDUIT, RACEWAYS & FITTINGS**

- A. Provide conduit with 3/4-inch diameter minimum, except where specifically shown smaller on the Drawings.
- B. Conduit, connectors, and fittings shall be approved for the installation of electrical conductors.
- C. Refer to Table 3.01A for approved conduit installation guidelines.
  - 1. Electrical Metallic Tubing (EMT)
    - a. EMT shall be rigid metallic conduit of the thinwall type in straight lengths, elbows, or bends and must conform to NFMA C80.3 and the requirements of UL 797.
    - b. Couplings and connectors shall be steel compression fittings. Where EMT enters outlet boxes, cabinets, or other enclosures, connectors must be the insulated-throat type, with a locknut. Fittings must meet the requirements of NEMA FB 1.
  - 2. Rigid Galvanized Steel Conduit
    - a. Rigid steel conduit (RGS), including couplings, elbows, bends, and nipples, shall conform to the requirements of UL 6 and NEMA C80.1 Steel fittings shall be galvanized by the hot-dip process.
    - b. Fittings for rigid steel conduit shall be threaded and shall conform to NEMA FB 1.
    - c. Gaskets shall be solid for fittings sized 1-1/2 inches and less. Conduit fittings with blank covers shall have gaskets except in clean, dry areas or at the lowest point of a conduit run where drainage is required.

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- d. Covers shall have captive screws and be accessible after the Work has been completed.
3. Rigid Aluminum Conduit
    - a. RAC, including couplings, elbows, bends, and nipples, shall conform to the requirements of UL 6 and ANSI C80.5.
    - b. Fittings for rigid aluminum conduit shall be threaded and shall conform to NEMA FB 1. Fittings shall be galvanized by the hot dip process, unless manufacturer dictates aluminum for specific application.
    - c. Gaskets shall be solid for fittings sized 1-1/2 inches and less. Conduit fittings with blank covers shall have gaskets except in clean, dry areas or at the lowest point of a conduit run where drainage is required.
    - d. Covers shall have captive screws and be accessible after the work has been completed.
  4. PVC-Coated Rigid Metal Conduit
    - a. Rigid galvanized metal conduit coated with 40 mils thick polyvinylchloride coating.
    - b. Fittings, elbows, supporting devices and accessories shall include factory applied 20 mils thick polyvinylchloride coating and be manufactured by the same as that of the conduit.
    - c. Use tools as recommended by the manufacturer so as not to damage PVC coating. Where coating is damaged, touch-up with PVC paint in the field after installation.
  5. Rigid Plastic Conduit
    - a. PVC Schedule 40: Conduit shall be made of polyvinyl chloride compound that shall be homogeneous plastic material free from cracks, holes or foreign inclusions. Conduit shall be rated for use with 90 degree C conductors, UL Listed. Use solvent cement to join conduits as manufactured the same as the conduit manufacturer.
    - b. PVC Schedule 80: Heavy wall PVC conduit that shall be made of polyvinyl chloride compound that shall be homogeneous plastic material free from cracks, holes or foreign inclusions. Conduit shall be rated for use with 90 degree C conductors, UL Listed. Use solvent cement to join conduits as manufactured the same as the conduit manufacturer.
  6. Flexible Metallic Conduit
    - a. Flexible metallic (FM) conduit shall meet the requirements of UL1.

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- b. Liquidtight flexible metallic conduit shall be provided with a protective jacket of PVC extruded over a flexible interlocked galvanized steel core to protect wiring against moisture, oil, chemicals, and corrosive fumes.
  - c. Fittings for flexible metallic conduit shall meet the requirements of UL 514B, Type I box connector, electrical, Type III coupling, electrical conduit, flexible steel, or Type IV adapter, electrical conduit.
7. Wireways
- a. Wireways and auxiliary gutters for use in exposed, dry locations shall be a prefabricated channel-shaped sheet metal trough with hinged or removable covers, associated fittings, and supports for housing, and protecting electrical wires and cables in accordance with UL 870.
  - b. Straight sections of trough, elbows, tees, crosses, closing plates, connectors, and hanging brackets shall be constructed from sheet steel of commercial quality not less than 16-gage. Sheet metal component parts shall be cleaned, phosphatized, and coated with a corrosion-resistant gray paint.
  - c. Straight sections of wireways and auxiliary gutters shall be solid or have knockouts as indicated in both sides and bottom, 3 inches on center.
  - d. Straight sections shall be not more than 5-feet long, with covers held closed with screws.
8. Conduit Seals
- a. Provide factory fabricated watertight conduit sealing bushing assemblies suitable for sealing around conduit, or tubing passing through concrete floors and walls. Provide a cast in place water stop wall sleeve with a mechanical pipe seal between the conduit and the sleeve. Construct seals with steel sleeve, malleable iron body, neoprene sealing grommets or rings, metal pressure rings, pressure clamps, and cap screws.
  - b. Provide E.Y.S. seal fittings with appropriate potting material where conduits enter or leave a Class 1, Division 1 or 2 environments or a Class 2, Division 1 or 2 environment.

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**2.02 SUPPORTING DEVICES**

- A. Supports, support hardware, and fasteners shall be protected with zinc coating or with treatment of equivalent corrosion resistance using approved alternative treatment, finish, or inherent material characteristic. Products for use outdoors shall be hot dip galvanized unless material is inherently corrosion resistant.
  
- B. Refer to Table 2.02A for approved supporting device installation guidelines.
  - 1. Conduit Supports
    - a. Single run hangers: Galvanized steel conduit straps or clamps, or cast metal beam clamps. Perforated straps and spring steel clips and clamps will not be permitted.
    - b. Group run hangers: Minimum 12-gauge galvanized performed U-channel rack with conduit fittings; 25 percent spare capacity.
    - c. Hanger rods: Threaded steel, 3/8-inch diameter, or as identified on the Drawings.
    - d. Vertical run supports: Minimum 12-gauge galvanized performed U-channel struts with conduit fittings.
  - 2. Equipment and Lighting Supports
    - a. U-channel: 12-gauge galvanized performed U-channel struts with fixture and conduit fittings, as applicable, unless indicated otherwise on the Drawings.
  - 3. Corrosive Area Supports
    - a. Clamp Hangers, Pipe Straps, and Clamp Back Spacers for use with PVC-coated rigid metal conduit shall have 40mil gray PVC exterior coating.
    - b. Clamp Hangers, Pipe Straps, etc. for use with PVC nonmetallic conduit shall be of nonmetallic PVC material.
    - c. Hanger Rods: 20mil gray PVC exterior coated rod with threaded ends only 3/8" and 1/2" sizes as required.
    - d. Strut Support: 20mil gray PVC exterior coating strut. Standard channel, slotted channel, and back to back channel are acceptable.

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- e. Provide Stainless steel hangers, rods and supports in lieu of PVC coated when indicated in the Supporting Devices Table below.

**TABLE 2.02A – Supporting Devices**

<b>Location/Equipment</b>	<b>Acceptable Support Type</b>
Shelter Building	Galvanized Steel U-Channel
Exterior	Galvanized Steel U-Channel

**2.03 BOXES AND FITTINGS**

- A. Boxes must have sufficient volume to accommodate the number of conductors entering the box in accordance with the requirements of NFPA 70 and UL 514A.
- B. In general, boxes that are exposed to weather, process areas, normally wet locations, and locations exposed in mechanical spaces shall be cast-metal. Boxes in all other finished areas shall be sheet metal. Boxes installed in corrosive areas, such as the chemical feed room, shall be nonmetallic.
- C. Refer to Table 2.03A for approved enclosure types.
  - 1. Sheet Metal Outlet Boxes
    - a. Sheet Metal Outlet Boxes: Standard type galvanized steel, minimum four inch square or octagon by 1-1/2 inch deep.
    - b. Luminaire and Equipment Supporting boxes: Rated for weight of equipment supported; include 2 inch male fixture studs where required.
    - c. Single Wall Type: Minimum size, four inch square by 1-1/2 inch or 2-1/8 inch deep, except as noted. Provide dry wall device covers raised 3/4 inch minimum to insure flush finish mounting.
    - d. Ganged Wall Type: Minimum depth three inches except as noted, ganged as required under common plate to contain devices shown. On 277 volt circuits ganged boxes for switches shall contain only one circuit or equip box with permanent barriers per NEC Art 404-8.
  - 2. Cast Outlet Boxes
    - a. Type FS shallow and type FD deep, cast fer alloy.
    - b. Provide number of threaded hubs as required.
    - c. Use in all exterior, damp and locations exposed in mechanical spaces.

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- d. Provide gasketed cover and accessories by box manufacturer for complete weatherproofing. Provide correct box to accept weatherproof covers as specified.
3. Sheet Metal Pull & Junction Boxes
    - a. Sheet metal boxes shall be standard type galvanized steel and must conform to UL 50.
    - b. Box dimensions shall be minimum four inch square or octagon by 2/1/2 inch deep.
    - c. Sizes up to 12x12x6 inch: Provide screw-type or hinged covers.
    - d. Sizes greater than 12x12x6 inch: Provide hinged covers.
    - e. Boxes shall be sized to accommodate all incoming raceways.
  4. Nonmetallic Outlet, Device, and Wiring Boxes
    - a. Conform to NEMA OS 2, "Nonmetallic Outlet Boxes, Device Boxes, Covers, and box Supports," and UL 514C, "Nonmetallic Outlet Boxes, Flush Device Boxes and Covers." Boxes shall be molded polyvinyl chloride (PVC), or fiberglass units of type, shape, size, and depth to suit location and application.
    - b. Boxes shall be equipped with threaded screw holes for device and cover plate mounting. Each box shall have a molded cover of matching material suitable for the application and location installed.

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**TABLE 2.03A – Electrical Enclosure Types**

<b>Location/Equipment</b>	<b>Acceptable Enclosure Type</b>
Shelter Building	NEMA 1G
Exterior	NEMA 4X

### **PART 3 – EXECUTION**

#### **3.01 CONDUIT**

##### **A. Uses Permitted**

1. Use liquid tight flexible metal conduit for the final 24 inches of connections to motors or control items subject to movement or vibration.
2. Use RGS for all exterior aboveground installations unless otherwise noted.
3. Use PVC coated rigid steel conduit, or as scheduled below, for installation in corrosive areas, and other areas as identified on the Drawings.
4. Exposed raceways in Manufacturing Area's, Utility Rooms, Mechanical Rooms, Warehouse Area's, etc., shall be Rigid Galvanized Steel below 15 ft.
5. Conduit and raceway runs in finished areas concealed in or behind walls, above ceilings, or exposed on walls and ceilings 15 feet or more above finished floors and not subject to mechanical damage may be electrical metallic tubing (EMT).
6. Use Schedule 40 PVC conduit for exterior direct buried installations. Use Schedule 40 PVC conduit for exterior concrete encased installations. Use Schedule 80 PVC conduit for underground installations under driveways. The transition from underground and from concrete encasement to riser shall be PVC coated rigid steel conduit to a minimum of 12" above finished floor and/or finished grade elevation. All elbows shall be prefabricated Rigid Steel to prevent wire burn through. Reference specification 26 05 43 "Underground Ducts and Raceways for Electrical Systems" for further requirements.
7. Install conduit seals for conduit penetrations of slabs on grade and exterior walls below grade and where indicated. Tighten sleeve seal screws until sealing grommets have expanded to form watertight seal. Provide seals for the interior of conduits that penetrate exterior or water bearing walls, consisting of gland type sealing bushings or RTV closed cell silicone foam. Refer to Table 3.01A below for approved conduit types:

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**TABLE 3.01A – Conduit Types**

Location/Equipment	Approved Conduit Type
Shelter Building	Electrical Metallic Tubing
Exterior	Rigid Galvanized Steel

- B. Power, lighting, control, emergency light and power, and special-service systems and all related components shall be installed in accordance with NFPA 70, and shall be enclosed in separate conduit or separate conduit systems as indicated on the Drawings and as specified herein.
- C. Any run of conduit between outlet and outlet, between fitting and fitting, or between outlet and fitting shall contain not more than the equivalent of three 90-degree bends, including those bends located immediately at the outlet or fitting. Field bends shall be made in accordance with the manufacturer's recommendations, which normally require use of a one-size-larger bender than would be required for uncoated conduit. Installed conduit and fittings shall be free of dirt and trash and shall not be deformed or crushed. Empty conduit shall have a pull rope stalled.
- D. Conduit shall be installed with a minimum of 3 inches of free air space separation from mechanical piping.
- E. Conduit in finished areas shall be installed concealed. Conduit passing through masonry or concrete walls shall be installed in sleeves. Conduit shall be securely clamped and supported at least every 10 feet vertically and 8 feet horizontally. Galvanized pipe straps shall be fastened to structure with bolts, screws, and anchors. Wooden masonry plugs shall not be used.
- F. Install exposed conduits, parallel or perpendicular to walls, ceilings, or structural members. Do not run through structural members. Avoid horizontal runs within partitions or sidewalls. Avoid ceiling inserts, lights, or ventilation ducts or outlets. Do not run conduits across pipe shafts or ventilation duct openings and keep conduits a minimum of 6 inches from parallel runs of flues, hot water pipes, or other sources of heat. Wherever possible, install horizontal raceway runs above water and steam piping.
- G. Do not run conduits exposed on the exterior surface of buildings. Conduits penetrating exterior walls below grade, at grade floors, or below grade floors shall be sealed to prevent moisture migration. The exterior of the conduit shall be sealed with a mechanical pipe seal. The interior conduit seal shall be a gland type sealing bushing or RTV closed cell silicone foam. Ensure that conduits do not retain water against these seals.
- H. Raceways penetrating fire rated walls, floors, and partitions shall be sealed with a fire rated sealant.

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- I. All conduits shall be supported with materials specifically made for this purpose. Do not use wire hangers. Do not attach any parts of the raceway system to ventilation ducts. Conduit supports shall be attached to the building. Support conduits on each side of bends and on a spacing not to exceed the following: 6 feet for conduits smaller than 1 1/4 inches and 8 feet for conduits 1 1/4 inches and larger. Support riser conduits at each floor level with clamp hangers. All underground conduits shall be securely anchored to prevent movement during placement of concrete or backfill. Use precast separators and heavy gauge wire ties or other approved fasteners.
- J. Provide E.Y.S. seal fittings with appropriate potting material where conduits enter or leave a Class 1, Division 1 or 2 environments or a Class 2, Division 1 or 2 environment, and chemical rooms.
- K. Conduit connections to boxes and fittings shall be supported not more than 36 inches from the connection point. Conduit bends shall be supported not more than 36 inches from each change in direction. Conduit shall be installed in neat symmetrical lines parallel to the centerlines of the building construction and the building outline. Multiple runs shall be parallel and grouped whenever possible on common supports. Exposed ends of conduit without conductors shall be sealed with watertight caps or plugs.
- L. Bonding wires shall be used in flexible conduit for all circuits. Flexible conduit shall not be considered a ground conductor.
- M. Liquid tight flexible metallic conduits shall be used in wet and oily locations and to complete the connection to motor-driven equipment.
- N. Electrical connections to vibration-isolated equipment shall be made with flexible metallic conduit in a manner that will not impair the function of the equipment.
- O. A polypropylene pull rope with a tensile strength not less than 130 pounds shall be installed in empty conduit.
- P. Electrical conduit may be embedded in concrete according to the provisions of Article 6.3 of ACI 318 "Building Code Requirements for Reinforced Concrete", provided the following conditions are met:
  - 1. Outside diameter of conduit shall not exceed 1/3 of concrete thickness. Maximum conduit outside diameter shall not exceed 3 inches when embedded in slab.
  - 2. Conduit shall not be placed closer than three diameters on center. Route conduit to minimize crossing of different conduit runs.
  - 3. Conduit shall not be embedded in structural concrete slabs less than four inches thick.

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4. A 1 1/2 inch minimum concrete cover shall be provided for conduits in structural concrete slabs.

**Q. Installation of Underground Conduit**

1. Minimum of 3/4 inch conduit in or under concrete slab on grade.
2. Where conduits are installed in concrete slabs, on the ground, underground, or exposed to the weather, make all joints liquid tight and gas tight.
3. Bury all underground conduit, except under concrete slabs placed on fill, to a depth of at least 30 inches below finished grade unless otherwise indicated on the Drawings.
4. Slope ducts to drain away from buildings into manholes and/or handholes. Adjust final slopes to coordinate with existing site utilities.
5. Install on undisturbed soil where possible. Concrete encase conduits as shown on Drawings. Use pit run gravel and sand, placed 8 inch lifts and compacted for backfill.
6. Reference Specification 26 05 43 Underground Ducts and Raceways for Electrical Systems for further requirements.

**R. Installation of Rigid Metal Conduit**

1. Ends of conduit shall be cut square, reamed and threaded, and joints shall be brought butt-to-butt in the couplings. Joints shall be mechanically tight. Conduit shall be protected against damage and the entrance of water or foreign material during construction.
2. Ninety-degree bends of conduit with a diameter larger than 1 inch shall be made with factory-made elbows. Conduit elbows larger than 2 1/2 inches shall be long radius. Field-made bends and offsets shall be made with an approved hickey or conduit-bending machine. Changes in directions of runs shall be made with symmetrical bends or cast-metal fittings.
3. At connections to sheet metal enclosures and boxes, a sufficient number of threads shall project through to permit the bushing to be drawn tight against the end of the conduit, after which the locknut shall be pulled up sufficiently tight to draw the bushing into firm electrical contact with the box. Conduit shall be fastened to sheet metal boxes and cabinets with two locknuts where required by NFPA 70 where insulating bushings are used, where bushings cannot be brought into firm contact with the box, and where indicated.
4. Conduit joints shall be made with tapered threads set firmly. Each length of conduit cut in the field shall be reamed before installation. Where

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conduit is threaded in the field, each threaded end shall consist of at least five full threads. Corrosion-inhibitive compound (cold galvanizing paint) shall be used on all conduit threads or any locations where the original hot galvanized surface has been compromised.

5. Conduit stubbed-up through concrete floors for connections to free-standing equipment except motor-control centers, cubicles, and other such items of equipment shall be provided with a minimum of a 12" riser above the floor slab is of sufficient thickness; if not, a floor box shall be provided and set flush with the finished floor. Conduits installed for future use shall be terminated with a coupling and plug set flush with the floor.

### **3.02 SUPPORTING DEVICES**

- A. Install supporting devices to fasten electrical components securely and permanently in accordance with NEC requirements.
- B. Coordinate with the building structural system and with other electrical installations.
- C. Conform to manufacturer's recommendations for selection and installation of supports.
- D. Install individual and multiple (trapeze) raceway hangers and riser clamps as necessary to support raceways. Provide U-bolts, clamps, attachments, and other hardware necessary for hanger assembly and for securing hanger rods and conduits.
- E. Support parallel runs of horizontal raceways together on trapeze type hangers.
- F. Support individual horizontal raceways by separate pipe hangers. Spring steel fasteners may be used in lieu of hangers only for 1 1/2 inch and smaller raceways serving lighting and receptacle branch circuits above suspended ceilings only. For hanger rods with spring steel fasteners, use 1/4 inch diameter or larger threaded steel. Use spring steel fasteners that are specifically designed for supporting single conduits or tubing.
- G. In vertical runs, arrange support so the load produced by the weight of the raceway and the enclosed conductors is carried entirely by the conduit supports with no weight load on raceway terminals.
- H. Support miscellaneous electrical components as required to produce the same structural safety factors as specified for raceway supports. Install metal channel racks for mounting cabinets, panelboards, disconnects, control enclosures, pull boxes, junction boxes, transformers, and other devices.
- I. Install sleeves in concrete slabs and walls and all other fire rated floors and walls for raceways and cable installations. For sleeves through fire rated wall or floor

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construction, apply UL listed fire-stopping sealant in gaps between sleeves and enclosed conduits and cables.

**3.03 BOXES AND FITTINGS**

- A. Pullboxes shall be furnished and installed where necessary in the conduit system to facilitate conductor installation. Conduit runs longer than 100 feet or with more than three right-angle bends shall have a pull box installed at a convenient intermediate location.
- B. Boxes and enclosures shall be securely mounted to the building structure with supporting facilities independent of the conduit entering or leaving the boxes.
- C. Bonding jumpers shall be used around concentric or eccentric knockouts.
- D. Installation of Outlet Boxes
  - 1. Use nonmetallic boxes in corrosive areas such as chemical feed area and as designated on the plans.
  - 2. Use explosion proof boxes in Hazardous areas as identified on the Drawings.
  - 3. Use cast metal boxes in all other locations. Each box with associated covers and fittings shall have a NEMA rating for each location installed.
- E. Installation of Pull and Junction Boxes
  - 1. Use general purpose boxes (NEMA 1) in finished areas with framed construction.
  - 2. Use dust-tight and oil-tight boxes (NEMA 12) in other dry interior areas.
  - 3. Use explosion proof boxes (NEMA 7) in hazardous areas as designated on the plans.
  - 4. Use watertight boxes (NEMA 4X) for exterior and wet locations on outdoor structure where moisture is present.
  - 5. Use corrosion resistant watertight boxes (NEMA 4X) for wet locations and corrosion filled areas, such as the chemical feed area, and as identified on the Drawings.

**END OF SECTION**

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## SECTION 26 05 43

### UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS

#### PART 1 – GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide all labor, materials, equipment and incidentals as shown, specified and required to furnish and install underground duct banks, manholes and handholes including all necessary excavation, backfill and surface restoration.
- B. Provide underground conduit duct banks with manholes and pullboxes for power, and lighting circuits as shown on the Drawings.
- C. Coordination: Duct bank routing when shown on the Drawings is diagrammatic. Coordinate installation with piping and other underground systems and structures and locate clear of interferences. Coordinate manhole and handhole installation with piping, sheet piling and other underground systems and structures and locate clear of interferences.

##### 1.02 RELATED DOCUMENTS

- A. Section 26 05 00 Common Work Results For Electrical
- B. Section 26 05 34 Raceways, Boxes, & Supporting Devices
- C. Section 26 05 19 Low-Voltage Electrical Power Conductors And Cables
- D. Section 26 05 26 Grounding And Bonding For Electrical Systems
- E. Section 26 21 00 Low Voltage Electrical Service Entrance

##### 1.03 QUALITY ASSURANCE

- A. Reference Standards: Electrical material and equipment shall conform in all respects to the latest approved standards of the following:
  - 1. National Electrical Manufacturers Association (NEMA)
  - 2. The American National Standards Institute (ANSI)
    - a. ANSI A14.3 Safety Requirements for Fixed Ladders
  - 3. The Institute Of Electrical And Electronic Engineers (IEEE)
  - 4. Insulated Cable Engineers Association (ICEA)

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5. National Electrical Code (NEC)
6. National Electrical Safety Code (NESC)
7. Massachusetts Electrical Code (Amendments)
8. ASTM A 48, Gray Iron Castings
9. OSHA

#### 1.04 SUBMITTALS

- A. Provide in accordance with Division 01 General Requirements. Shop Drawings:  
Submit for approval the following:
  1. Layouts showing the proposed routing of duct banks and the locations of manholes, handholes and areas of reinforcement.
  2. Profiles of duct banks showing crossings with piping and other underground systems.
  3. Typical cross sections.
  4. Installation procedures.
  5. Manufacturer's technical information for manholes, handholes and accessories proposed for use.
  6. Drawings showing interior and exterior manhole and handhole dimensions and details of openings, jointing, inserts, reinforcing, size and locations of openings, and accessory locations.
  7. Certificate of concrete and steel used in underground pre-cast concrete utility structures, according to ASTM C858.
  8. Product Data for nonmetallic conduit and manhole accessories.

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- B. Record Drawings
  - 1. Layouts showing the actual routing of duct banks including the dimensions and depth of the top of duct bank below grade. Record drawings for duct banks should also include cross sections of the duct bank indicating the circuit, use, conduit size, orientation and number of conduits.
  - 2. Locations of manholes, handholes and areas of reinforcement.

**1.05 DEFINITIONS**

- A. Duct: Electrical conduit and other raceway, either metallic or nonmetallic, used underground, embedded in earth or concrete.
- B. Duct bank: 2 or more conduits or other raceway installed underground in the same trench or concrete envelope.
- C. Handhole: An underground junction box in a duct or duct bank with cover accessible from grade.
- D. Manhole: an underground utility structure, large enough for a person to enter, with facilities for installing and maintaining cables. Where required manholes shall comply with the Utility Companies requirements.

**1.06 PROJECT CONDITIONS AND COORDINATION**

- A. Coordination with other Underground Utilities:
  - 1. Locate all existing underground utilities through the use of an underground utility piping location services company. Locate the existing underground utilities and piping before any excavation is to begin.
  - 2. Coordinate conduit routing, duct bank and manholes with other new and existing underground utilities. Revise locations and elevations as required to suit field conditions and ensure that conduits, duct runs, manholes and handholes do not interfere with existing and new underground utilities and piping.

**PART 2 – PRODUCTS**

**2.01 DUCT BANK CONDUIT**

- A. Duct: Schedule 40 and Schedule 80 PVC conduit and fittings in accordance with Section 26 05 34 Raceways, Boxes and Supporting Devices.
- B. Rigid Steel Conduit: Rigid steel conduit and fittings in accordance with Section 26 05 34 Raceways, Boxes and Supporting Devices.

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- C. All shielded instrumentation and communications cable shall be installed in ferrous metal, steel conduit throughout the entire run of conduit from end to end.

**2.02 MANHOLES**

- A. Manholes shall conform to the requirements as shown and detailed on the Drawings.
- B. Material and Construction
  - 1. Pre-cast reinforced concrete.
  - 2. Minimum interior dimensions as indicated on the Drawings or required by the Utility Company.
  - 3. Duct entrances sized and located to suit duct banks. Duct-bank penetration shall be watertight.
  - 4. Modular sections with tongue-and-groove joints. Joints shall be gasketed and water tight.
  - 5. Nominal inside dimensions as shown.
  - 6. Base Section: Shall include sump and grate and ground rod openings.
  - 7. Sump Covers; ASTM A48; Class 30B galvanized iron.
- C. Frames and Covers
  - 1. Material: Cast iron conforming to ASTM A 48, Class 30A.
  - 2. Covers: 42" minimum diameter, watertight, sealed type marked "ELECTRICAL" in raised two inch letters.
  - 3. Frame shall be grouted on the manhole.
  - 4. Manufacturer: Provide frames and covers of one of the following:
    - a. Neenah Foundry Company
    - b. Flockhart Foundry Company
    - c. Campbell Foundry Company
    - d. Approved equal
- D. Pulling Irons

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1. Material: Galvanized steel
2. Cast in the wall opposite to the centerline of each incoming duct bank and 12 inches below centerline of bottom line of ducts.
3. Product and Manufacturer: Provide one of the following:
  - a. Cat. No. DU2T3 by McGraw Edison Company
  - b. Cat. No. 8119 by A.B. Chance Company
  - c. Approved equal

**E. Cable Racks**

1. Cable racks shall adequately support cables with space allowed for future cables. Provide as indicated to support mounting channels and racks. Cast-in Place anchors with minimum rated pullout working capacity of 2000 pounds. Pennsylvania Insert Corp. 5/8-11-INSERT, with 5/8-11 hex head cap screw made from 316 stainless steel.
2. Each rack shall be a vertical assembly of 24 inch cable racks extending from within 6 inches of the manhole roof slab to within 6 inches of the manhole floor.
3. Cable Rack Mounting Channel: Heavy duty non-metallic stanchions. Underground Devices, Inc. model C36 or approved.
4. Cable Racks: Heavy duty non-metallic racks. 8, 14, 20 inches as indicated.
5. Product and Manufacturer: Provide one of the following:
  - a. Underground Devices, Inc. model RA 08, RA14, RA20 or approved
  - b. Approved equal

**F. Insulators**

1. Material: Porcelain
2. Product and Manufacturer: Provide one of the following:
  - a. Cat. No. J-5122 by Joslyn Manufacturing and Supply Company
  - b. Cat. No. 2120 by Hubbard and Company.
  - c. Approved equal

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G. Manhole Steps

1. Material: Extruded aluminum
2. Steps spaced evenly at approximately twelve to sixteen inch centers and shall project evenly from manhole walls.
3. Manufacturer: Provide manhole steps of one of the following:
  - a. Flockhart Foundry Company
  - b. Neenah Foundry Company
  - c. Approved equal

**2.03 HANDHOLES**

A. The pull/splice box underground enclosures shall be constructed of polymer concrete consisting of sand and aggregate bound together with a polymer resin. Internal reinforcement may be provided by means of steel, fiberglass, or a combination of the two. Handholes for installation in roadways shall be concrete reinforced H20 traffic rated.

B. Enclosure

1. The enclosure must be manufactured with an open or closed bottom and a removable cover. The enclosures shall be green or concrete gray in color.
2. The enclosures shall be designed to be installed flush to grade with the cover fitting flush to the box.
3. The enclosures shall be suitable for installation in either direct or buried native soil, embedded in concrete, or embedded in asphalt surfacing. (A concrete collar is required for installation in asphalt).
4. The enclosures shall be of a stackable design for greater installation flexibility.
5. All covers are to be equipped with a minimum of two stainless steel lockdown mechanisms. All covers shall have a logo recessed into the cover and it shall read electric.
6. All enclosure covers will have some type of recessed access point to allow removal of the cover with a hook. The access points will be placed in such a location to allow for the greatest amount of leverage and safety possible.

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7. Enclosures shall be designed and suitable for installation and use through a temperature range of -40°C (-40°F) to 60°C (140°F).
8. A certified copy of all test reports must be signed and stamped by a registered professional engineer and submitted prior to shipment of products.

C. Material Requirements

1. Permanent deflection of any surface shall not exceed 10 percent of the maximum allowable static design load deflection.
2. The covers shall be skid resistant and have a maximum coefficient of friction of 0.50 on the top surface of the cover. Coatings will not be allowed.
3. Any point on the covers must be able to withstand a 70 foot-pound impact administered with a 12 pound weight having a "C" tup (ASTM D-2444) without puncturing or splitting. The test shall be performed with the cover resting on a flat, rigid surface such as concrete or a 1" steel plate.
4. Covers shall have molded lettering, ELECTRIC or COMM as applicable.
5. Fastening devices used to secure the cover to the box shall be capable of withstanding a minimum torque of 15 foot-pounds and a minimum straight pullout strength of 750 pounds.
6. The material is tested according to the requirements of ASTM D543, Section 7, Procedure 1, for chemical resistance. The manufacturer is responsible for proof of compliance with the latest version of the ASTM standards.
7. Other required acceptance standards are:
  - a. ASTM D756, Procedure E: Accelerated Service Exposure.
  - b. ASTM G53: Recommended Practice for Operating Light and Water Exposure on Nonmetallic Materials (with a U.V.A. 340 bulb).
  - c. ASTM D570, Section 5, 6.1, 6.5: Water Absorption.
  - d. ASTM D790: Flexural Properties
  - e. ASTM D635: Flammability Test

D. Manufacturers: Provide handholes as manufactured by

1. Strongwell Quazite or approved equal.

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**PART 3 – EXECUTION**

**3.01 GENERAL**

- A. Concrete mixture design:
  - 1. Per ACI 301, Section 4, "Concrete Mixtures".
  - 2. 28-day design compressive strength: 4,500 pounds per square inch, except as otherwise specified.
  - 3. Water to cementitious materials ratio: not to exceed 0.42 except as otherwise specified.
- B. Provide not less than 3 inches of concrete between the outside of a duct and the earth. Provide not less than 2 inches of concrete between adjacent ducts. Refer to Drawings for spacing requirements. Provide side forms for each duct bank.
- C. All duct line concrete pours shall be continuous between manholes or handholes and between manholes or handholes and structures.
- D. Where duct lines pass through concrete walls, concrete envelopes shall be extended through the finished flush with inside surfaces. Watertight construction joints of an approved type shall be provided.
- E. Duct banks shall be reinforced when laid on backfill covering new pipelines, roads, parking lots or any are subject to vehicular traffic. Beneath these areas, install reinforcing bars as shown on the Drawings, extending 10 ft beyond area needing protection.
- F. Duct lines shall be laid in trenches on mats of gravel not less than 6 inches thick and well graded.
- G. All electrical duct banks shall be colored red for safety purposes.
- H. Install raceways to drain away from buildings. Raceways between manholes or handholes shall drain toward the manholes or handholes. Raceway slopes shall not be less than 3 in per 100 ft.
- I. Make raceway entrances to buildings and vaults with hot dipped rigid galvanized steel conduit not less than 10 ft long. Conduits which are not concrete encased for runs below floor slabs in slab-on-grade construction shall be hot dipped rigid galvanized steel conduit. Conduits which are concrete encased for runs below floor slabs in slab-on-grade construction shall be encased under the slab to their respective equipment.

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- J. Raceway terminations at manholes shall be with end bells for PVC conduit and insulated throat grounding bushings with lay-in type lugs for metal conduit.

**3.02 INSTALLATION**

- A. Provide excavation and backfilling required for ductbank manhole and handhole installation.
- B. Make duct bank installations and penetrations through foundation walls watertight.
- C. Assemble duct banks using non-magnetic saddles, spacers and separators. Position separators to provide 3-inch minimum separation between the outer surfaces of the ducts.
- D. Firmly fix ducts in place during pouring of concrete. Carefully spade and vibrate the concrete to insure filling of all spaces between ducts.
- E. Make bends with sweeps of not less than 48-inch radius or 5 degree angle couplings.
- F. Make a transition from non-metallic to PVC coated rigid steel conduit where duct banks enter structures or turn upward for continuation above grade. Terminate the ducts in insulated grounding bushings. Continue ducts inside buildings with steel, metallic conduit.
- G. Where ducts enter manholes and handholes, terminate the ducts in suitable end bells.
- H. Provide expansion/deflection fittings in accordance with the requirements specified in Section 26 05 34 Raceways, Boxes and Supporting Devices.
- I. Do not backfill with material containing large rock, paving materials, cinders, large or sharply angular substances, corrosive material or other materials which can damage or contribute to corrosion of ducts or cables or prevent adequate compaction of fill.
- J. Slope duct runs for drainage toward manholes and away from buildings with a slope of approximately 3 inches per 100 feet.
- K. After completion of the duct bank and prior to pulling cable, pull a mandrel, not less than 12 inches long and with a cross section approximately one-fourth inch less than the inside cross section of the duct, through each duct. Then pull a rag swab or sponge through to make certain that no particles of earth, sand or gravel have been left in the duct.
- L. Install a bare stranded copper duct bank ground cable in each duct bank envelope. Make ground electrically continuous throughout the entire duct bank system.

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Connect ground cable to building and station ground grid or to equipment ground buses. In addition, connect ground cable to steel conduit extensions of the underground duct system. Provide ground clamp and bonding of each steel conduit extension, where necessary to maintain continuity of the ground system. Terminate ground conductor at last manhole or handhole for outlying structures.

- M. Install a warning ribbon approximately 12 inches below finished grade over all underground duct banks. The identifying ribbon shall be a PVC tape, 3-inches wide, yellow color, permanently imprinted with "CAUTION BURIED ELECTRIC LINE BELOW" in black letters.
- N. Plug and seal all empty spare ducts entering buildings and structures. Seal all ducts in use entering buildings and structures. Seal shall be watertight, O-Z/Gedney Type Dux Duct Sealing Compound or equal.
- O. Install duct banks in conformance with National Electrical Code and National Electrical Safety Code.
- P. Install manholes and handholes where shown on Drawings. Verify final locations in field.
- Q. Complete installation of manholes and handholes so that structures are watertight. Provide expansion/deflection fitting for each conduit entry into the manholes.
- R. Provide sump opening in manhole floor.
- S. Provide grading rings or brick stacks for manholes when required to adjust manhole cover to proper grade. Stacks shall be minimum of 12 inches in height, constructed on the roof slab or cone section on which the manhole frame and cover shall be placed. The height of the stack shall be such as is necessary to bring the manhole frame to the proper grade.
- T. Cable Racks
  - 1. Provide cable hooks to support each cable on each rack along the cable run within the manholes.
  - 2. Individually support each cable at each hook on porcelain insulators.
  - 3. In the manhole securely tie each cable in place at each insulator block to prevent excessive movement of insulators, cables, or fireproof tape. Tie cables with non-metallic 3/4-inch strapping tape as manufactured by 3M or tie down with nylon straps.
- U. Conduits shall extend 3 inches above concrete slab surface, unless otherwise indicated. All conduits shall be bushed to protect cables and provide means for grounding.

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- V. Duct Bank Conduit Spacers: Non-metallic, snap together intermediate and bottom pieces, sized for conduit diameter and code spacing. Carlon "Span-Loc" or approved. Separators shall be compatible with the conduit utilized. The joints of the conduits shall be staggered by rows and layers so as to provide a duct line having the maximum strength. During construction, partially completed duct lines, shall be protected from the entrance of debris such as mud, sand, and dirt by means of suitable conduits plugs. As each section of a duct line is completed, a testing mandrel not less than 12 inches long with a diameter  $\frac{1}{4}$  inch less than the size of the conduit, shall be drawn through each conduit, after which a brush having the diameter of the duct, and having stiff bristles shall be drawn through until the conduit is clear of all particles of earth, sand and/or gravel; conduit plugs shall then be immediately installed. Provide a plastic pull rope, having a minimum of 3 additional feet at each end, in all spare ducts.

**3.03 DUCT BANK INSTALLATION**

- A. All bends shall have a radius greater than 36 inches or 12 times conduit inside diameter whichever is greater.
- B. Install duct with minimum slope of 4 inches per 100 feet. Slope duct away from building entrances.
- C. Install no more than equivalent of three 90-degree bends between pull points.
- D. Provide suitable fittings to accommodate expansion and deflection where required.
- E. Use suitable separators and chairs installed not greater than 4 feet on centers. Conduit separation shall be per code, and not less than 3 inches.
- F. Securely anchor duct to prevent movement during concrete placement. Use re-bar holders at spacers and secure with #4 re-bar driven into earth minimum of 1 foot.
- G. Connect to manhole wall using #6 re-bar dowels. Dowels shall be located at each corner, and 12 inches on center. Insert dowels minimum 3 inches into manhole and 3 feet into duct bank.
- H. Tops of concrete-encased ducts shall be:
1. Not less than 24in and not less than shown on the Drawings, below finished grade.
  2. Not less than 30in and not less than shown on the Drawings, below roads and other paved surfaces.
- I. Tops of direct burial ducts and conduits shall be:

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1. Not less than 24 inches and not less than shown on the Drawings, below finished grade.
2. Not less than 30 inches and not less than shown on the Drawings, below roads and other paved surfaces.

**3.04 PRE-CAST MANHOLE INSTALLATION**

- A. Install and seal pre-cast sections in accordance with manufacturer's instructions.
- B. Install manholes plumb.
- C. Attach cable racks to inserts after manhole installation is complete.
- D. Provide 12 inches minimum gravel bedding under manholes, and 12 inches gravel fill around manholes.
- E. Conduit/Ductwork penetration shall be grouted and sealed. Penetration shall be watertight.

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**3.05 CABLE PULLING**

- A. The inspection, handling, storage, temperature conditioning prior to installation, bending and training limits, pulling limits, and calculation parameters for installation of all cables must comply with the manufacturer's recommendations. For ease of installation and prevention of cable damage, the Contractor shall utilize quadrant blocks located properly along the cable run. Failure to comply with any of the above shall make this Contractor responsible for any cable failures that occur within the manufacturer's warranty period.
- B. Cable lubricant shall be soapstone, graphite or talc for rubber or plastic jacketed cables.
- C. Lubricants for assisting in the pulling of jacketed cables shall be those specifically recommended by the cable manufacturer.
- D. Cable pulling tensions shall not exceed the maximum pulling tensions recommended by the cable manufacturer.
- E. All medium voltage cables shall be individually fire/arc proofed.

**3.06 CABLE TERMINATING**

- A. Terminations of insulated power and lighting cables shall be protected from accidental contact, deterioration of coverings and moisture by the use of terminating devices and materials. Terminations shall be made using materials and method as indicated or specified herein or as designed by the written instruction of the cable manufacturer and termination kit manufacturer.

**3.07 GROUNDING**

- A. Duct banks shall be grounded with a bare stranded copper ground wire that is run within the duct bank and is bonded and grounded at both ends. Conduit shall not be used as the ground conductor.
- B. Manholes shall be grounded with ground rods. A bare stranded copper ground wire from the ground wire loop shall be used to bond together and ground the manhole cover frame, ladder support bracket, concrete inserts, cable racks, duct bank ground conductors, and the shields of any medium voltage cables that are spliced in the manhole.
- C. Grounding: Install a ground rod for each manhole. Bond all exposed metal manhole accessories and the concrete reinforcing rods with bare copper wire and connect to the ground rod and to the ductbank ground cable. Provide foam sealant for rod penetration in manhole floor for water tight seal.

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- D. Install a bare stranded copper duct bank ground cable in each duct bank envelope. Make ground electrically continuous throughout the entire duct bank system. Connect ground cable to building and station ground grid or to equipment ground buses. In addition, connect ground cable to steel conduit extensions of the underground duct system, manholes and handholes. Provide ground clamp and bonding of each steel conduit extension, where necessary to maintain continuity of the ground system.

**END OF SECTION**

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## SECTION 26 21 00

### LOW-VOLTAGE ELECTRICAL SERVICE ENTRANCE

#### PART 1 - GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide the labor, tools, equipment, and materials necessary to provide service entrance work in accordance with the Drawings and as specified herein. Extent of service entrance work shall be as indicated on the Drawings and as specified herein.

##### 1.02 RELATED DOCUMENTS

- A. Related Sections
  - 1. Section 26 05 00 Common Work Results For Electrical

##### 1.03 QUALITY ASSURANCE

- A. Electric Utility Company: Eversource
- B. Install work in accordance with Utility Company's rules and regulations.
- C. Reference Standards.
- D. National Electrical Code (NEC), Including Articles 230, 250, And 338
- E. Massachusetts Electrical Code (Amendments)
- F. National Electrical Manufacturers Association (NEMA) Compliance
- G. Underwriters' Laboratories, INC. (UL) Compliance
  - 1. UL 50 Electrical Cabinets and Boxes
  - 2. UL 854 Service Entrance Cables
  - 3. UL 869 Electrical Service Equipment
- H. Institute Of Electrical And Electronic Engineers (IEEE) Compliance
- I. American National Standards Institute (ANSI) Compliance

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#### 1.04 SUBMITTALS

- A. Provide in accordance with Division 01 General Requirements.
- B. Furnish manufacturer's product data, test reports, and materials certification as required.
  - 1. Product Data: Submit manufacturer's data on service entrance equipment and accessories.

#### 1.05 PROJECT CONDITIONS

- A. The Contractor shall be responsible for providing and installing all service entrance conduit and conductors for associated service work as indicated on the Drawings.
- B. Services shall be wired for 120/240V single phase 3-wire as indicated on the Drawings.

### PART 2 - PRODUCTS

#### 2.01 MATERIALS

- A. General: Provide service entrance equipment and accessories; of types, sizes, ratings and electrical characteristics indicated, which comply with utility and manufacturer's standard materials, design and construction.
- B. Conductors
  - 1. Copper conductors with XHHW insulation, 600 volt rated.
  - 2. Cable identifications shall indicate the manufacturer's name, wire size, insulation type, voltage, etc.
  - 3. Spade connectors and lug extensions shall be provided as required to accommodate all service conductors at transformer.
- C. Metering
  - 1. Provide utility meter and meter enclosure for the building service as required by the local utility company.
  - 2. Coordinate all metering requirements with utility company for a complete installation in accordance with the utility company's specifications.
- D. Manholes, Handholes and Pullboxes
  - 1. Provide in accordance with Section 26 05 43 Underground Ducts and Raceways for Electrical Systems.

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### **PART 3 - EXECUTION**

#### **3.01 INSTALLATION**

- A. Provide and install required conduit wire, pullboxes, and accessory items to accomplish the Work involved in providing the electrical service as shown on the Drawings.
- B. Coordinate service work with the Owner and utility company to insure proper timing of installation and connection of equipment.
- C. Obtain all permits, pay all fees and provide all materials and labor necessary for interfacing with utility equipment to install electric service.
- D. Furnish and install all electrical conduits for low voltage cables and low voltage wire and accessory items necessary to accomplish the Work detailed herein or in the Drawings.
- E. Furnish and install utility meter, meter enclosure, and all associated metering conduits in accordance with the utility company's requirements.
- F. All service conductors shall be pulled to the utility riser pole, by the contractor, with a 20-foot uncut coil of conductors at the top of the riser pole for later connection by utility to pole mounted transformer secondary per local utility company requirements. Primary wiring and terminations shall be by the utility company.

**END OF SECTION**

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**SECTION 26 32 13.13**

**DIESEL-ENGINE-DRIVEN GENERATOR SET**

**PART 1 - GENERAL**

**1.01 DESCRIPTION OF WORK**

- A. Furnish, install, test and make ready for operation 1 diesel-engine-driven generator set and automatic transfer switch from a single manufacturer.

**1.02 REFERENCES AND STANDARDS**

- A. The generator set covered by these specifications shall be designed, tested, rated, assembled and installed in strict accordance with all applicable standards below:
  - 1. CSA C22.2 No14
  - 2. CSA 282
  - 3. CSA 100
  - 4. EN61000-6
  - 5. EN55011
  - 6. FCC Part 15 Subpart B
  - 7. ISO8528
  - 8. IEC61000
  - 9. UL508
  - 10. UL2200
  - 11. UL142
  - 12. Designed to allow for installed compliance to NFPA 70, NFPA99 and NFPA 110

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**1.03 RELATED SECTIONS**

- A. Section 26 05 00 Common Work Results for Electrical

**1.04 WORK INCLUDED**

- A. Installation
  - 1. The work includes installing a complete integrated generator system. The system consists of a diesel generator set and automatic transfer switch with related component accessories.
- B. Fuel System
  - 1. The Contractor shall provide a full tank of diesel fuel for each generator for the completion of all testing as specified in the contract documents.
- C. System Test
  - 1. A complete system load test shall be performed after all equipment is installed. Guidelines in the Start-up Section.
- D. Requirements, Codes and Regulations
  - 1. The equipment supplied and installed shall meet the requirements of the NEC and all applicable local codes and regulations. All equipment shall be of new and current production by a Manufacturer who has 5 years of experience building this type of equipment. Manufacturer shall be ISO9001 certified.

**1.05 ACCEPTABLE MANUFACTURERS**

- A. Caterpillar
- B. Cummins Power Generation
- C. Kohler
- D. Or Equal

**1.06 SUBMITTALS**

- A. Engine-generator submittals shall include the following information, and be submitted in accordance with Division 01:
  - 1. Factory published specification sheet.
  - 2. Manufacturer's catalog cut sheets of all auxiliary components such as battery charger, control panel, enclosure, fuel system filter, etc.

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3. Dimensional elevation and layout drawings of the generator set, enclosure and transfer switchgear and related accessories
4. Weights of all equipment.
5. Concrete pad recommendation, layout and stub-up locations of electrical and fuel systems
6. Interconnect wiring diagram of complete emergency system, including generator, switchgear, battery charger, control panel, and remote alarm indications
7. Engine mechanical data, including heat rejection, exhaust gas flows, combustion air and ventilation air flows, fuel consumption, etc.
8. Generator electrical data including temperature and insulation data, cooling requirements, excitation ratings, voltage regulation, voltage regulator, efficiencies, waveform distortion, and telephone influence factor
9. Generator resistances, reactance's and time constants
10. Generator locked rotor motor starting curves
11. Manufacturer's documentation showing maximum expected transient voltage and frequency dips, and recovery time during operation of the generator set at the specified site conditions with the specified loads
12. Manufacturer's and dealer's written warranty

**1.07 SYSTEM RESPONSIBILITY**

**A. Generator Set Distributor**

1. The completed engine generator set shall be supplied by the Manufacturer's authorized distributor only.

**B. Requirements, Codes, and Regulations**

1. The equipment supplied and installed shall meet the requirements of NEC and all-applicable local codes and regulations. All equipment shall be new, of current production. There shall be one source responsibility for warranty, parts and service through a local representative with factory trained service personnel.

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## 1.08 WARRANTY

- A. Two Year Standby (ISO 8528-1: ESP) Generator Set Warranty
  - 1. The manufacturer's standard warranty shall in no event be for a period of less than two (2) years from date of initial start-up of the system and shall include repair parts, labor, reasonable travel expense necessary for repairs at the job site, and expendables (lubricating oil, filters, antifreeze, and other service items made unusable by the defect) used during the course of repair. Running hours shall be limited to 500 hours annually for the system warranty by both the manufacturer and servicing distributor. Submittals received without written warranties as specified will be rejected in their entirety.

## 1.09 PARTS AND SERVICE QUALIFICATIONS

- A. Service Facility
  - 1. The engine-generator supplier shall maintain 24-hour parts and service capability within 100 miles of the project site. The distributor shall stock parts as needed to support the generator set package for this specific project. The supplier must carry sufficient inventory to cover no less than 80% parts service within 24hrs and 95% within 48 hours.
- B. Service Personnel
  - 1. The dealer shall maintain qualified factory trained service personnel.

## PART 2 – PRODUCTS

### 2.01 GENERAL REQUIREMENTS

- A. Genset Requirements
  - 1. The generator set shall be Standby Duty rated at 35kW, 44kVA, 146A, 1800RPM, 0.8 power factor, 120/240V, 1-Phase, 60Hz, including radiator fan and all parasitic loads. Generator set shall be sized to operate at the specified load at a maximum ambient of 110°F (43.3°C) before any deration and altitude of 500 feet (152.4m). The engine generator set shall be capable of reliably starting the connected loads in the order listed in the table below. This shall be accomplished without exceeding the voltage and frequency specifications listed below:

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Maximum Allowable Starting Voltage Dip	Maximum Allowable Peak Voltage Dip	Maximum Allowable Frequency Dip
15%	15%	5%

Load Name	Load Rating (HP/kVA)	Starting Method
<b>Step 1:</b>		
Panel LP1	48kVA	General Loads Computer/Electronics, HVAC

2. Standby Power Rating

- a. Power is available for the duration of an emergency outage
- b. Average Power Output = 70% of standby power
- c. Load = Varying
- d. Typical Hours/Year = 200 Hours
- e. Maximum Expected Usage = 500 hours/year
- f. Typical Application = Standby

B. Material and Parts

1. All materials and parts comprising the unit shall be new and unused.

C. Engine

1. The engine shall be diesel fueled, four (4) cycle, water-cooled, while operating with nominal speed not exceeding 1800RPM. The engine will utilize in-cylinder combustion technology, as required, to meet applicable EPA non-road mobile regulations and/or the EPA NSPS rule for stationary reciprocating compression ignition engines. Additionally, the engine shall comply with the State Emission regulations at the time of installation/commissioning. Actual engine emissions values must be in compliance with applicable EPA emissions standards per ISO 8178 – D2 Emissions Cycle at specified kW/bHP rating. Utilization of the “Transition Program for Equipment Manufacturers” (also known as “Flex Credits”) to achieve EPA certification is not acceptable. The in-cylinder engine technology must not permit unfiltered exhaust gas to be introduced into the combustion cylinder.

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2. Engine Governing

- a. The engine governor shall be an electronic Engine Control Module (ECM) with 24-volt DC Electric Actuator. The ECM shall be enclosed in an environmentally sealed, die-cast aluminum housing which isolates and protects electronic components from moisture and dirt contamination. Speed droop shall be adjustable from 0 (isochronous) to 10%, from no load to full rated load. Steady state frequency regulation shall be +/- 6RPM. Speed shall be sensed by a magnetic pickup off the engine flywheel ring gear. A provision for remote speed adjustment shall be included. The ECM shall adjust fuel delivery according to exhaust smoke, altitude and cold mode limits. In the event of a DC power loss, the forward acting actuator will move to the minimum fuel position.

2.02 GENERATOR

A. Generator Specifications

1. The synchronous three phase generator shall be a single bearing, self-ventilated, drip-proof design in accordance with NEMA MG 1 and directly connected to the engine flywheel housing with a flex coupling. The generator shall meet performance class G2 of ISO 8528. The excitation system shall enable the alternator to sustain 300% (250% for 50Hz) of rated current based on the 125C (Class H) or 105C (Class F) rise rating for ten seconds during a fault condition and shall improve the immunity of the voltage regulator to non-linear distorting loads. The excitation system shall be of brushless construction and be independent of main stator windings (either permanent magnet or auxiliary windings).

B. Voltage Regulator

1. Digital Voltage Regulator

- a. The digital voltage regulator shall be microprocessor based with fully programmable operating and protection characteristics. The regulator shall maintain generator output voltage within +/- 0.25% for any constant load between no load and full load. The regulator shall be capable of sensing true RMS in three phases of alternator output voltage, or operating in single phase sensing mode. The voltage regulator shall include a VAR/Pf control feature as standard. The regulator shall provide an adjustable dual slope regulation characteristic in order to optimize voltage and frequency response for site conditions. The voltage regulator shall include standard the capability to provide generator paralleling with reactive droop compensation and reactive differential compensation.

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- b. The voltage regulator shall communicate with the Generator Control Panel via a J1939 communication network with generator voltage adjustments made via the controller keypad. Additionally, the controller shall allow system parameter setup and monitoring, and provide fault alarm and shutdown information through the controller. A PC-based user interface shall be available to allow viewing and modifying operating parameters in a windows compatible environment

**2.03 CIRCUIT BREAKER**

A. Circuit Breaker Specifications

1. Provide a generator mounted 100% circuit breaker, molded case, manually operated trip, 2 pole, NEMA 1/IP22 sized as indicated on the Contract Drawings. Breaker shall be a thermal magnetic breaker with adjustable instantaneous settings. Breaker shall be UL/CSA Listed, connected to engine/generator safety shutdowns. Breaker shall be housed in an extension terminal box which is isolated from vibrations induced by the generator set. Mechanical type lugs, sized for the circuit breaker feeders shown on drawing, shall be provided by the installation contractor.

**2.04 CONTROLS - GENERATOR SET MOUNTED**

- A. Provide a fully solid-state, microprocessor based, generator set control. The control panel shall be designed and built by the engine manufacturer. The control shall provide all operating, monitoring, and control functions for the generator set.

B. Environmental

1. The generator set control shall be tested and certified to the following environmental conditions:
  - a. -40°C to +70°C Operating Range
  - b. 95% humidity non-condensing, 30°C to 60°C
  - c. IP22 protection for rear of controller; IP55 when installed in control panel
  - d. 5% salt spray, 48 hours, +38°C, 36.8V system voltage
  - e. Sinusoidal vibration 4.3G's RMS, 24-1000Hz
  - f. Electromagnetic Capability (89/336/EEC, 91/368/EEC, 93/44/EEC, 93/68/EEC, BS EN 50081-2, 50082-2)
  - g. Shock: withstand 15G

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C. Functional Requirements

1. The following functionality shall be integral to the control panel:
  - a. The control shall include a 33 x 132 pixel, 24mm x 95mm, positive image, transfective LCD display with text based alarm/event descriptions.
  - b. Audible horn for alarm and shutdown with horn silence switch
  - c. Standard ISO labeling
  - d. Multiple language capability
  - e. Remote start/stop control
  - f. Local run/off/auto control integral to system microprocessor
  - g. Cooldown timer
  - h. Lamp test
  - i. Push button emergency stop button

D. Digital Monitoring Capability

1. The controls shall provide the following digital readouts for the engine and generator. All readings shall be indicated in either metric or English units.
  - a. Engine
    - 1) Engine oil pressure
    - 2) Engine coolant temperature
    - 3) Engine RPM
    - 4) Battery volts
  - b. Generator
    - 1) Generator AC volts (Line to Line, Line to Neutral, and Average)
    - 2) Generator AC current (Average and Per Phase)
    - 3) Generator AC Frequency

E. Alarms and Shutdowns

1. The control shall monitor and provide alarm indication and subsequent shutdown for the following conditions. All alarms and shutdowns are accompanied by an engine hour stamp that is stored by the control panel for first and last occurrence.

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2. Engine Alarm/Shutdown
  - a. Low oil pressure alarm/shutdown
  - b. High coolant temperature alarm/shutdown
  - c. Loss of coolant shutdown
  - d. Overspeed shutdown
  - e. Overcrank shutdown
  - f. Emergency stop depressed shutdown
  - g. Low coolant temperature alarm
- F. Inputs and Outputs
  1. Programmable Digital Inputs
    - a. The Controller shall include the ability to accept eight (8) total with six (6) programmable digital input signals. The signals may be programmed for either high or low activation using programmable Normally Open or Normally Closed contacts.
  2. Programmable Relay Outputs
    - a. The control shall include the ability to operate eight (8) total with six (6) form A (normally open) programmable relay output signals, integral to the controller. Relay shall be rated for a maximum of 2A @ 30VDC.
    - b. Four sets of contacts rated for a maximum of 2A @ 30VDC shall be made available for each of the following statuses:
      - 1) Generator Running
      - 2) Generator Fail
- G. Maintenance
  1. All engine, voltage regulator, control panel, and accessory units shall be accessible through a single electronic service tool. The following maintenance functionality shall be integral to the generator set control:
    - a. Engine running hours display
    - b. 20 events are stored in control panel memory
    - c. Engine crank attempt counter
    - d. Engine successful starts counter
    - e. 40 events are stored in control panel memory

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- f. Programmable cycle timer that starts and runs the generator for a predetermined time. The timer shall use 7 user-programmable sequences that are repeated in a 7-day cycle. Each sequence shall have the following programmable set points:
  - 1) Day of week
  - 2) Time of day to start
  - 3) Duration of cycle

II. Annunciator (NFPA 99/1101, CSA 282)

- 1. Provide a local, control panel mounted, annunciator to meet the requirements of NFPA 1101, Level 1.
- 2. Annunciators shall be networked directly to the generator set control.
- 3. Local annunciator shall include a lamp test pushbutton, alarm horn and alarm acknowledge pushbutton.
- 4. Provide the following individual light indications for protection and diagnostics:
  - a. Overcrank
  - b. Low coolant temperature
  - c. High coolant temperature warning
  - d. High coolant temperature shutdown
  - e. Low oil pressure warning
  - f. Low oil pressure shutdown
  - g. Overspeed
  - h. Low coolant level
  - i. EPS supplying load
  - j. Control switch not in auto
  - k. High battery voltage
  - l. Low battery voltage
  - m. Battery charger AC failure
  - n. Emergency stop

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- o. Spare
- p. Spare

**2.05 COOLING SYSTEM**

- A. The generator set shall be equipped with a rail-mounted, engine-driven radiator with blower fan and all accessories. The cooling system shall be sized to operate at full load conditions and 110°F ambient air entering the room or enclosure (If an enclosure is specified). The generator set supplier is responsible for providing a properly sized cooling system based on the enclosure static pressure restriction.

**2.06 FUEL SYSTEM**

- A. Fuel System
  - 1. The fuel system shall be integral with the engine. In addition to the standard fuel filters provided by the engine manufacturer, there shall also be installed a primary fuel filter/water separator in the fuel inlet line to the engine. All fuel piping shall be black iron or flexible fuel hose rated for this service. No galvanized piping will be permitted. Flexible fuel lines shall be minimally rated for 300°F and 100psi.
- B. Fuel Sub Base Tank
  - 1. Provide a double wall sub-base tank constructed to meet all local codes and requirements. A fuel tank base of 24 hour capacity shall be provided as an integral part of the enclosure. It shall be contained in a rupture basin with 110% capacity. The tank shall meet UL142 standards. A locking fill cap, a mechanical reading fuel level gauge, low fuel level alarm contact, and fuel tank rupture alarm contact shall be provided.

**2.07 EXHAUST SYSTEM**

- A. Silencer
  - 1. A critical grade silencer, companion flanges, and flexible stainless steel exhaust fitting properly sized shall be furnished and installed according to the manufacturer's recommendation. Mounting shall be provided by the contractor as shown on the drawings. The silencer shall be mounted so that its weight is not supported by the engine nor will exhaust system growth due to thermal expansion be imposed on the engine. Exhaust pipe size shall be sufficient to ensure that exhaust backpressure does not exceed the maximum limitations specified by the engine manufacturer.
  - 2. The complete exhaust system shall be internal to the sound attenuated enclosure. Units with roof mounted or externally exposed silencers are not acceptable.

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## 2.08 STARTING SYSTEM

- A. Starting Motor
  - 1. A DC electric starting system with positive engagement shall be furnished. The motor voltage shall be as recommended by the engine manufacturer.
- B. Jacket Water Heater
  - 1. Jacket water heater shall be provided and shall be sized to insure that genset will start within the specified time period and ambient conditions.
- C. Batteries
  - 1. Batteries - A lead-acid storage battery set of the heavy-duty diesel starting type shall be provided. Battery voltage shall be compatible with the starting system.
- D. Battery Charger
  - 1. Battery Charger - A current limiting battery charger shall be furnished to automatically recharge batteries. The charger shall be dual charge rate with automatic switching to the boost rate when required. The battery charger shall be mounted on the genset package or inside the genset enclosure/room.

## 2.09 ENCLOSURE

- A. Sound Attenuated Enclosure
  - 1. The complete diesel engine generator set, including generator control panel, silencer, engine starting batteries, and fuel oil tank, shall be enclosed in a factory assembled, sound attenuated enclosure mounted on the fuel tank base.
    - a. A weather resistant, sound attenuated enclosure of steel with electrostatically applied powder coated baked polyester paint. The enclosure shall have a resulting sound level of 76dba @ 7m with the genset running under full load. It shall consist of a roof, side walls, and end walls. Fasteners shall be either zinc plated or stainless steel. The sound attenuated enclosure shall reduce the sounds of the generator as required to meet all local, state and federal laws, codes, regulations and standards.
    - b. Enclosure Sound Attenuation: Acoustical foam shall be provided between all supports and inside doors and sound baffles on air intake and air discharge.

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## 2.10 AUTOMATIC TRANSFER SWITCH

- A. An automatic transfer switch with number of poles, voltage and current ratings as shown on the plans and specified herein shall be provided for each generator. Each ATS shall consist of a power transfer switch unit and a control module interconnected to provide complete automatic operation. All equipment shall be new and of current production by an international firm which manufactures the generator, controls, and transfer switch. The company selected will assemble the standby generator set and transfer switch as a matched unit so that there is one-source responsibility for warranty, parts and service through a local representative with factory-trained personnel.
- B. Electrical Requirements:
1. Automatic transfer switches not intended for continuous duty or repetitive load transfer switching are not acceptable.
  2. The automatic transfer switch shall be rated in amperes for total system transfer including control of motors, electric-discharge lamps, electric heating, and tungsten-filament lamp load. Switches rated 400 amperes and below shall be suitable for 100% tungsten-filament lamp load. Switches rated above 400 amperes shall be suitable for 30% tungsten-filament load.
  3. The automatic transfer switch shall be rated to withstand the rms symmetrical short circuit current available at the automatic transfer switch terminals, with the type of overcurrent protection shown on the plans.
- C. The transfer switch shall have the following characteristics:
1. Voltage and Current rating as indicated on the Drawings.
  2. 2 Pole
  3. 3 wire, 1 phase
  4. Solid Neutral
  5. The withstand and closing ratings with a current-limiting fuse shall be 200,000 Amps.
  6. The withstand and closing ratings with any overcurrent protective device shall be 25,000 Amps.
  7. NEMA 1 Enclosure.
  8. The switch shall be a 600 volt class.

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D. Mechanical Requirements

1. All main contacts shall be of silver composition. The main contacts shall be protected by arcing contacts in sizes 400 amperes and above. The main contacts shall be of the blow-on configuration and of segmented construction in ratings 600 amperes and above.
2. All contacts, coils, springs, and control elements shall be conveniently removable from the front of the transfer switch without major disassembly or disconnection of power conductors.
3. The contact transfer time shall not exceed one-sixth of a second.
4. All moveable parts of the operating mechanism shall remain in positive mechanical contact with the main contacts during the transfer operation without the use of separate mechanical interlocks.
5. All contacts, coils, springs, and control elements shall be conveniently removable from the front of the transfer switch without major disassembly or disconnection of power conductors.
6. The neutral conductor shall be solidly connected as shown on the plans, a neutral conductor terminal plate with fully rated AL-CU pressure connectors shall be provided.

E. Transfer Switch Control System

1. The control module shall direct the operation of the transfer switch. The module's sensing and logic shall be a built-in microprocessor-based system for maximum reliability, minimum maintenance, and inherent digital communications capability. The control settings shall be stored in nonvolatile EEPROM. The module shall contain an integral programmable clock and calendar. The control module shall have a keyed disconnect plug to enable the control module to be disconnected from the transfer mechanism for routine maintenance. The control module shall be mounted separately from the transfer mechanism unit for safety and ease of maintenance. Interfacing relays shall be industrial control grade plug-in type with dust cover.
2. The control module shall include programming keypad, alphanumeric display for monitoring settings and diagnostic values, key-lockable program selector switch, light-emitting diode status indication, and user instructions. These features shall be user accessible when the enclosure door is closed.

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3. The control module shall be capable of storing the following records in memory for access either locally (at the control module) or remotely (at a computer):
    - a. Number of hours transfer switch is in the emergency position (total and since record reset)
    - b. Number of hours the emergency is available (total and since record reset)
    - c. Total days that control has been energized (total and since record reset)
    - d. Total transfers in either direction (total and since record reset)
    - e. Date of record reset
    - f. Date of last exercise period
    - g. Date, time, and description of the last four source failures
    - h. Elapsed time during the most recent source outage
- F. Transfer Switch Operation & Accessories
1. The voltage of each phase of the normal source and a single phase of the emergency source shall be monitored with pickup adjustable from 75% to 100% and dropout adjustable from 70% to 95% of nominal. Adjustment must be digital. An automatic minimum differential of 2% shall be maintained between pickup and dropout settings. Repetitive accuracy of the setting shall be  $\pm 2\%$  or better over an operating temperature range of  $-20^{\circ}\text{F}$  to  $150^{\circ}\text{F}$  ( $-29^{\circ}\text{C}$  to  $65.5^{\circ}\text{C}$ ). The settings shall be fully field-adjustable by keypad or keyboard (local or remote) in increments of 1 Volt without opening the enclosure door and without the use of special tools or separate meters. Factory settings shall be pickup at 90% and dropout at 85%. A light-emitting diode shall indicate that normal and/or emergency voltage is within the set point parameter. The indication shall be viewable when the enclosure door is closed.
  2. The control module shall include four time delays that are fully field-adjustable by keypad or keyboard in increments of 1 second over the entire range. Adjustments and viewing of the time delay values shall be accessible when the enclosure door is closed. Light emitting diodes shall indicate when the timing feature is running and when the time delay has ended. Required time delays shall be as follows: Input values outside the allowable parameters shall cause a "range error" message to be displayed.
    - a. Time delay for engine start to delay initiation of transfer for momentary source outages: Range 0-6 seconds. Factory set at 5 seconds.
    - b. Time delay for transfer to emergency: Range 0-5 minutes. Factory set at 5 seconds.

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- c. Time delay for transfer back to normal: Range 0-30 minutes. Factory set at 5 seconds.
  - d. Time delay for engine cool-down: Range 0-30 minutes. Factory set at 5 seconds.
3. The user shall have the ability to manually program an engine start and run for a period of up to 72 hours in the loaded or unloaded mode of operation. The time delay transfer to emergency and/or normal may be bypassed during the run period. A numeric indication shall be displayed of the run time remaining in hours and minutes. The run period may be stopped at any time with a single keystroke. After the run period has stopped, the engine shall run unloaded for the cool-down time.
4. User terminals shall be available to connect a normally closed contact that, when opened, signals the control module to start and transfer load to the engine-generator. Closing these contacts shall initiate a retransfer and engine cool-down sequence. The load shall be transferred to an available utility source immediately if the generator source should fail.
5. The following features shall be built into the control module logic. These features shall be enabled at the factory or in the field by installing an insulated program jumper provided by the vendor as standard.
  - a. Anti-single phasing protection shall detect regenerative voltage as a failed source condition.
  - b. In-phase monitoring shall continuously monitor the contactor transfer times, source voltage, frequency and phase angle to provide a self-adjusting, zero crossing contactor transfer signal.
  - c. Manual operation override shall function to bypass any manual switch accessories if the source to which the transfer switch is positioned fails. This program jumper shall be factory installed.
  - d. Plant Exerciser: Programmable seven-day, fourteen-day or calendar exerciser. Each exerciser mode shall be capable of performing up to two exercise runs in up to five exercise event periods. The exerciser period shall be programmed with the enclosure door closed. The exercise time may be reset at any time with a single keystroke. The engine shall be allowed to run when the exercise period is terminated.
  - e. All phases of normal and all or single phases of emergency shall be monitored for overvoltage and single phase of normal and emergency for over- and under-frequency. The values shall be programmed with the enclosure door closed.
  - f. Extended Time Delay: Allows the time delay settings to be extended to 99 minutes.
6. Light emitting diodes shall indicated the following:

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- a. Contactor Position
  - b. Transfer Switch Position Sensing Fault
  - c. Transfer Switch Fail to Transfer
  - d. Internal Control Module Fault
  - e. Manual Transfer Operation
  - f. External Fault Condition (two inputs)
  - g. ATS in Normal
  - h. ATS in Emergency
  - i. Generator Running
  - j. Generator Fault
  - k. Programming Switch Not In Off
  - l. The system status messages shall also be shown on the alphanumeric display.
  - m. A lamp test push button shall light all light-emitting diodes.
7. The control module shall have a three-position, key-operated, programming control switch. The key shall be removable in any position. The positions shall be:
- a. Off--Allows all enabled accessories to be monitored only. Settings cannot be changed while in this position.
  - b. Local--Allows all enabled accessory settings to be changed by local keypad entry.
  - c. Remote--Allows all enabled accessories to be altered via the remote communications port.
8. A momentary-type test switch shall be provided to simulate a normal source failure.
9. The transfer switch shall be able to control up to 12 isolated form C auxiliary contacts rated 5A, 120/240VAC resistive and shall have the following user programmable functions:
- a. Utility available (within voltage, frequency & phase balance limits)
  - b. Generator source available (within voltage, frequency & phase balance limits)
  - c. Second engine start contact
  - d. Utility and Generator sources available
  - e. Transfer Fail
  - f. Load on Generator

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- g. Load on Utility
  - h. Load Shed
  - i. Generator Failure
  - j. Generator Running
  - k. ATS in normal
  - l. ATS in emergency
10. A set of gold-flashed contacts rated 10 amps, 28VDC shall be provided for a low-voltage engine start signal when the normal source fails.

**PART 3 - EXECUTION**

**3.01 INSTALLATION**

- A. Install equipment in accordance with manufacturer's recommendations, the Drawings and specifications, and all applicable codes.

**3.02 SERVICE**

- A. The supplier shall maintain a national service organization that is factory trained and certified for transfer switch equipment. In addition, the genset dealer organization shall be available 24 hours per day, 365 days per year.

**3.03 START-UP AND TESTING**

- A. Coordinate all start-up and testing activities with the Engineer and Owner. After installation is complete and normal power is available, the manufacturer's local dealer shall perform the following: Perform a 4 hour load bank test at a 1.0PF at full nameplate rating. Loadbank, cables and other equipment required for this test to be supplied by the genset supplier.

**3.04 OPERATION AND MAINTENANCE MANUALS**

- A. Provide two (2) sets of operation and maintenance manuals covering the generator, switchgear, and auxiliary components. Include final as-built wiring interconnect diagrams and recommended preventative maintenance schedules.

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### 3.05 TRAINING

#### A. On-Site Training

1. Provide on-site training to instruct the owner's personnel on the proper operation and maintenance of the equipment. Review operation and maintenance manuals, parts manuals, and emergency service procedures.
2. Training shall be provided in two (2) complete separate sessions to accommodate plant staff of varying shifts.
3. The instruction shall be dedicated and intensive and shall be provided by competent instructors fully familiar with the equipment.
4. The instructions shall be presented in an eight hour session. The Field Service engineer will provide Instructions on the operation and maintenance of the generator engine, alternator, battery system, circuit breaker, control system, and appurtenances.
5. The Owner will provide a suitable classroom environment on site for the instruction session.
6. The owner may elect to record the training sessions for future reference.
7. Training shall be scheduled with at least seven (7) working days advance notice.
8. Provide both classroom training and hands-on equipment operation covering the following:
  - a. Safety precautions
  - b. Features and construction of generator and accessories
  - c. Routine inspection, test and maintenance procedures
  - d. Routine cleaning
  - e. Routine preventative maintenance
  - f. Interpretation of readings of indicating and alarm devices
  - g. Review operating and maintenance manuals
  - h. Review troubleshooting operations

**END OF SECTION**

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## SECTION 26 41 00

### LIGHTNING PROTECTION SYSTEM

#### PART 1 -GENERAL

##### 1.01 DESCRIPTION OF WORK

- A. Provide a complete lightning protection system for the Plymouth, MA Communications Tower and Shelter Building. The system shall provide safety for the tower, shelter building and the buildings contents and occupants by preventing damage caused by lightning. The design of this system is to be in strict accordance with this section of the specifications and all Drawings that apply.
- B. The lightning protection system shall be designed and installed by a firm actively engaged in the installation of Master Labeled Lightning Protection Systems and shall be so listed by Underwriters Laboratories Inc. (UL).
- C. The work covered under this section of the specification consists of providing labor, materials and services required for the completion of a functional and unobtrusive lightning protection system approved by the engineer and Underwriters Laboratories Inc.

##### 1.02 RELATED DOCUMENTS

- A. Related Sections
  - 1. Section 26 05 00 Common Work Results For Electrical
  - 2. Section 26 05 26 Grounding & Bonding for Electrical Systems

##### 1.03 REFERENCES

- A. The completed lightning protection system shall comply with the latest issue of the following standards and form a part of this specification:
  - 1. NFPA 780, Standard for the Installation of Lightning Protection Systems
  - 2. UL 96A, Installation Requirements for Lightning Protection Systems

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**1.04 SUBMITTALS**

- A. Submit in accordance with Division 01 General Requirements.
- B. Submittal Package: Submit the shop drawings, product data, and quality control submittals specified below at the same time as one complete package. The shop drawings, and product data shall bear the seal of a professional engineer licensed to practice in the State of the project location.
- C. Shop Drawings: Detailed scale drawings of the complete system as proposed to be installed
- D. Product Data
  - 1. Catalog Sheets, specifications, and installation instructions
  - 2. Bill of materials
- E. Samples: One of each product if requested. Samples will be returned and if approved, may be used in the Work.
- F. Quality Control Submittals
  - 1. Proof that the firm installing the system is actively engaged in the installation of UL Master Labeled Lightning Protection Systems
  - 2. Installer's Qualifications Data: Include the following for each person who will be performing the Work:
    - a. Name
    - b. Employers name, business address, and telephone number
    - c. Name and addresses of the required number of similar projects on which meet the experience criteria
- G. Contract Closeout Submittals
  - 1. Master Label Application Form: One copy of completed and accepted Master Label Application Form from Underwriters Laboratories

**1.05 QUALITY ASSURANCE**

- A. The installing contractor shall furnish a UL Master Label or Letter of Findings upon completion of the installation.

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**PART 2 PRODUCTS**

**2.01 STANDARD**

- A. All materials used in the installation shall be new and shall comply in weight, size and composition as required by UL 96A and NFPA 780 and shall be labeled or listed by Underwriters Laboratories Inc. for use in lightning protection systems. The system furnished under this specification shall be the standard product of a manufacturer regularly engaged in the production of lightning protection equipment. The manufacturer shall be listed by UL as a recognized manufacturer of lightning protection components.

**2.02 MATERIALS**

- A. Class I materials shall be used on structures that do not exceed 75 feet in height and Class II materials shall be used on structures that are 75 feet or higher above average grade.
- B. Copper materials shall not be mounted on aluminum surfaces including Galvalume, galvanized steel and zinc; this includes these materials that have been painted.
- C. Aluminum materials shall not come into contact with earth or where rapid deterioration is possible. Aluminum materials shall not come into contact with copper surfaces.

**2.03 AIR TERMINALS**

- A. Air terminals shall project a minimum of ten inches above the object or area it is to protect and shall be located as required by the lightning protection standards and design requirements.
- B. Air terminals shall be installed on stacks, tower structures, mechanical units and other metallic objects not located within a zone of protection and which have an exposed metal thickness less than 3/16 of an inch. Objects having an exposed metal thickness 3/16 of an inch or greater shall be connected to the lightning protection system as required by the specified standards using main size conductor and bonding plates having a minimum of 3 square inches of surface contact area.
- C. Air terminal bases shall be securely fastened to the structure in accordance the specified standards including the use of adhesive that is compatible with the surface it is to be used on or stainless steel fasteners.
- D. Main conductors shall be sized in accordance with the specified standards for Class I or Class II structures and shall provide a two way horizontal or downward path from each air terminal to connections with the ground system. Conductors shall be free of excessive splices and no bend of conductor shall form a final included angle of less than neither 90 degrees nor have a radius of bend less than 8 inches.

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- E. Down conductors shall be sized in accordance with the specified standards and in no case shall be smaller than the main conductor. Down conductors shall be installed on each tower structure leg or supporting member. In no case shall a structure have fewer than two down conductors. In general, all down conductors shall be installed and connected to the facility grounding system. Where down conductors are installed exposed on the exterior of a structure and are subject to physical damage or displacement, guards shall be used to protect the conductor a minimum of 6 feet above grade. Down conductors may only be installed on the exterior of the building when it's not possible to install on the interior of the building and only when specifically approved by the Engineer. Metallic guards shall be bonded at each end.

**2.04 GROUND TERMINATIONS**

- A. Ground electrodes shall be copper clad steel and a minimum 3/4" diameter and 10 feet long. A ground electrode shall be provided for each down conductor. The down conductor shall be connected to the ground electrode using a bronze ground rod clamp having a minimum of 1 1/2" contact between the ground electrode and the conductor measured parallel to the axis of the ground electrode, or by an exothermically welded connection. Ground electrodes shall be located a minimum of 2 feet below grade and shall be installed below the frost line where possible (excluding shallow topsoil conditions).
- B. Where the structural steel framework is utilized as the down conductor for the system, ground terminals shall be connected to columns around the perimeter of the structure at intervals averaging not more than 60 feet apart. Columns shall be grounded using either bonding plates having 8 square inches of surface contact area or by exothermically welded connections.
- C. All ground electrodes shall be interconnected with a ground loop conductor on structures that exceed 60 feet in height. The ground loop conductor shall be sized in accordance with the specified standards and as shown on design drawings.

**2.05 EQUIPOTENTIAL GROUNDING**

- A. Common interconnection of all grounded systems within the building shall be insured by interconnecting to the lightning protection system using main size conductor and fittings.
- B. This interconnection shall include but is not limited to the electrical service, telephone and antenna system grounds as well as all underground metallic piping systems including water, gas and sewer. Interconnection to a gas or water line shall be made on the customer's side of the meter.
- C. Grounded metal bodies located within the required bonding distance as determined by the bonding distance formula in the latest edition of NFPA-780 Standard for the Installation of Lightning Protection Systems shall be bonded to the lightning protection system using the required bonding conductors and connections.

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## 2.06 SURGE PROTECTION

- A. Surge suppression shall be provided at all power service entrances and at entrances of conductive signal, data and communication services.

## PART 3 – EXECUTION

### 3.01 INSTALLATION

- A. The installation shall be installed by an UL listed lightning protection installation company. Acceptable companies shall have been installing UL listed lightning protection systems for a minimum of 5 years.

### 3.02 COORDINATION

- A. Coordinate the installation of the lightning protection system with other trades.

### 3.03 INSPECTION AND CERTIFICATION

- A. New Structures
  - 1. Upon completion of the installation of the lightning protection system the contractor shall furnish the UL Master Label issued by Underwriters Laboratories Inc.
- B. Additions or renovations
  - 1. If the protected structure is an addition to or is attached to an existing structure that does not have a functioning lightning protection system, the contractor shall certify that the new system installed complies with the specified standards and shall advise the owner on the lightning protection work required on the existing structure so that a Master Label may be obtained.
  - 2. If the protected structure is an addition to or is attached to an existing structure that does have a lightning protection system the contractor shall advise the owner of any additional work that may be required in order to bring the existing lightning protection system into compliance with the specified standards and thus qualify for a Reconditioned Master Label from Underwriters Laboratories Inc.

**END OF SECTION**