

**SECTION 16000
ELECTRICAL WORK**

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. In general, the work specified in this division of the specifications includes the furnishing of all labor, material, auxiliaries, and services necessary to install complete and properly operating electrical systems, including all fees and permits necessary.
- B. The Contractor shall be required to coordinate all electrical system connections with Duke Energy and shall furnish and install all equipment or material necessary to provide complete electrical services in accordance with all their requirements.

1.2 GENERAL REQUIREMENTS

- A. Provide and submit for approval electrical line drawings, control wiring diagrams, SCADA system diagrams and electrical details in adequate detail to ensure a fully operational system.
- B. The Contractor shall furnish and install all wire, cables, conduits, wiring, wiring devices, boxes, lighting fixtures, motor controllers, safety switches, relays, control equipment, and all other accessories indicated, specified or required for complete power, control and instrumentation systems for the project facilities. The basic materials and methods included in this section shall be applicable throughout the project.
- C. All electrical apparatus and lighting equipment shall be in compliance with the Florida Building Code Fifth Edition (2014) Energy Conservation, and the Federal Energy Policy Act of 2005, including all subsequent updates, revisions, and replacements.

1.3 SUBMITTALS

- A. A complete design for the overall electric system shall be submitted for review and approval. All elementary and schematic diagrams shall be provided with indication of system coordination and complete description of sequence of operation.
- B. A complete operation and maintenance instruction manual, including system schematics which reflect "as-built" modifications, shall be provided. All drawings included within the operation and maintenance manuals shall be reduced to a maximum dimension of 11 inches x 17 inches and shall be legible and reproducible. One copy of the operation and maintenance manual submittal shall be provided in PDF format.
- C. One complete set of design drawings shall be neatly marked as a record of the "as-built" installation. The drawings shall reflect the actual installed locations of all equipment and indicate the exact routing and elevations of all concealed conduits. One copy of the final as-built drawings shall be provided in PDF format.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. All material shall be new and shall conform with the standards of the Underwriter's Laboratories, Inc., American National Standards Institute, National Electrical Manufacturers' Association, Insulated Power Cable Engineers Association, and Institute of Electrical and Electronic Engineers in every case where such a standard has been established for the particular type of materials in question.
- B. The use of a manufacturer's trade name and catalog number is not intended to indicate preference but only the type and quality of the product desired. Products of reputable manufacturers of equal quality and functional type will be acceptable. Substitutes which tend to lower the quality of the work will not be permitted.

Acceptance of alternate equipment does not relieve the Contractor of the responsibility of compliance with the performance and accuracy requirements of these specifications. In all cases, the burden of proof that the material or equipment offered for substitution is equal in construction, efficiency, and service to that named shall rest on the Contractor and, unless the proof is satisfactory to the Engineer, the substitution will not be approved.

- C. Wherever possible, equipment items having the same or similar rated capacity or function shall be identical.

2.2 RACEWAYS

- A. Metallic Conduit (Aluminum): All conduit shall be heavy wall rigid aluminum of standard pipe weight unless noted otherwise.
 - 1. Couplings, conduit unions, conduit fittings, etc., shall be aluminum, shall have conventional trade dimensions, and shall be internally threaded with a tapered thread at each end to fit the tapered thread specified for the corresponding size conduit. Conduit outlet body covers shall be cast construction.
 - 2. All conduits, couplings, and fittings run exposed to corrosive atmospheres, and all conduit elbows and risers within concrete encasement shall have a gray or black factory-applied PVC coating of not less than 20 mils thickness. Damaged PVC coatings shall be repaired with an approved compound. Conduit supports, channels, and mounting apparatus shall be type 316 stainless steel.
- B. Flexible Conduit: All flexible conduit shall be Type LTA liquid-tight flexible aluminum conduit made with flexible aluminum core covered with an extruded PVC jacket, unless noted otherwise. Fittings shall be the type specifically designed for flexible conduit use and shall form watertight connections. Flexible conduit fittings shall be aluminum construction.
 - 1. Flexible conduit shall only be used for connections from conduits, junction boxes, or motor controllers to mechanical equipment or where the location of the connection is such that it is impractical to make a rigid conduit connection, where vibration isolation is required, or where specifically called for on the drawings. Flexible conduit shall be used for connection to all motors.

C. Non-Metallic Conduit: Non-metallic conduit, couplings, and fittings shall be Schedule 40 PVC unless noted otherwise. All PVC conduit joints shall be solvent-welded in accordance with the manufacturer's recommendations.

1. Underground conduits and conduit embedded within slabs on grade shall be non-metallic; however, conversion shall be made to rigid metallic conduit before conduit runs exit encasement. Conversion elbows, fittings and risers within the concrete encasement shall be PVC coated rigid aluminum conduit.
2. Underground conduits shall be installed not less than 24 inches below grade.
3. Underground pull boxes shall be provided for all miscellaneous underground conduit runs over 200 feet long.
4. A minimum 3-inch-wide polyethylene warning tape, yellow for electrical and orange for telephone, with imprinted legend, shall be installed in the backfill above all underground conduits. Warning Tape shall be Allen Terra Tape, or equal and shall be guaranteed not to discolor. Unless indicated otherwise, the tape shall be 12 inches below the finished ground grade.

2.3 WIRES AND CABLE

- A. Low Voltage Cable: Low voltage wire and cable shall be 600 volt, single-conductor copper, rated 90 degrees C dry and 75 degrees C wet. Unless indicated otherwise, low voltage building wire shall have XHHW-2 insulation.
- B. Instrumentation Cable: Instrumentation cable shall be single twisted pair or triad as indicated.
1. Twisted shielded pair cable shall be stranded, tinned copper conductors with cross-linked polyethylene primary insulation, overall foil shield with tinned copper braid, and chlorinated polyethylene jacket, 600V; Belden 3072F.
 2. Twisted shielded triad cable shall be stranded, tinned copper conductors with cross-linked polyethylene primary insulation, overall foil shield and chlorinated PVC jacket, 300V; Belden 8770.

2.4 TERMINAL BLOCKS AND WIRE MARKING

- A. Terminal blocks for power conductors shall be 600 volt, three pole unit construction type with high pressure solderless connectors, headless socket screws, and ampere rating equal to or greater than the ampacity of the maximum conductor size to be terminated; Square D Type LBC, or equal.
- B. Terminal blocks for control and instrumentation conductors shall be 600 volt, sectional rail mounted terminal blocks with plastic pre-printed terminal numbering markers on both the inside and outside tracks, and provisions for center terminal bridge jumper cross connections with no loss of space on terminal or rail; Siemens 8WA1 011-1DF11, or equal. Terminal blocks for general control connections shall be feed-through terminal blocks; terminal blocks for instrumentation signal circuits shall be knife type test/disconnect terminal blocks; and terminal blocks for cable shield termination and grounding shall be ground blocks.
- C. Cable and conductor markers shall be heat shrinkable sleeve markers with permanent legible

machine printed markings.

2.5 BOXES

- A. General: Boxes shall be installed at all locations necessary to facilitate proper installation and equipment connection, including each conduit/cable transition.
1. Minimum dimensions of boxes shall not be less than NEC requirements and shall be increased if necessary, for practical reasons or where required to suit conditions.
 2. Boxes shall have only the holes necessary to accommodate the conduits at point of installation. All boxes shall have lugs or ears to secure covers.
 3. All boxes shall be rigidly secured in position. All boxes, except on unfinished ceilings and walls, and where conduit is run exposed, shall be so set that the front edge of box shall be flush with or recessed not more than 1/4-inch behind the finished wall or ceiling line.
- B. Outlet Boxes: The location of outlets will be determined in the field. All outlets shall be coordinated with the work of other sections of these specifications to prevent outlets or fixtures from being covered by pipe, duct, etc.
1. Outlet boxes shall be cast aluminum one piece hub type standard gang boxes with rubber gaskets. Wiring device boxes shall be equipped with cast screw-type covers; Crouse-Hinds Series FS or equal.
- C. Pull Boxes: Pull boxes, including junction boxes and terminal boxes, shall be installed at all necessary points, whether indicated or not, to prevent injury to the insulation or other damage that might result from pulling resistance or other reasons during installation. Unless indicated otherwise, pull boxes shall be NEMA 4X aluminum or 316 stainless.
- D. Underground Pull Boxes: Underground pull boxes shall be minimum 30-inch x 17-inch x 18-inch deep compositolite service boxes constructed of reinforced polymer concrete suitable for traffic loading, with locking cover and molded logo.

2.6 WIRING DEVICES

- A. Wall Switches: Wall switches shall be specification grade, totally-enclosed, toggle switches rated 20 ampere, 120/277 volt. Switches shall be single pole, double-pole, 3-way, or 4-way as indicated; GE-5951 through 5954, Hubbell 1221 through 1224, Leviton 1221 through 1224, or equal. Wall installed outdoors or in corrosive atmospheres shall be weatherproof and vapor-tight. Weatherproof and vapor-tight switches shall consist of standard wall switches as previously specified, enclosed in Series FS condulets equipped with vapor-tight gasketed covers; Appleton Series FSK- 1VTS-A, or equal.
- B. Receptacles: Receptacles shall be specification grade, grounding type, totally- enclosed, duplex receptacles rated 20 ampere, 125 volt; GE 8300-9, Hubbell 5362- GRY, Leviton 5362-GY, or equal.
1. Receptacles installed outdoors or in corrosive atmospheres shall be weatherproof. Weatherproof receptacles shall each consist of standard duplex receptacles as previously specified, enclosed in Series FS conduit equipped with a weatherproof

cover; Crouse-Hinds WLRD or equal. Outdoor receptacle covers shall be aluminum in-use covers; Crouse-Hinds WIUMV, or equal. Outdoor receptacles installed on circuits without ground fault protection shall be type GFCI.

2.7 MOTOR STARTERS

- A. Manual Motor Starters: Manual motor starters shall be 600-volt, toggle-type suitable for installation within standard outlet boxes. Enclosures for all starters not installed in outlet boxes, and all starters located outdoors, or in corrosive atmospheres, shall be NEMA 4X aluminum or type 316 stainless steel.
- B. Magnetic Motor Starters: Unless indicated or required otherwise, each motor starter shall be of the combination type complete with molded case motor circuit protector; full-voltage magnetic starter; manual resetting, 3-pole, bimetallic thermal overload relay; individual 120-volt control power transformer; enclosure door-mounted pilot control devices; and all required accessory control components.
 - 1. Motor starter enclosures located outdoors, or in corrosive atmospheres, shall be NEMA 4X type 316 stainless steel.
 - 2. Unless indicated otherwise, motor starters for all motors 25 hp and above shall be of the solid-state reduced voltage type.

2.8 DISCONNECT SWITCHES

- A. Disconnect switches shall be 600-volt rated heavy-duty safety switches with full cover interlocks and quick-make, quick-break mechanisms. Switches shall be fused or non-fused, of capacities noted; Square-D Type HD or equal.
 - 1. Disconnect switches located outdoors, or in corrosive atmospheres, shall have NEMA 4X type 316 stainless steel enclosures.
 - 2. Unless indicated otherwise, fuses shall be Mersen type TRS-R Class RK5 current limiting time-delay fuses.

2.9 CIRCUIT BREAKERS

- A. Circuit breakers shall be 600-volt thermal magnetic, quick-make, quick-break molded case air circuit breakers, with trip-free operation, incorporating an internal trip bar and a single external handle. Circuit breaker ratings shall be coordinated with the installed service and loads supplied. Unless indicated otherwise, circuit breakers shall be rated not less than 25,000 amperes RMS symmetrical.
 - 1. Enclosed circuit breakers located outdoors, or in corrosive atmospheres, shall have NEMA 4X type 316 stainless steel enclosures.
 - 2. Circuit breakers used as a service disconnecting device shall be 100% rated and UL service entrance rated; shall be equipped with long time, short-time, instantaneous and ground fault adjustments for system selectivity; and shall be fully rated for the maximum fault current, without the use of current limiters.

2.10 SUPPORT SYSTEMS

- A. Groups of two or more conduits, and all boxes and equipment, shall be mounted on a system of minimum 1-5/8-inch x 1-5/8-inch heavy wall aluminum or 316 stainless steel channel with a minimum of 25% unused capacity.
- B. Support system hardware shall be aluminum or stainless steel.

2.11 CONTROL DEVICES

- A. Control Stations - Control stations shall be 30 mm, heavy-duty, corrosion resistant, water-tight and oil-tight, complete with NEMA 13 cast aluminum enclosures: Eaton Type E34, Square-D Type SK, or equal.
 - 1. Safety lockout stations (SAFE-OFF) shall be equipped with 316 stainless steel padlock devices for padlocking in the de-energized position: Eaton 10250A63, Square-D Type K5, or equal.
 - 2. Control stations installed outdoors, or in corrosive atmospheres, shall have watertight, NEMA 4X cast aluminum enclosures.

2.12 CONTROL COMPONENTS

- A. General - Where indicated or required by the functions specified, control components shall be furnished and installed with-in control panels, motor control center, or other approved locations. Suitable nameplates shall be provided for all panel door or surface-mounted control devices. All component terminals, including auxiliary contacts, shall be wired to master terminal boards.
- B. Instruments - Instruments shall be of standard size not less than 5-1/2" in width and they shall present a uniform appearance when mounted upon the panels. Instruments shall have scales 5" in length and shall be accurate within 1% of full scale. Instrument scales shall be selected with full-load readings at 75% of the scale range, unless specified otherwise or approved.
- C. Pilot Devices: Selector switches, pushbuttons, indicating pilot lights, and additional pilot devices as required, shall be 600-volt rated heavy-duty, oil-tight, 30mm pilot devices as manufactured by General Electric, Cutler-Hammer, or equal.
 - 1. Pushbuttons shall be standard type with anodized aluminum rings and colored buttons.
 - 2. Selector switches shall be standard handle type with anodized aluminum rings and handles.
 - 3. Pilot lights shall be full brightness LED type.
 - 4. All pilot devices shall have appropriate nameplates and locking means for locking in the de-energized mode, and shall be color coded (red - start, on, open, up; green - stop, off, close, down; black - test, silence, miscellaneous).
- D. Running Time Meters - Hour meters shall be non-reset type with register to indicate hours and tenths of hours up to 99,999.9 hours. Each meter shall be a 2-1/2" round panel mounting type, suitable for operation on 120-volt control circuits; Engler Model 10NG1 or equal.
- E. Control Relays - Where required for control system operation, control relays shall be 3P3T,

11 pin octal type, with 10-amp contacts, internal LED, test button, and large ice cube style case; Cutler-Hammer D3PF3AA, D3PF3AT1, or equal.

1. Time delay relays shall be potentiometer adjustable time setting, 1.0% repeatability, 2PDT plug-in type time delay relays with, 10-amp contacts, 8-pin square sockets and hold-down springs. Delay on de-energize mode shall not require input power during the timing; Potter & Brumfield CK Series, or equal.

F. Power Monitors: Where required for control system operation, 3 phase power monitors shall be provided. Power monitors shall be surface-mounted type consisting of a phase angle sensing circuit driving a DPDT electromechanical relay. Power monitors shall sense loss of any phase, low voltage on any or all phases, and phase sequence reversal.

Power monitors shall be field-adjustable, provided with fault indication, and adjustable time delay (0-20 seconds); Diversified Electronics Series SLD or equal.

G. Alarm Horns: Alarm horns shall be piezoelectric audible signal devices; Mallory Sonalert, or equal. Each alarm horn shall be equipped with an enable/disable control switch. Unless indicated otherwise, alarm horns shall be installed within the associated control equipment enclosure. Exterior alarm horns shall be weatherproof semi-flush mounted.

2.13 CONTROL PANELS:

A. Where indicated on the drawings, specified, or required by the functions specified, control panels, including all necessary accessories, shall be provided for power distribution and control of the associated equipment. Each control panel shall be equipped with an incoming line main circuit breaker and an incoming line surge protection device (SPD). Each three-phase control panel shall be equipped with a three-phase power monitor.

B. Control panel components shall be inner-panel or door-mounted, wired to terminal boards with identifying numbers. All contacts, including spare auxiliaries, shall be wired to terminal boards. All wiring shall be neatly bundled with wire ties, or in wireways, and all wiring shall be identified by color coding and numbering. Wiring shall be coded: black - primary power; red - AC control wiring; blue - DC control wiring; white - neutral; and green - ground.

C. Unless indicated otherwise, each control panel shall be furnished with red (running) and green LED pilot lights, H-O-A selector switch, circuit breaker type combination motor starter, running time meter and control circuit equipment for each motor controlled. Motor starters for all motors 25 HP and above shall be the solid-state reduced voltage type. Multiplex control panels shall be furnished with an automatic alternator and lead selector switch. Each control panel shall be equipped with an independent control power system including all required control power transformers, protective fusing, and separate control power main breaker. Control panels shall be equipped with power monitors, an exterior red flashing alarm light, alarm horn, alarm test switch, and a 120-volt convenience outlet.

D. Control panels shall be furnished with a thermostatically controlled condensation heater and all additional accessories as indicated. Control operation shall be as specified or as required for proper operation of the equipment controlled. In general, for each associated alarm condition, control panels shall be furnished with amber pilot lights and auxiliary contacts for remote indication.

E. Exterior panels shall be NEMA 12/3R with oil-resistant gasketing and full-sized door-in-door

construction. Inner door shall have door-mounted control devices and slotted flush latch. Blank outer door shall have three-point latching handle with padlocking provisions.

- F. A compact cooling fan shall be installed inside the enclosure to provide air circulation and eliminate hot spots within the enclosure. The fan shall provide 50,000 hours of continuous operation without lubrication or service. Finger guards shall be mounted on each side of fan for safety. The enclosure shall be oversized as required to eliminate the need for an enclosure air conditioning system.
- G. Control panel enclosures shall be Type 316 stainless steel with all stainless-steel hardware.

2.14 GROUNDING

- A. The project's grounding system shall consist of a grounding electrode system in accordance with NEC specifications, bonded to a main ground bus interconnecting all power distribution equipment. Ground rods shall be located at each outdoor electrical equipment pad, and as indicated or required, and shall be bonded to the main ground bus. Ground rod sections shall be coupled and driven to establish a maximum resistance to remote earth of 5 ohms throughout the grounding system.
- B. Ground rods shall be minimum 10 feet long, 5/8-inch diameter, copper-clad steel sections.
- C. Main ground bus cable shall be minimum No. 1/0, 19 strand tinned copper. Bonding jumpers shall be minimum No. 2 tinned copper.
- D. Unless noted otherwise, all grounding conductors shall be insulated and shall have green colored insulation.
- E. All grounding hardware such as clamps, connectors, couplings, lugs, bolts, nuts, and washers shall be of silicone bronze.

2.15 SURGE PROTECTION

- A. The Contractor shall furnish and install UL 1449 (latest edition) listed surge protection devices (SPD) for the protection of all AC electrical circuits from the effects of lightning-induced currents, substation switching transients, and internally generated transients from inductive and/or capacitive load switching. Surge protection devices shall be provided for all switchgear, switchboards, motor control centers, power distribution panels, lighting panels, control panels, instrumentation panels, etc.
- B. Each SPD unit shall be marked with a short circuit current rating and shall not be installed at a point on the system where the available fault current is in excess of that rating.
- C. Complete UL 1449 performance ratings, including the fault current rating and VPR rating, shall be posted on the UL label of each SPD.
- D. Submit copies of the UL Standard 1449 Listing documentation for each proposed SPD.
- E. AC power surge protection devices (SPD), formally transient voltage surge suppressors (TVSS),

shall utilize heavy duty ‘large block’ MOVs, each exceeding 30mm diameter, with redundant modules per phase. SPD equipment shall provide suppression elements between all phases and each phase conductor and the system neutral. AC power surge protection equipment shall be APT, or equal.

- F. SPD shall be UL labeled as Type 1, intended for use without need for external or supplemental overcurrent controls. Every suppression component of every mode, including N-G, shall be protected by internal overcurrent and thermal overtemperature controls. SPDs relying upon external or supplementary installed safety disconnectors do not meet the intent of this specification.
- G. SPD shall be UL labeled with 200kA Short Circuit Current Rating (SCCR). Fuse ratings shall not be considered in lieu of demonstrated withstand testing of SPD, per NEC 285.6.
- H. SPD shall be UL labeled with 20kA Inominal (I-n) for compliance to UL 96A Lightning Protection Master Label and NFPA 780.

I. Minimum surge current capability (single pulse rated) per phase shall be:

Service Entrance Equipment:	300kA
Power Distribution Equipment:	200kA
Panelboards & Control Panels:	100kA

- J. SPD shall provide surge current paths for all modes of protection: L-N, L-G, and N-G for Wye systems; L-L, L-G in Delta and impedance grounded Wye systems.
- K. UL 1449 Listed Voltage Protection Ratings (VPRs) shall not exceed the following:

System Voltage	L-N	L-G	L-L	N-G
208Y/120	700V	700V	1200V	700V
480Y/277	1200V	1200V	1800V	1200V

Numerically lower is allowed/preferred; old-style Suppressed Voltage Ratings (SVRs) shall not be submitted, nor evaluated due to outdated less-strenuous testing)

L. UL 1449 Listed Maximum Continuous Operating Voltage (MCOV):

System Voltage	Allowable Voltage Fluctuation (%)	MCOV
208Y/120	25%	150V
480Y/277	15%	320V

- M. SPD shall have UL 1283 EMI/RFI filtering with minimum attenuation of -50dB at 100kHz.
- N. SPD shall include visual LED diagnostics including a minimum of one green LED indicator per phase, and one red service LED. SPD shall include an audible alarm with on/off silence function and diagnostic test function (excluding branch).
- O. Warranty – Each SPD shall have a warranty period of not less than 10 years, incorporating unlimited replacements of suppressor parts if they are destroyed by transients during the

warranty period.

PART 3 - EXECUTION

3.1 CODES, PERMITS, AND INSPECTIONS

- A. The installations shall be in accordance with the regulations of the latest editions of the National Electrical Code, National Electrical Safety Code, applicable city, state, and local codes and regulations and other applicable codes, including utility company codes.
- B. All permits required by state or local ordinances shall be obtained and after completion of the work, a certificate of final inspection and approval from the electrical inspector shall be furnished to the Owner. All permits for installation, inspections, connections, etc., shall be taken out and paid for as part of the work under this section.

3.2 CONDUIT INSTALLATION

- A. Unless otherwise indicated, exposed conduit shall be rigid aluminum, underground conduit and conduit encased in concrete shall be Schedule 40 PVC. Conduit transitions from underground or encased to exposed shall be PVC coated rigid aluminum, including the transition elbows and risers.
- B. All conduits shall be run in such a manner as to cause the least interference with other trades. Conduits shall be joined by means of couplings or 3-piece coupling type conduit unions. Joints shall be set up tight. Runs shall be straight and true; elbows, offsets, and bends shall be uniform and symmetrical. Installation workmanship shall be of the best quality and skill.
- C. Conduits shall be of sizes required to accommodate the number of conductors in accordance with the tables given in the current edition of National Electrical Code or as noted on the drawings. The minimum size of conduit shall be 3/4-inch.
- D. Conduit runs shall terminate below the particular section of the motor control center or equipment to which their respective circuits run. Concealed conduits shall be run in as direct a line as possible. Exposed conduits shall be run parallel to or at right angles with the lines of the building. All bends shall be made with standard conduit ells, conduit bent to not less than the same radius, or aluminum conduit outlet bodies with gasketed cast iron covers. Adjacent conduit runs shall be installed with concentric bends. All bends shall be free from dents or flattening. Not more than the equivalent of four quarter bends shall be used in any one run between terminals at cabinets, outlets, and junction or pull boxes. Boxes shall be located in accessible locations.
- E. Conduit shall be continuous from outlet to outlet and from outlets to cabinets, junctions, or pull boxes and shall enter and be secured to all boxes in such a manner that each system shall be electrically continuous from point of service to all outlets. Insulated grounding bushings shall be used on all metallic conduit. Terminals of all conduits shall be plugged with an approved cap to prevent the entrance of foreign materials when exposed during construction.
- F. As far as practicable, all exposed conduits shall be run without traps. Where dips are unavoidable, a pull box or approved conduit outlet body shall be placed at each low point. Conduit systems shall be completed before conductors are drawn in.

- G. Where exposed conduit needs clamping to the structures, clamps shall consist of aluminum 1-hole pipe straps and pipe spacers, stainless steel bolts of appropriate size to fill the holes in the straps and spacers, and approved expansion shields. Clamps used with aluminum conduit, and clamps located outdoors or in "corrosive atmospheres", shall be PVC coated, aluminum or type 316 stainless steel. Clamps shall be bolted to the structure or where necessary to intermediate type 316 stainless steel brackets. Spacing between conduit supports shall not exceed the recommendations published by the National Electrical Code. No deformed, split, or otherwise defective conduit or fitting shall be installed. Conduit shall be installed with a minimum number of joints.
- H. Aluminum Myers hubs shall be used for all threaded conduit connections to enclosures that do not contain integral threaded conduit hubs. Conduit connections to enclosures located outdoors shall only enter the bottom of the enclosure.
- I. Where conduit has been cut in the field, it shall be cut square using a hand or power hacksaw or approved pipe cutter using cutting knives. The use of pipe cutters with cutter wheels will not be permitted. The cut ends of the field-cut conduit shall be reamed to remove burrs and sharp edges. Where threads have to be cut on conduit, the threads shall have the same effective length and shall have the same thread dimensions and taper as specified for factory-cut threads on conduit. Conduits installed in the work with threads not complying with these requirements shall be removed and replaced.

Where conduit installed in concrete or masonry extends across building joints, expansion joints with approved type grounding straps and clamps shall be installed. Expansion joints shall be Type XJ as manufactured by Crouse-Hinds, Appleton, or equal. Where conduit enters a building through the concrete foundation, below final grade, approved type FSK entrance seals shall be used.

- J. All conduit shall be cleaned, prior to pulling in wire and cable, by pulling a stiff wire brush of the size of the conduit through it. This cleaning shall remove all foreign matter, including water, from the conduit. All boxes in which the conduit terminates shall be cleaned of all concrete, mortar, or other foreign matter and all threads in boxes shall be left clean and true upon completion of the work.
- K. All spare, future, or empty conduits shall be equipped with a pull wire prior to capping.
- L. All conduits, fittings, and electrical equipment used within hazardous areas shall comply with requirements of the National Electrical Code for the type of hazardous location encountered and shall be furnished as specified for "corrosive atmospheres".
 - 1. In such hazardous locations, conduits terminating at boxes enclosing electric switching, or circuit opening equipment, shall be sealed at the entrance to the enclosure with approved, compound-filled, sealing fittings to prevent passage of explosive or combustible gases through the conduits.
 - 2. All conduits exiting from such hazardous locations or entering said locations shall be similarly sealed at point of exit or entrance.

3.3 WIRE AND CABLE INSTALLATION

- A. The installation of wires and cables includes all splicing of these wires and cables to each

other and connecting them to receptacles, switches, control boxes, lighting fixtures, motors, and all other electrical apparatus installed under this Contract. All cable installation methods shall correspond to manufacturer's recommendations.

- B. Wire and cable shall be suitably protected from weather or damage during storage and handling and it shall be first-class condition when installed.
- C. The minimum size of wire or cable conductor shall be No. 12, unless indicated otherwise on the drawings. Wire sizes No. 8 and larger, and all wire sizes utilized for control or instrumentation, shall be stranded. All sizes called for in the specifications or shown on the drawings are American Wire Gauge sizes.
 - 1. No wire smaller than No. 12 shall be used for any branch circuit unless noted otherwise on the drawings. Larger sizes shall be used where required or indicated on the drawings. If the single distance from the panelboard to the first device exceeds 50 feet, the minimum size for this run shall be No. 10 AWG with the minimum between devices as No. 12 AWG.

All sizes of wire and cable furnished and installed under these specifications shall be color-coded with a separate color for each phase and neutral used consistently throughout. Each conductor shall have factory color-coded insulation. As an alternative, wire sizes No.8 and larger shall have black insulation and shall be color-coded with waterproof phasing tape at each termination, junction box, pull box, etc. All 277/480 volt wiring shall be color-coded yellow, brown, and orange for hot legs (Phase A, B, and C, respectively). All 120/208-240-volt wiring shall be color-coded black, blue, and red for hot legs (Phase A, B, and C, respectively). The grounded neutral conductor of each circuit shall be color-coded white. Grounding conductors shall be color-coded green.

- D. All wires and cables shall, as far as practicable in the judgment of the Engineer, be continuous from origin to destination without running splices in intermediate pull boxes, junction boxes, or wireways. At the ends of these wires and cables, only sufficient slack shall be left as may be required for making proper connections. There shall be no unnecessary slack.
- E. In connecting wires and cables to apparatus, various methods shall be used depending upon the local conditions. In general, solderless pressure connectors shall be used for terminals, taps, and splices for all wires and cables. Solderless pressure connectors or vinyl-covered steel spring-type connectors shall be securely fastened and shall not loosen under vibration or normal strain. All connections shall be in accordance with manufacturer's recommendations and shall be with connectors approved for the particular connection conditions.
- F. Where wires and cables are connected to metallic surfaces, the coated surfaces of the metal shall be polished before installing the mechanical connector. The lacquer coating of the conduits shall be removed where a ground clamp is to be installed.
- G. All soldered joints shall be made mechanically strong before soldering and shall be carefully soldered without the use of acid and shall be taped with insulating tape to a thickness equal to that of the insulation.
- H. The installation of wires and cables shall include the furnishing and installing of all hangers, racks, cable cleats, and supports that may be necessary to make a neat and substantial wiring installation in all pull boxes, wireways, cable channels, and in such other locations as may be

required. Plastic ties shall be used to hold the wires and cables together and to the racks or supports.

- I. Each junction box, terminal box, control cabinet, or other terminal location containing a total of 4 or more conductor terminations or splices, shall be equipped with 1 or more terminal boards, as required, for connecting each wire including the spare wires. Each wire terminal shall be permanently marked throughout the entire system using, wherever possible, the notation of the wires given on the manufacturer's wiring diagrams. Sufficient terminal blocks shall be provided to terminate all wires routed to the enclosure including all spare conductors. In addition, the greater of 20 percent or four unused spare terminals shall be provided. All connections for future functions shall be wired to numbered terminal blocks, grouped separate from the terminal blocks in use. Terminal blocks shall be grouped to isolate power conductors from control conductors and to separate AC circuits from DC circuits.
- J. Each control, instrumentation, and power cable and conductor shall be marked with the proper feeder symbol or termination number in each manhole, handhole, pull box, wireway, terminal cabinet, panelboard, switchboard and all additional locations required to provide positive identification. Each conductor shall be marked at each point of termination following final installation.
- K. The electrical installation shall maintain suitable isolation between power, control and instrumentation conductors. Approved isolation barriers shall be provided within each pull box, terminal box, wireway, cable tray, handhole, manhole, etc.

3.4 GROUNDING

- A. The concrete-encased steel reinforcement within the foundation of each structure shall be grounded, with a minimum of one 20-foot ground rod, at each corner column and at intermediate columns at distances not to exceed 60 feet. The main ground bus shall be interconnected to each ground rod throughout the structural grounding system with a continuous bare copper cable loop, minimum No. 4/0 (19 strand), buried 30 inches below grade and 24 inches outside the structural footing.
- B. A minimum of one 20-foot ground rod shall be located within each manhole and handhole. The main ground bus shall be interconnected to each ground rod throughout the underground conduit bank system with a continuous tinned copper cable, minimum No. 1/0 (19 strand), installed within the backfill 6 inches above the direct buried conduits.
- C. All grounding connections shall be made in the same manner as current carrying connections are made with bolted clamps and solderless connectors. All underground grounding system connections, cable-to-cable, cable-to-ground rod, etc., shall be made with exothermic-fused connections. Contact surfaces shall be equal in area to those of current carrying connectors. All contact surfaces shall be thoroughly cleaned before connections are made.
- D. All ground connections shall be made with connectors or lugs approved for the specific type of connection.
- E. Insulated-type grounding bushings shall be used for all metallic conduit terminations.
- F. Permanent and effective ground connections shall be provided for transformer secondary

neutrals.

- G. The metallic frame of each motor, generator, transformer, panelboard, lighting fixture, outlet box, control equipment enclosure, etc. shall be grounded to the ground bus of the power distribution equipment with an insulated grounding conductor included in the feeder or branch circuit conduit.
- H. Installed ground cables shall be protected from subsequent mechanical damage. Sleeves shall be provided in foundation walls and in floors to facilitate installation of ground cables. Where ground cables enter buildings through sleeves, the sleeves shall be sealed with jute packing and approved sealing compound.

3.5 SURGE PROTECTION

- A. Surge protection devices (SPD) shall be provided for all switchgear, switchboards, motor control centers, power distribution panels, lighting panels, control panels, instrumentation panels, etc.
- B. Service Entrance - Each SPD installed on service entrance equipment shall be replaceable modular construction. A UL approved disconnect switch shall be provided as a means of servicing disconnect if a 60A breaker is not available.
- C. Power Distribution - Each SPD installed on switchboards or motor control centers shall be replaceable modular construction. Each SPD shall have an independent means of servicing disconnect such that the protected power distribution equipment remains energized. A 30A breaker (or larger) may serve this function.
- D. Sub Panels - Each SPD installed on power distribution panelboards, lighting panelboards, control panels, unit equipment, etc. shall be encapsulated construction.
- E. SPD equipment shall be installed per manufacturer's installation instructions with lead lengths as short (less than 24") and straight as possible. Gently twist conductors together.
- F. Installer may reasonably rearrange breaker locations to ensure short & straightest possible leads to SPDs.
- G. SPD shall be installed on the load side of the main service disconnect.
- H. Before energizing, installer shall verify service and separately derived system Neutral to Ground bonding jumpers per NEC.
- I. Status indication pilot lights for each SPD shall be remote mounted and shall be visible from the front of the protected equipment enclosure.

3.6 TESTING

- A. Upon completion, the Contractor shall provide all necessary instruments and special apparatus to thoroughly test the complete installation and shall conduct all tests that may be required to ensure system is free of all improper grounds and short circuits, and that all the feeders are properly balanced. All electrical equipment shall be tested to determine proper

polarity, phasing, relay settings, and operation. System shall be checked for quality and completeness. Any objectionable noise, heating, voltage drop, or excessive current draw, after in operation, shall be identified and corrected.

- B. Prior to energization, the electrical system ground resistance shall be tested. Additionally, the insulation resistance of all electrical gear, power feeders, and electric motors shall be measured. Upon completion of all corrective measures required, certified acceptance reports, including tabulations of all initial and final resistance measurements, shall be submitted for approval.
- C. Each motor starter overload element, and each motor circuit protector, shall be selected and adjusted to coordinate with the nameplate full-load current and service factor of the actual motors installed. Improper units shall be replaced. Upon completion of all corrective measures required, certified compliance reports, including tabulation of the actual full load current and voltage measurements for each phase of each motor, together with the nameplate current rating, overload element rating, and motor circuit protector setting, shall be submitted for approval.
- D. System testing shall include complete circuit breaker tests for each power circuit breaker and complete thermal surveys of all new and existing electrical apparatus. Upon completion of all corrective measures required, certified acceptance reports, including satisfactory infrared photographs, shall be submitted for approval.

3.7 GUARANTEES

- A. All materials and workmanship shall be guaranteed to be free from defects. Any part of the system considered defective by the Engineer within the guarantee period shall be immediately replaced or corrected without further expense to the Owner.
- B. Upon final completion, the Contractor shall furnish certification from each equipment manufacturer that all equipment has been installed in accordance with the requirements of these specifications, is ready for permanent operation, and that nothing in the installation shall render the warranty null and void.

END OF SECTION