

SECTION 16401
LOW-VOLTAGE ELECTRICAL WORK—GENERAL REQUIREMENTS

PART 1 GENERAL

1.01 SCOPE OF WORK

The Contractor shall furnish all labor, materials, equipment, and incidentals necessary for a complete corrosion-resistant and operable electrical installation, including all fees, charges, and permits necessary. Work of this Section includes electrical installation requirements for equipment of other Sections. This Section is general and may include specifications for materials and equipment not contained within the scope of this project.

- A. The Contractor shall provide temporary and permanent electrical services of proper voltage and phase as required for the Project. All single-phase temporary receptacle outlets shall be provided with ground fault protection in accordance with NEC Article 590.6 and installed in accordance with NEC 406.8.
- B. The Contractor shall coordinate the work of this Section with others involved in the construction of the project.
- C. The Contractor shall coordinate with the local power company to schedule and arrange for connection of the proposed electrical systems to the electrical distribution system.

1.02 RELATED WORK

- A. The provisions of all other Technical Sections of the Specifications are fully applicable to this Section as if incorporated in this Section.

1.03 SUBMITTALS

- A. The Contractor shall submit a complete list of materials and equipment to be incorporated in the work to the Owner for review within 30 days after the Award of Contract.
- B. The list shall include catalog numbers, cut sheets, diagrams, and other descriptive data required to demonstrate conformance with the Specifications. Partial lists will not be acceptable.
- C. The basis of acceptance shall be the manufacturer's published ratings for the equipment. The manufacturer shall be regularly engaged in the manufacture of products specified.

- D. Shop drawings shall be submitted for the following items of equipment:
1. Wiring Devices
 2. Safety Switches
 3. Circuit Breakers
 4. Motors
 5. Motor Starters
 6. Relays
 7. Control Devices
 8. Transformers
 9. Transient Voltage Surge Suppressors
- E. Contents of the shop drawings shall include the following:
1. Details of construction, outline and assembly drawings
 2. Dimensions
 3. Materials
 4. Finish
 5. Ratings
 6. Accessories
 7. Trim
 8. Engineering data
 9. Ladder type schematic control diagrams and wiring diagrams
 10. Calculations for harmonic current and voltage distortion
 11. Test Equipment datasheets and proposed test procedures for testing the grounding system.
- F. The Contractor shall submit the manufacturer's literature for the equipment listed in Paragraph 1.03C above to the Owner for review, including the following:
1. Written description of equipment function, normal operating characteristics and limiting conditions.
 2. Recommended assembly, installation, alignment, adjustment, and calibration instructions.
 3. Operating instructions.
 4. Guide to troubleshooting.
 5. Maintenance instructions and timetables.
 6. Parts List and an assembly drawing with the parts identified.

G. Transient voltage surge suppressor submittals shall include the following:

1. UL 1449 peak let-through voltage documentation.
2. Category C3 peak let-through voltage test results.

1.04 WORK SEQUENCE (NOT USED)

1.05 REFERENCES

Reference standards and recommended practices referred to in this Specification Section shall be the latest revision of any such document in effect at the bid time. The following documents are a part of this Section. Where this Section differs from these documents, the requirements of this Section shall apply.

A. American National Standards Institute (ANSI)

1. ANSI C2—National Electrical Safety Code (NESC).
2. ANSI C12.20—For Electricity Meters – 0.2 and 0.5 Accuracy Classes.
3. ANSI C62.41—Guide on Surge Voltages in AC Power Circuits Rated up to 600V.
4. ANSI C62.45—Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000V and less) AC Power Circuits.
5. ANSI C80.1—Electric Rigid Steel Conduit (ERSC).
6. ANSI C82.9—High-Intensity Discharge and Low-Pressure Sodium Lamps, Ballasts, and Transformers.

B. American Society for Testing and Materials (ASTM)

1. ASTM A36—Standard Specification for Carbon Structural Steel.
2. ASTM A48—Standard Specification for Gray Iron Castings.
3. ASTM A153—Zinc Coating (Hot Dip) on Iron and Steel Hardware.
4. ASTM B8—Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

C. Federal Specifications and Standards (FSS)

1. FSS A-A-50552—Fittings for Cable, Power, Electrical and Conduit, Metal, Flexible.
2. FSS A-A-50553A—Fittings for Conduit, Metal (Thick-Wall (Rigid) and Thin-Wall (EMT) Type).
3. FSS A-A-50563A—Conduit Outlet Boxes, Bodies and Entrance Caps, Electrical: Case Metal.

4. FSS A-A-55809A—Insulation Tape, Electrical, 600V, Polyvinyl Chloride, Pressure-Sensitive Adhesive.
5. FSS A-A-55810—Conduit, Metal, Flexible.
6. FSS A-A-59213—Splice Connectors.
7. FSS A-A-59544—Cable and Wire, Electrical (Power, Fixed Installation).
8. FSS W-C-375D—Circuit Breakers, Molded Case; Branch Circuit and Service.
9. FSS W-C-596G(2)—Connector, Electrical Power (General Specification).
10. FSS W-S-896F(1)—Switches, Toggle (Toggle and Lock), Flush-Mounted (General Specification).

D. National Electrical Manufacturers Association (NEMA)

1. NEMA ICS 1—Industrial Controls and Systems: General Requirements.
2. NEMA ICS 6—Industrial Controls and Systems: Enclosures.
3. NEMA MG 1—Motors and Generators.
4. NEMA ST 20—Dry-Type Transformer for General Applications.
5. NEMA TC 2—Electric Polyvinyl Chloride (PVC) Tubing and Conduit.
6. NEMA TC 3—PVC Fittings for Use with Rigid PVC Conduit and Tubing.
7. NEMA WD 1—General Color Requirements for Wiring Devices.

E. National Fire Protection Association (NFPA)

1. NFPA 70—National Electrical Code (NEC).
2. NFPA 101—Life Safety Code.

F. Underwriters Laboratories, Inc. (UL)

1. UL 6—Electrical Rigid Metal Conduit – Steel.
2. UL 50—Enclosures for Electrical Equipment.
3. UL 67—Panelboards.
4. UL 83—Thermoplastic-Insulated Wires and Cables.
5. UL 360—Liquid-Tight Flexible Steel Conduit.
6. UL 467—Grounding and Bonding Equipment.
7. UL 489—Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
8. UL 510—Polyvinyl Chloride Polyethylene and Rubber Insulating Tape.
9. UL 514B—Fittings for Conduit and Outlet Boxes.
10. UL 651—Schedule 40 and 80 Rigid PVC Conduit and Fittings.
11. UL 698—Industrial Control Equipment for Use in Hazardous (Classified) Locations.
12. UL 698A—Industrial Control Panels Relating to Hazardous (Classified) Locations.
13. UL 797—Electrical Metallic Tubing.

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- 14. UL 1449—Transient Voltage Surge Suppressors.
- 15. UL 1660—Liquid-Tight Flexible Nonmetallic Conduit.

G. Institute of Electrical and Electronics Engineers (IEEE)

- 1. 117—Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.

1.06 QUALITY ASSURANCE (NOT USED)

1.07 WARRANTY

- A. All equipment and materials supplied shall be warranted against defective design, materials, and workmanship for a minimum of 1 year, or as specified in this Section, against normal use. The warranty period shall begin once the total project is accepted by the Owner and shall cover replacement of equipment and/or repair, including labor, travel time, and miscellaneous expenses at no cost to the Owner for the full warranty period.

1.08 DELIVERY, STORAGE, AND HANDLING

- A. The Contractor shall deliver materials with manufacturer's tags and labels and UL labels intact. Packaged material shall be delivered in the manufacturer's original, unopened containers bearing the manufacturer's name, brand, and UL label. Materials and equipment shall be stored in a dry, clean location. Handle and store so as to avoid damage. Items delivered in broken, damaged, rusted, or unlabeled condition shall be removed from the project site immediately and replaced with acceptable items. The Contractor shall provide suitable protection of materials and equipment from dust and moisture. The Contractor shall be responsible for the condition of materials and equipment until they are accepted by the Owner.

1.09 QUALIFICATIONS (NOT USED)

1.10 TESTING REQUIREMENTS (NOT USED)

1.11 MAINTENANCE (NOT USED)

1.12 OPERATION AND MAINTENANCE MANUAL

- A. Before final acceptance of this project, an operation and maintenance manual shall be submitted to the Owner. The manual shall include manufacturer's literature as outlined in Paragraph 1.03E above, drawings corrected in accordance with shop drawing review comments and including all modifications, and lists of suppliers and/or service shops that can provide parts and accessories and equipment repair for

the items of equipment listed in Paragraph 1.03C above. The lists shall include a contact name, telephone number, and address.

- B. A test report detailing the results of the grounding system test shall be provided with the O&M Manual.

1.13 CODES, INSPECTIONS, AND FEES

- A. The Contractor shall obtain all necessary permits and inspections required for the work of this Section and pay all charges incidental to this work. The Contractor shall deliver to the Owner all certificates of inspection issued by authorities having jurisdiction.

1.14 PROJECT REQUIREMENTS (NOT USED)

PART 2 PRODUCTS

2.01 MATERIALS AND EQUIPMENT

- A. All material and equipment shall be new and listed or labeled for use within the United States by a Nationally Recognized Testing Laboratory (NRTL). Equipment shall be provided with a specific listing, such as UL, when indicated in this Section or in other portions of the Contract Documents. Only products by manufacturers regularly engaged in the production of specified units will be acceptable.
- B. Where two or more units which perform the same function or are of the same class of equipment or materials are required, provide all units from a single manufacturer.
- C. Provide materials and equipment of suitable composition to perform satisfactorily when exposed to corrosive conditions of the project site.
 - 1. Provide breather and drain fittings in all raceways and enclosures where necessary to prevent condensation or trapping of moisture.
 - 2. Provide heaters in all control panels to prevent condensation.

2.02 CONDUIT

- A. Rigid Metal Conduit: Rigid metal conduit shall be zinc-coated steel and shall conform to UL 6. Fittings shall be cast or malleable iron, zinc-coated, and shall conform to FSS A-A-50563A and UL 514B.
 - 1. PVC-coated rigid steel conduit, elbows, and fittings shall be coated with a bonded polyvinylchloride which is permanently fused on at the factory.

- a. Aboveground conduit system PVC coating shall have a minimum thickness of 40 mils. Couplings and condulets shall have overlapping pressure sealing sleeves.
 - b. Below-ground conduit system PVC coating shall have a minimum thickness of 20 mils.
 - c. Below-ground conduit system PVC coating for extreme corrosive conditions shall have a minimum thickness of 20 mils and shall have external and internal bonded coatings.
- B. Rigid Nonmetallic Conduit: Rigid nonmetallic conduit shall be polyvinyl chloride compound and shall conform to NEMA TC-2 and UL 651. Conduit shall be sunlight resistant, rated for use with 90 °C conductors. Fittings shall be of the same polyvinyl chloride compound and from the same manufacture as the conduit and shall conform to NEMA TC-3 and UL 514B. Conduit and fittings shall be joined by a solvent cement. The type of cement and the procedure for application shall be as recommended by the conduit manufacturer. The conduit shall be Carlon Plus 40 and Plus 80, or equal.
- C. Liquidtight Flexible Metal Conduit: Liquidtight flexible metal conduit shall be made with galvanized steel flexible conduit covered with an extruded PVC jacket. Fittings shall be compression type specifically designed for use with flexible conduit and shall form watertight connections. Box connectors shall have an “O” ring between the fitting body and the enclosure.
- D. Liquidtight Flexible Nonmetallic Conduit: Liquidtight flexible nonmetallic conduit shall be an assembly of a hard PVC spiral completely surrounded by flexible PVC. Conduit shall conform to UL 1660 for use as indicated in Article 351 of the NEC and shall be sunlight resistant.
- 1. Fittings shall be compression type designed for use with the flexible conduit. Box connectors shall have “O” ring between the fitting body and the enclosure.
 - 2. Conduit shall be “Carflex” manufactured by Carlon, or equal.

2.03 BOXES

- A. General: Boxes shall be sized as recommended by the NEC or as shown on the Drawings.

1. Boxes shall be nonmetallic or code-gauge galvanized steel, stainless steel, or cast metal, as specified or shown on the Drawings.
 2. Cast metal boxes shall be cast iron and shall be gasketed of the type indicated on the Drawings.
- B. Outlet Boxes: Outlet boxes shall be sheet steel, cast metal, or nonmetallic.
1. Sheet steel boxes shall be cadmium-coated or zinc-coated.
 2. Cast metal boxes shall conform to FSS A-A-50563A.
 3. Non-metallic boxes shall conform to UL 514C.
 4. Fixture outlet boxes and junction boxes shall be 4-inch, octagonal.
 5. Switch and receptacle outlet boxes shall be 2 inches wide by 4 inches high by 2 inches deep.
 6. Junction box extensions and covers shall conform to UL 514A.
 7. Boxes installed in wet locations or on exterior surfaces shall be gasketed.

2.04 WIRE AND CABLE

- A. Conductors: All conductors shall be annealed soft drawn copper, conforming to ASTM B8, FSS A-A-59544, UL 83, and the latest requirements of the NEC. All conductors shall have THW or THWN type insulation, rated at 600 volts, unless specifically noted otherwise.
1. Other types of insulation may be used as permitted by the NEC. The Contractor shall be responsible for change in conduit size and conductor size to maintain the ampacity of the circuit.
 2. Wire #8 AWG and larger shall be stranded concentric lay. Wire sizes #14, #12, and #10 AWG shall be stranded for control and motor power and solid for light and receptacle circuits.
 3. Conductors shall be as manufactured by Senator Wire & Cable Company, Larabee Wire Manufacturing Company, Inc., Southwire Company, or equal.
- B. Conductor splices shall conform to FSS A-A-59213. Acceptable: Scotchcast Splicing Kit, 3M Company. Plastic tape shall conform to FSS A-A-55809A.

2.05 CIRCUIT BREAKERS

- A. The Contractor shall provide molded-case thermal magnetic circuit breakers of the type, size, and electrical characteristics specified or indicated on the Drawings. Circuit breakers used as service entrance disconnects shall be suitable and rated as service entrance equipment.
- B. Circuit breakers shall be of single-unit construction, and multi-pole circuit breakers shall have trip elements in each pole with common trip bar. Frame size 225 amperes or larger shall have adjustable magnetic instantaneous trip and shall have interchangeable thermal magnetic trip units.
- C. Shunt trip shall be installed in circuit breakers where required by the Drawings or Specifications.
- D. Circuit breaker interrupting ratings shall be equal to the available short circuit current at the point of installation with the minimum ratings as follows:

<u>Frame Size</u>	<u>240 V</u>	<u>480 V</u>
100 A	18,000	14,000
225 A	25,000	22,000
400 A	42,000	30,000
800 A	42,000	30,000
1200 A	42,000	30,000

- E. Provide NEMA Type 1 enclosures for general duty indoor use. Enclosures shall be NEMA 4X stainless steel for exterior locations unless indicated otherwise.
- F. Circuit breakers shall be as manufactured by General Electric, ITE, Square D, or Cutler-Hammer/Westinghouse, or approved equal.

2.06 MOTORS

- A. Motors shall be provided with the equipment driven by the motor, unless otherwise indicated or specified, and shall conform to the latest requirements of NEMA, IEEE, ANSI, NEC, and Anti-Friction Bearing Manufacturer's Association (AFBMA) standards, where applicable.
 - 1. Motors shall be of sufficient capacity to operate the driven equipment, under all load and operating conditions, without exceeding 100% of the motor's nameplate horsepower rating, excluding the service factor, and without exceeding the motor's rated temperature limits.

2. Motors shall be furnished with permanent, highly visible stainless steel nameplates. Nameplates shall include all motor ratings, accessories, and special features.
- B. Motors may be single speed or variable speed as required for the application.
1. Motors for variable-speed applications shall be designed for operation at the rated maximum speed and at reduced speed throughout the variable-speed range without overloading. Motors for variable-speed operation shall be inverter duty rated and compatible with the associated variable-speed control equipment and operating conditions, including the effects of harmonic current and voltage distortion. Motors for variable-speed operation shall be equipped with a normally closed automatic reset winding thermostat in addition to all accessory equipment recommended by the variable-speed equipment manufacturer. Thermostat leads shall be brought to the motor connection box.
 2. Motors 100 HP and above shall be equipped with two normally closed automatic reset winding thermostats. Thermostats shall be imbedded in the stator winding, between phases, connected in series, with leads brought to the motor connection box.
- C. Motors shall be NEMA Design B, unless otherwise indicated or specified, and shall be suitable for continuous duty operation. Motor currents and torque shall be in accordance with NEMA MG1-12.34 and MG1-12.37.
1. Three-phase, single-speed, squirrel-cage induction motors less than 50 HP shall be rated 208-230/460 volt for use on 208-, 240-, or 480-volt, three-phase, 60-Hz systems.
 2. Multi-speed motors and motors 50 HP and larger may be single voltage as required for the particular voltage.
 3. Single-phase general-purpose induction motors shall be split-phase or capacitor start rated 115/230-208 volt, single-phase, 60 Hz. Motors 1-1/2 HP and larger shall be NEMA Design M. Motors smaller than 1-1/2 HP shall be NEMA Design L or N. Motor currents and torque shall be in accordance with NEMA MG1-12.31, MG1-12.32, and MG1-12.33.
- D. Motors shall be provided with Class F non-hygroscopic insulation system using materials and an insulation system evaluated in accordance with IEEE 117 classification tests. Temperature rise shall be limited to a maximum of 80° C, by resistance, at a service factor of 1.0 in an ambient temperature of 40° C. Motors shall have multiple dips and bakes of varnish treatment for additional protection.

- E. Motors larger than 5 HP shall be provided with locked-rotor current not exceeding NEMA Code letter “G.”
- F. Motors shall be furnished with a minimum service factor of 1.15.
- G. Motors shall be suitable for full voltage across-the-line-type starting, unless otherwise specified or indicated on the Drawings.
- H. Motors shall be equipped with ball, open, single-row, deep-groove Conrad-type bearings conforming to the AFBMA Standard 20. Drive end bearings may be cylindrical roller type for belted drives.
 - 1. Bearing life shall be 17,500 hours minimum for belted applications and 100,000 hours minimum for flexible direct-coupled applications.
 - 2. The bearing identification number shall be stamped on the motor nameplate.
 - 3. The lubrication system shall consist of a capped grease fitting inlet, a relief plug 180 degrees from inlet, and a grease reservoir in bracket and cast inner cap.
 - 4. Bearings shall be greased by the manufacturer with a premium moisture-resistant polyuria-thickened grease containing rust inhibitors and suitable for operation over a temperature range of -25° C to 120° C.
- I. The motor enclosure, including frame with integrally-cast feet and/or vertical P-base mounting, end brackets, bearing inner caps, fan guards, and conduit box and cover shall be ASTM Type A48, Class 25 cast iron or better.
 - 1. Conduit boxes shall be provided with the number and size of conduit connections, as shown on the Drawings. The conduit box shall allow rotation to accommodate conduit connection Provision for grounding shall be made using a mounted clamp-type lug in the conduit box.
 - 2. Motors shall be equipped with lifting lugs. Motor enclosures shall be equipped with stainless-steel screens for all openings in accordance with NEMA MG 1 for guarded machines.
 - 3. Vertical hollow-shaft motors shall be equipped with non-reverse ratchets to prevent backspin.
 - 4. Motors shall be NEMA MG 1 open drip-proof, weather-protected Type I, totally enclosed fan-cooled, or explosion-proof as specified in other sections of the Specifications or indicated on the Drawings.

- J. Motors shall be capable of the following starts per hour, unless otherwise specified, without overheating or causing damage to the motor.
 - 1. 60 HP and below, six starts per hour.
 - 2. Above 60 HP, four starts per hour.
 - 3. Submersible motors, 10 starts per hour.

- K. Motors 5 HP and above, except submersible motors, shall be provided with a 120-volt single-phase space heater. Leads shall be brought to the motor terminal box.

2.07 MOTOR STARTERS

- A. Magnetic Motor Starters: Magnetic motor starters shall be rated in accordance with NEMA standards, sizes, and horsepower ratings. Starters shall be sized for the horsepower ratings as indicated on the Drawings or required by the driven equipment. Minimum sizes and type of starter shall be as indicated on the Drawings and shall have the following features:
 - 1. Magnetic starters shall be equipped with double-break silver-alloy contacts. All contacts shall be replaceable without removing power wiring or removing the starter from the panel or enclosure.
 - 2. Coils shall be of molded construction. All coils shall be replaceable from the front without removing the starter from the panel or enclosure.
 - 3. Overload relays shall be the melting-alloy type with a replaceable control module. Thermal units shall be of one-piece construction and interchangeable. The starter shall be inoperative if the thermal unit is removed. Three-phase starters shall have overload relays in all three phases. Reset button shall be accessible without opening the door or panel. Visible trip indication for overload phase indication shall be provided. The relay shall have a Form C contact, which operates when the overload relay trips; the contact shall be wired to terminal blocks for remote use.
 - 4. All motor starters shall have their own control power transformer for individual starter control voltage, except where installed in control panels in which a common control power transformer may be incorporated. Control voltage shall be 120 VAC. Control power transformers shall be sized to include motor space heater load, starter or contactor coil, timers, relays, and other devices as indicated or specified. Primary inputs and the ungrounded secondary output of the control power transformer shall be fused.

5. Starters shall be suitable for adding at least four external electrical interlocks of any arrangement, normally open or normally closed. Starters shall be supplied with a minimum of two interlock contacts.
 6. All magnetic starters shall be provided with terminal blocks for wiring devices external to the starter enclosure. The starter shall be supplied in a NEMA 1 enclosure unless otherwise indicated or specified.
 7. The starter shall be capable of starting the motor the number of times per hour stated for motors or as required by the pumping sequence, without causing damage to the starter.
 8. Panel-mounted elapsed-time meters shall have six register wheels indicating up to 99,999.9 hours, without a reset knob, and be rated at 115 VAC, 60 Hz. The panel manufacturer shall provide one meter for each motor installed and connect the meter so that the meter will record the time that the motor is energized.
 9. Equip all magnetic controllers and/or starters, unless otherwise noted, with a three-position selector switch labeled "Hand-Off-Automatic" or as indicated. Switch in Hand position shall start motor.
 10. Equip all magnetic controllers and/or starters with indicating lights as follows: green-power on, red-running.
 11. A list of overload relay heater elements installed in each starter shall be included in the Operation and Maintenance Manual. The list shall identify the starter by name of equipment and show the type, size, and model number of the heater element.
- B. Full-Voltage Non-reversing Starters (FVNR): Full-voltage non-reversing motor starters shall be designed for across-the-line full-voltage starting and stopping of squirrel-cage motors and shall be the combination type with motor circuit protector unless otherwise indicated.
1. The starters shall be rated 600 VAC, 60 Hz.
- C. Combination Starters:
1. All motor starters shall be combination type unless noted otherwise.
 2. Combination starters shall be manufactured in accordance with the latest published NEMA Standards. Combination starters shall consist of circuit breaker, a fused disconnect, or a motor circuit protector, as indicated on the

Drawings, and a magnetic motor starter as specified above. Combination starters shall have an interrupting rating sufficient for the short circuit current available at the line terminals with a minimum rating of 14,000 RMS symmetrical amperes at 480 volts. All combination starters shall be mounted in a NEMA 1, General Purpose enclosure, unless otherwise indicated on the Contract Drawings.

3. The operator and operator arm shall be permanently attached to the handle of the breaker with positive indication of switch position with door either open or closed. The door and switch shall be interlocked to prevent closing the switch when the door is open.
4. The door latch shall be tamper proof with a coin-proof slot in the door handle latch. The door handle shall have double safety interlocking of the operator and door handle to prevent opening of the door when the breaker is in the "ON" position. An interlock bypass shall be provided to allow access to authorized personnel. All exposed parts shall be dead when the switch is in the "OFF" position.
5. Padlocking facilities shall be provided to positively lock the disconnect in either the "ON" or "OFF" position with from one to three padlocks with the door open or closed.
6. Combination starters shall be Allen-Bradley, Cutler-Hammer/Westinghouse, Square D, or approved equal.

D. Control Devices:

1. Pushbutton control, when indicated on the Drawings, shall be non-illuminated, momentary contact (unless otherwise indicated), oil-tight, pushbutton with no guard. Pushbutton controls shall be Square D Type "K" or approved equal.
2. Selector switch operators, when indicated on the Drawings, shall be two- or three-position, non-illuminated, oil-tight switches with normal return to all positions. Selector switch operators shall be Square D Type "K" or approved equal.
3. Pilot lights shall be 120-volt LED push-to-test type.
4. Control relays shall be double pole, double throw sealed, plug-in type relays with din rail or panel mount base, rated for 10A current at 120Vac, with internal LED pilot light to indicate relay coil is energized.

5. Provide time delay relays in all motor starters larger than 5 HP to provide a sequenced start-up of motors upon energization. Sequence shall start with largest motor, next largest, etc. The timer shall have a range of 5 to 180 seconds.

2.08 TRANSIENT-VOLTAGE SURGE SUPPRESSORS

A. Primary transient-voltage surge suppressor shall be installed at the main service on the load side of the main breaker or automatic transfer switch as indicated on the Drawings.

1. Primary service transient-voltage surge suppressors shall be listed in accordance with UL 1449 and shall be tested to Category C3 (20 kV, 10 kA, 8/20 μ sec. Waveform) in accordance with ANSI/IEEE C62.41 and C62.45. Suppressors shall meet or exceed the following criteria:

- a. Single impulse current rating of 160,000 amperes per phase (8/20 μ sec. waveform).
- b. Pulse life rating of 1,000 occurrences with no clamping drift for Category C (8/20 μ sec. waveform).
- c. UL 1449 peak let-through voltage shall not exceed the following:

<u>Voltage</u>	<u>L-N</u>	<u>N-G</u>
120/208 or 120/240	500	500
277/480	800	800

- d. The test for Category C3 peak let-through voltage ANSI/IEEE C.62.41 (20 kV-1.2/50 μ s) shall be conducted by an independent testing laboratory. Documentation of the test shall be submitted with the shop drawings.
- e. Peak let-through voltage measured in UL and ANSI/IEEE testing shall include the effect of 6-inch leads connected to the complete unit.
- f. Turn-on and turn-off times shall be less than 1.0 nanosecond.

B. Secondary transient-voltage surge suppressors shall be installed on the secondary side of step-down transformers or at the associated panelboards, at control panels, and at motor disconnects or junction boxes as indicated on the Drawings. Suppressors at panelboards shall be connected to a 30-amp multi-pole breaker. All other suppressors shall be fused.

1. Secondary transient-voltage surge suppressors shall be listed in accordance with UL 1449. Suppressors shall meet or exceed the following criteria:
 - a. Single impulse current rating of 80,000 amperes per phase (8/20 μ sec. waveform).
 - b. Pulse life rating of 1,000 occurrences with no clamping drift for Category C (8/20 μ sec. waveform).
 - c. UL 1449 peak let-through voltage shall not exceed the following:

<u>Voltage</u>	<u>L-N</u>	<u>N-G</u>
120/208 or 120/240	500	500
277/480	800	800
 - d. The test for Category C3 peak let-through voltage ANSI/IEEE C.62.41 (20 kV-1.2/50 μ s) shall be conducted by an independent testing laboratory. Documentation of the test shall be submitted with the shop drawings.
 - e. Peak let-through voltage measured in UL and ANSI/IEEE testing shall include the effect of 6-inch leads connected to the complete unit.
 - f. Turn-on and turn-off times shall be less than 1.0 nanosecond.

C. Minimum requirements for surge suppressors:

1. Provide suppression elements between each phase or leg and the system neutral and between the neutral conductor and ground.
2. Each module of modular type suppressors shall be externally fused. The status of each module shall be monitored on the front of the enclosure and on each module.
3. The suppressor failure mode shall be of a “fail-short” design.
4. Visible indication of proper connection and operation shall be provided.
5. Modular-type suppressors shall have an internal disconnect and current limiting fuses. Encapsulated suppressors shall have external fuse or circuit breaker protection.
6. Terminals shall be provided for all necessary power and ground connections and shall accommodate #10 to #1 AWG wire sizes.

7. Suppressors shall be of solid-state componentry and shall operate bidirectionally.
 8. Suppressors shall have a warranty guarantee period of at least 5 years.
- D. All transient-voltage surge suppressors shall be of the same manufacture and shall be installed in accordance with the manufacturer's installation instructions. The mounting position shall be selected to provide the shortest lead possible between the suppressor and the point of connection.
- E. Transient-voltage surge suppressors shall be as manufactured by Advanced Protection Technologies, Inc., or approved equal.

2.09 GROUNDING

- A. Ground rods shall be copper-clad steel, 3/4-in-x-10-ft sectional type, with couplings and driving studs for installation.
- B. The conductor shall be bare, stranded copper, complying with ASTM B8, for main power ground and instrument ground, unless otherwise indicated. Grounding conductors run in conduit shall have green insulation.
- C. Connection to the ground rod shall be made with exothermic welding kits by Cadweld or approved equal. "Acorn" type clamps are not acceptable. Ground connections to equipment frames, building steel, etc., shall be made with equipment grounding lugs or clamps intended for grounding purposes.

2.10 PLASTIC CAUTION TAPE

- A. The Contractor shall provide a continuous non-metallic caution tape, 12 inches below finished grade, above each duct or conduit run. The tape shall be 6 inches wide, imprinted to indicate underground electric utilities, as manufactured by Griffolyn, Terra-Tape, or equal.

PART 3 EXECUTION

3.01 LAYOUT OF CONDUIT AND WIRING SYSTEMS

The Contractor shall lay out the work and shall be responsible for all necessary lines, levels, elevations, and measurements. The Drawings indicate the extent and general arrangement of the components. The Contractor shall become familiar with the work of other trades engaged in the construction. The exact routing of raceways and locations of equipment may be governed by structural conditions and obstructions. The Contractor shall coordinate with the details of equipment

shop drawings for power and control connections to equipment furnished by others. This is not to be construed as permitting redesigning systems.

- A. Submit all requests for changes in the proposed layout due to structural features, equipment locations, and similar conditions to the Owner, with the following provisions:
 - 1. Detail the reasons for the changes.
 - 2. Submit requests within 30 days after award of Contract.
 - 3. Make no changes without written approval of the Owner.
- B. Examine areas scheduled to receive electrical equipment and material for conditions which will adversely affect the execution, permanence, or quality of the work. Determine field conditions by actual measurement. Do not proceed with installation until defects have been corrected.

3.02 INSTALLATION

- A. General: Comply with NEC, NESC, local codes, and rules and regulations of local agencies having jurisdiction. Coordinate electrical installation of systems and packaged equipment items specified in other sections of these Specifications.
 - 1. Conductors, circuit breakers, motor controllers, and protective devices indicated or specified shall be sized to serve the electrical equipment furnished and shall meet all requirements of the NEC. Voltage drop shall be limited to 3%, including main service, feeder, and branch circuit.
 - 2. Coordinate protective, control, and signaling devices.
- B. Grounding and Bonding: The Contractor shall establish a grounding and bonding system that electrically connects metal structural materials, equipment enclosures, conduits, outlet boxes, cabinets, motor frames, fixtures, devices, transformer cases, switchgear enclosures, incoming service neutral conductor, and the earth. The common point of attachment for the grounding and bonding system shall be at the main service disconnect unless otherwise indicate in this Section or in the Drawings. The grounding and bonding system shall be properly bonded and sized in accordance with NEC. Solidly bond all non-current-conducting metal parts to the electrical installation grounding bus. A green insulated grounding conductor shall be carried with each circuit.
 - 1. Provide common grounds throughout the system.
 - 2. Provide a ground grid consisting of driven copper-clad steel ground rods connected by bare copper conductor at the service entrance and/or as shown

on the Drawings. Resistance to remote earth shall be 10 ohms or less before connection to the system.

- C. Identification: Equipment such as but not limited to disconnect switches, motor starters, control panels, etc., shall be clearly marked.
1. Identify all devices operating at more than 250 VAC phase-to-phase or 125 VAC phase-to-ground with red enamel letters or numerals of appropriate height applied with a stencil.
 2. Except as otherwise noted, all equipment shall be marked with engraved nameplates of laminated two-color phenolic plastic having white letters. Attach each nameplate with stainless steel screws. Align nameplates on equipment being marked in the center near the top.
 3. Panelboards and control panels shall have designation in 1/2-inch-high letters and voltage in 1/4-inch-high letters centered above the door on exterior trim.
 4. Mark equipment mounted remotely from the source of power (such as pumps and fans) with equipment number, source of power, and starter location. Where starters are remotely mounted, marking shall include equipment name, number, and location.
 5. Conductors shall be identified at each termination, pull box, junction box, handhole, point of entry to or exit from wireways, panelboards, control panels, and other points of access. Tags or labels shall be securely affixed to the conductor in visible locations. Tags shall be durable plastic with the designation stamped on one side with suitable dies. Labels shall be permanent with legible black characters on white heat-shrink tubing or equivalent identification acceptable to the Owner.
 - a. Power conductors shall be color-coded to identify phases, neutral and switch legs, using plastic, self-sealing tape. Tags or labels shall identify the switchboard, MCC, panel, etc., it is served from and the circuit number.
 - b. The control conductor (including monitor and instrumentation conductors) shall be identified by color coding and tag or label as to wire number (corresponding to the manufacturer's wiring diagram) and equipment name.
 - c. Power wiring and control wiring shall be identified in all handholes with a waterproof permanent tag attached to the cable with plastic cable ties.

- D. Equipment Connections: Provide complete system with all power and control connections required for proper operation.
- E. Conduit:
1. Rigid galvanized steel (RGS) conduit may be used as follows:
 - a. Exposed in buildings.
 - b. Exposed with PVC coating where indicated on the Drawings.
 - c. Concealed in poured concrete.
 - d. Below grade with PVC coating where indicated on the Drawings.
 2. Rigid non-metallic (PVC) conduit may be used as follows:
 - a. Concealed in walls and floors, Schedule 40.
 - b. Below-grade direct burial, Schedule 80.
 3. Burial depth of conduit shall be measured from the top of the conduit to the top surface of finished grade, pavement, concrete, or similar cover as follows:
 - a. 24 inches (minimum) below unpaved areas,
 - b. 30 inches (minimum) below stabilized subbase in paved areas.
 4. For concrete slabs on grade and foundations, conduit burial depth shall be measured from the bottom of the concrete slab or foundation as follows:
 - a. 12 inches (minimum) below concrete slabs on grade or foundations.
 5. It shall be the responsibility of the Electrical Contractor to coordinate the location and depths of all electrical conduits to be installed under this Contract with other trades. Particular attention shall be given to all locations where conduits enter a structure or building from underground. Proper clearances from the top of the conduits to the bottom of slabs and foundations shall be maintained.
 6. Where conduits rise through slabs on grade, curved portion of bends shall not be visible above the finished slab.
 7. Conduit stub-up to above grade and conduit stub-up out of or from below floor slab shall be rigid galvanized steel from and including the last 90° bend.

8. Galvanized conduits which penetrate concrete in wet locations shall be protected by a 20-mil sheath of PVC at the penetration extending from 2 inches within the concrete to the first coupling or fitting outside the concrete.
9. Stub-ups through concrete slabs for connection of future equipment or conduits runs shall be provided with couplings threaded inside for plugs and shall be set flush with the finished floor or slab. Install screwdriver-operated threaded flush plugs in couplings. Provide pull wire in all empty conduit runs.
10. Avoid bends and offsets, where possible. Make bends and offsets with an approved hickey or conduit bending machine. Install plastic (PVC) coated conduit and fittings in accordance with the manufacturer's installation manual using tools designed for installing plastic (PVC) coated conduit and fittings. Touch up any and all damaged areas with manufacturer-recommended coating compound. Do not install crushed or deformed conduit. Use expansion fittings or other approved devices where conduit or tubing crosses expansion joints. Prevent dirt or trash from lodging in conduits, boxes, and fittings. Free clogged conduit of all obstructions or replace conduit.
11. Supports:
 - a. Pipe straps, wall brackets, hangers, or ceiling trapeze.
 - b. Use wood screws or screw-type nails for fastening to wood. Use toggle bolts for fastening to hollow masonry units. Use concrete inserts or expansion anchors for fastening to concrete. Use machine screws, welded threaded studs, or spring-tension clamps for fastening to steel work.
 - c. Power-driven threaded studs may be used in lieu of expansion bolts or machine or wood screws where acceptable to the Owner.
 - d. Use threaded C-clamps on rigid steel conduit only.
 - e. Do not weld conduit or pipe straps to steel structures.
 - f. Non-metallic conduit through 1-inch size shall use one-hole snap-strap clamps and 1-1/4-inch through 2-inch shall use two-hole snap-strap clamps, with maximum spacing between supports as outlined in the NEC based on 50°C conductor temperature. Clamps shall be manufactured from a nylon compound.

12. Expansion couplings shall be used in all straight lengths of non-metallic conduit in exposed applications. Maximum spacing between expansion couplings shall be 100 feet.
13. Connections: All conduits, where they enter sheet metal enclosures such as panelboards, pull boxes or outlet boxes, shall be secured in place by galvanized locknuts and bushings, one locknut inside of box with bushing on conduit end and one locknut outside of box for rigid conduit. The locknuts shall be tightened against the box without deforming the box.
 - a. Conduit connections shall use fittings to maintain NEMA rating of enclosures.
 - b. All bushings and conduit box connectors shall have the insulating material permanently fastened to the fittings.
 - c. Grounding bushings shall be used in switchgear and motor control centers.
 - d. Conduit connections exposed in wet locations shall be by watertight threaded hub. Metallic conduit box connections may use a two-piece hub with built-in recessed neoprene gasket such as Appleton Uni-Seal. Non-metallic conduit box connectors may use a neoprene flat washer or "O" ring placed over threads of the fitting between the shoulder of the fitting and the box.

F. Boxes:

1. The Contractor shall provide outlet, pull, junction, or terminal boxes in wiring or conduit systems wherever required for pulling wires, making connections, and mounting devices or fixtures.
 - a. Indicated locations are approximate only. Coordinate actual location with all work to be performed in the space or area and for the equipment to be served.
 - b. Locate outlets so that fixtures and other items will be symmetrically located according to the space or area layout.
 - c. Outdoor switch and receptacle outlets shall use non-metallic boxes and covers.

2. Outlet boxes in exposed work or wet locations shall be cast metal. Sheet metal boxes shall be concealed in walls or ceiling. Non-metallic boxes shall be used with non-metallic conduit.
 3. Supports:
 - a. In open overhead spaces, cast boxes threaded to rigid metallic conduit need not be separately supported unless used for fixture support.
 - b. Use wood screws or screw-type nails for fastening to wood. Use toggle bolts for fastening to hollow masonry units. Use concrete inserts or expansion anchors for fastening to concrete. Use machine screws or welded, threaded studs for fastening to steel work.
 - c. Power-driven threaded studs may be used in lieu of expansion bolts or machine or wood screws where acceptable to the Engineer and the Owner.
- G. Wiring Devices: Receptacles installed outdoors shall be the ground-fault circuit-interrupter type.
- H. Wiring:
1. The Contractor shall provide a complete system of conductors as indicated.
 2. Size shall be as required by the NEC and shall be #12 AWG minimum for power and lighting circuits and #14 AWG minimum for control and alarm circuits.
 3. Crimp-on insulated wire terminals shall be used on stranded wire for terminations.
 4. Splices shall be in accessible locations only and shall be insulated-pressure type for #10 AWG and smaller wires. For #8 AWG and larger, use solderless connectors covered with an insulation material equivalent to the conductor insulation.
- I. Appearance: All items shall be cleaned or touched up as necessary to ensure first-class condition.

3.03 FIELD TESTS AND OBSERVATION

- A. General: Do not enclose or cover any work until it has been observed, tested, and accepted.

1. Provide all personnel, equipment, and instruments required for observation and testing.
 2. Demonstrate that all circuits and devices are in operating condition. Tests shall include the following:
 - a. Megger all motor windings before operation for insulation resistance and, if found low, dry out windings to secure acceptable insulation resistance.
 - b. Check control center components, buses, starters, breakers, relays, alarms, interlocks, etc., and place in service in accordance with the manufacturer's instructions. Inspect and adjust electrical equipment before energization.
 - c. Megger all power cables and wiring for insulation resistance and record.
 - d. Check all motors for correct lubrication and lubricate, if required, in accordance with the manufacturer's instructions.
 - e. Check direction of rotation of all motors and reverse, if necessary.
 3. Assemble in binders and turn over to the Owner all instruction bulletins, lubrication schedules, operating instructions, pamphlets, parts lists, prints, etc. accompanying or attached to apparatus and equipment.
 4. Notify the Engineer and the Owner 1 week before test date.
- B. Ground Rod Test: Before any wire is connected to ground rods, test each rod for resistance to ground.
1. The testing instrument shall be a direct reading, single test, portable ground testing megger.
 2. The test procedure shall be as recommended by the manufacturer of the test instrument used.
 3. The make and model of the test instrument and a copy of the test procedure shall be submitted to the Owner before the test is conducted.
 4. Do not conduct tests within 48 hours after rainfall or during foggy weather.

5. If ground resistance exceeds 10 ohms, additional grounds shall be driven.
6. The grounding test shall be witnessed by the Engineer or other representative of the Owner. A copy of the test results and method shall be included in the maintenance manual. Deliver one copy of the test results to the Engineer and the Owner within 1 week after the test.

3.04 ADJUST AND CLEAN

- A. The Contractor shall remove excess and waste materials from the project site.
- B. Remove defective work and replace with material that meets Specification requirements or repair to the satisfaction of the Owner.
- C. Touch up scratches, abrasions, voids and other defects in factory- or shop-finished surfaces.

END OF SECTION