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16A -- SCOPE

16A.1 Scope of Work

16A.1.1 The work to be performed under this Contract includes all labor, tools and material necessary to furnish, install, test, and place in operation a complete operable electric system as specified herein and as indicated on applicable drawings. Only that equipment or material which is specifically so designated herein or on the drawings will be furnished by others.

16A.1.2 The Contractor shall examine the specifications for the various items of mechanical equipment and shall provide all circuit breakers, switches, pushbuttons, and other controls and appurtenances which are not specified to be with the equipment. The Contractor shall erect all electrical equipment not definitely stated to be erected by others and shall furnish and install all conduits and cables necessary to make all connections required to place all equipment in complete operation. The Contractor shall install all items which are exclusively electrical unless stated otherwise in the detailed specifications or on the drawings.

16A.1.3 The work shall include complete installation of secondary power distribution systems, motor branch circuits, lighting, control systems, grounding system and other miscellaneous items as indicated on the drawings and specifications herein.

16A.1.4 Submittals shall be made to the Owner or to his designated Representative in accordance with the General Conditions of the Contract. Submittals are often made under the general term of "Shop Drawings" but include all items listed in the General Conditions.

16A.1.5 Some submittal requirements listed in the General Conditions or within the specifications are not ordinarily termed as "Shop Drawings", but still must be submitted as above.

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16A.1.6 Submittals

- a. See Section 16B.10 of these specifications for the submittals required in this Division.

16A.1.7 Instrumentation - The Contractor shall furnish and install complete, all raceway and wiring for instrumentation systems, including conduit, tray, and signal, power, control and thermocouple wiring as shown on applicable instrumentation and electrical drawings.

16A.1.9 The work shall include complete testing (as described herein or recommended by equipment manufacturers) of all equipment and wiring at the completion of the work and making any minor connection changes or adjustments necessary for the proper functioning of the system and equipment. Power distribution, lighting, control, and all miscellaneous systems shall be properly adjusted and in working order, as required, at time of final acceptance.

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16B -- GENERAL

16B.1 General

16B.1.1 The General Conditions and/or Special Conditions apply to all work of this specification, which shall be done as shown on the plans, and as specified, and shall be properly coordinated with work in other Specifications.

16B.2 Intent

16B.2.1 This specification is intended to define and describe the requirements for installation of the Electrical System and to define and describe the material (and equipment) to be furnished therewith. This specification supplements all electrical drawings for this job and both shall be strictly adhered to in providing a complete Electrical System for the subject contract.

16B.3 Plans

16B.3.1 The drawings and these specifications are complementary to each other; what is called for by one shall be as binding as if called for by both. If a conflict between drawings and specification is discovered, this shall be referred to the Owner's Representative as soon as possible for resolution. Should a conflict occur between the drawings or specifications or codes, it will be assumed that the more expensive method has been estimated unless such alternate has been agreed to prior to submission of bids.

16B.3.2 The electrical layouts indicated are generally diagrammatic. The location of outlets and equipment are approximate unless dimensioned. The exact locations and routing of conduits shall be governed by structural conditions and physical interferences and by the location of electrical terminations on equipment.

16B.3.3 Where job conditions require reasonable changes in indicated locations and arrangements, the Contractor shall make such changes without extra cost to the Owner.

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16B.3.4 A list of applicable drawings is included in the Invitation to Bid.

16B.3.5 These drawings may be superseded by later revised or detailed drawings or Specification Addenda prepared by the Engineer. New drawings may be added for clarification or detail. The Contractor shall conform to all reasonable changes without extra cost to the Owner.

16B.3.6 All equipment shall be located and installed so that it will be readily accessible for operation and maintenance. The Owner reserves the right to require minor changes in location of outlets or equipment prior to roughing in without incurring any additional costs or charges.

16B.3.7 The Contractor shall examine the architectural, structural, and mechanical plans and shop drawings for the various equipment in order to determine exact routing and final terminations for all conduits and cables. Embedded conduit stubups where not located on the drawings shall be stubbed up as near as possible to equipment terminals.

16B.3.8 Electrical work shall be performed in cooperation with all other trades in order to secure the best arrangement of the work as a whole. No changes in the work shall be made without the written acceptance of the Owner's Representative.

16B.3.9 Trenching, excavation and backfilling shall be done in accordance with the requirements set forth in the Site Work section of these specifications.

The Contractor shall furnish all labor, equipment and material for trenching, excavation and backfill, concrete, and reinforcing for electrical work such as but not limited to underground raceway construction, equipment pads and foundations (transformers, switchgear, panels, starters, etc.), and outdoor lighting towers or post pedestal as specified in these specifications or as shown on the drawings. The Contractor shall furnish and install all leveling channel.

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16B.4 Temporary Installations

16B.4.1 Temporary installations used during construction shall conform to the requirements of the National Electrical Code (NEC), the National Electrical Safety Code (NESC) and the Occupational Safety and Health Act (OSHA) for the protection of personnel and property.

16B.5 Codes

16B.5.1 The electrical system shall be installed and equipment and material shall be furnished in accordance with applicable sections of the following Codes and Standards. Issues that are current at the date of this Specification are the basis for this Contract.

- a. National Electrical Code
- b. National Electrical Safety Code
- c. National Fire Protection Association
- d. State Building Codes
- e. Local Municipal Codes and Ordinances
- f. Public Utility Regulations
- g. National Electrical Manufacturers Association
- h. American National Standards Institute
- i. Institute of Electrical and Electronics Engineers
- j. Insulated Cable Engineers Association
- k. Underwriters' Laboratories, Inc.
- l. Occupational Safety and Health Act

16B.5.2 Where requirements contained in this specification are higher or more rigid than those in the Codes or Standards referred to above, this specification shall govern.

16B.5.3 In the case of conflict between mandatory Code requirements and specification or drawing requirements, the Code shall be followed in each case, but only after submitting such proposed changes to the Owner's Representative for approval.

16B.5.4 Before acceptance of the work, the Contractor shall deliver to the Owner a Certificate of Compliance from the Middle Department Association of Fire Underwriters or other inspection bureau having jurisdiction.

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16B.6 Permits

16B.6.1 The Contractor shall pay for all permits, inspections and other costs incidental to providing electrical installations.

16B.7 Circuit Arrangement

16B.7.1 Any switch or set of contacts used for control of electrical equipment shall simultaneously open all ungrounded conductors feeding the equipment.

16B.7.2 Alternating current control circuits shall be grounded and one side of each current consuming device shall be connected to the grounded conductor. All control contacts shall be installed in the ungrounded side of the circuit. Motor overload device contacts shall be installed on the grounded side of the circuit unless specified or shown otherwise.

16B.7.3 Thermal overload relays shall be installed in all ungrounded conductors supplying a motor.

16B.8 Services and Coordination

16B.8.1 The Contractor shall cooperate with the Engineer and shall provide assistance at all times for the inspection of the electrical work performed under this Contract. He shall remove covers, operate machinery, or perform any reasonable work which, in the opinion of the Owner's Representative will be necessary to determine the quality or adequacy of the work.

16B.8.2 The Contractor shall check dimensions, examine drawings and coordinate his work with that of other crafts to prevent conflicts. If conflicts occur, the Owner's Representative may elect to decide which installation shall have preference. No additional compensation will be approved for modifying installations made prior to resolution of conflicts.

16B.8.3 All deviations from the plans must be approved by the Owner.

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16B.9 Materials

16B.9.1 All material shall be new, free from defects, and of the quality specified or shown, and shall be approved and listed by Underwriters' Laboratories, Inc. (UL), Factory Mutual (FM) or codes and standards established for the class of equipment or material, unless waived by the Owner. Each type of material shall be of the same manufacture and quality throughout the work, unless waived by the Owner.

16B.9.2 Where particular types or brand names are specified, it is understood that there will be no substitutions except with the approval of the Owner in writing.

16B.9.3 If such types or brand names are qualified in the specifications by the words "or approved equal", or similar wording and if the Contractor wants to substitute a material or article considered by him to be "equal", the proposed substitution shall be clearly spelled out in writing to the Owner together with the difference in price, if any, which will result from the acceptance of such substitution.

16B.9.4 Any anticipated delay in completion of construction due to substitution of alternate material, equipment or systems will be grounds for disapproval of the substitution.

16B.10 Submittals

16B.10.1 The Contractor shall, within thirty (30) days after signing of the Contract, submit for acceptance a list giving names of manufacturers, catalog number and model or type designations and application of all materials he proposes using on the project. Items used which are below the standard of quality of the specified items or which would create a hazardous or unsightly condition or which would be misapplied, will be subject to rejection. Items rejected must be replaced by the Contractor at no additional cost to the Owner. Any materials erected by the Contractor prior to acceptance of the same will be at his own risk, and materials not accepted must be removed immediately from the site.

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16B.10.2 Shop drawings shall be submitted for acceptance prior to manufacture for panelboards, and switches. These drawings shall show layouts, dimensions, construction details, elementary diagrams, connection diagrams, and nameplate engraving tables. All diagrams except for switchgear shall conform to Joint Industrial Conference (JIC) standards.

16B.10.3 All records of all tests and inspections as specified in Section 16E of this Division shall be submitted by the Contractor before the date of final acceptance of the contract.

16B.11 Record Drawings and Instruction Manuals

16B.11.1 The Contractor shall maintain a neatly marked set of record drawings showing the installed location of conduits, cables, junction and pull boxes, and outlets or terminations. He shall also produce and maintain a set of interconnection diagrams showing terminals and terminal numbers of the various pieces of equipment.

16B.11.2 Record drawings shall be kept current with the work and shall be subject to inspection by the Owner's Representative at any time. Prior to acceptance of the work, the Contractor shall submit the record prints and up-to-date reproducibles of all elementary, connection, and interconnection diagrams to the Owner's Representative.

16B.11.3 The Contractor shall provide the Owner and Engineer with complete sets of manufacturer's operating and maintenance instructions and spare parts in suitable binders for all major items of equipment furnished in accordance with the requirements set forth in the "General Requirements" section of these specifications.

16B.12 Utility Connections

16B.12.1 The Contractor shall pay all utility connection costs and shall give the utility sufficient notification in order that permanent power will be available at the installation when it is put into operation. The Contractor shall consult with the utility to coordinate the electrical service installation work and to insure that the metering and

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service equipment meets the utility requirements in effect at the time of construction.

16B.13 Painting

16B.13.1 Panelboards, Equipment Rack, disconnect switches, control stations, and miscellaneous enclosures shall be painted except stainless steel, galvanized steel, plastic and aluminum which shall not be painted. Ferrous materials shall be treated with zinc phosphate, bonderized or otherwise given a rust-preventive treatment acceptable to the Engineer. The material shall then be primed and painted with a durable enamel. The color shall be manufacturer's standard unless otherwise noted. The final coating shall be free from blemishes.

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16D -- INSTALLATION

16D.1 Conduit

16D.1.1 Conduit installation shall be in accordance with the best trade practices and as specified in these specifications and as indicated on the drawings.

16D.1.2 All conduit installation as shown on the drawings shall be installed exposed unless otherwise indicated.

16D.1.3 Exposed conduit shall be rigid galvanized steel of standard trade size as specified on the drawings. Minimum size shall be 3/4 in.

16D.1.4 Conduit in slab or underground shall be hot-dipped galvanized rigid steel heavy wall conduit of standard trade sizes. Minimum size shall be 1 in.

16D.1.5 Conduit in duct banks, encased in concrete, shall be PVC plastic. Sizes shall be as indicated on drawings.

16D.1.6 Maximum length of run between outlets shall be 100 ft for straight runs. Not more than four (4) equivalent 90° bends will be permitted between outlets. Bonded expansion fittings shall be provided at all building expansion joints.

16D.1.7 Conduits shall be cut square and cut ends shall be reamed carefully to remove burrs, and threaded with straight threads. Conduit joints shall be made up with an approved conductive thread seal applied to the male threads only.

16D.1.8 Field fabricated bends shall be free of indentations or elliptical sections due to improper fabrication. Bends in metallic raceways shall be made while "cold" and in no case shall raceways be heated. Raceways shall not be bent through more than 90°. The radius of the bends shall not be less than six times the internal diameter of the raceway.

16D.1.9 It shall be the responsibility of the Contractor to protect all conduit terminations from mechanical injury and to prevent the entry of moisture and foreign matter into the conduit system by properly capping terminations.

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16D.1.10 A No. 14 gauge galvanized iron fish wire shall be installed in all empty conduits.

16D.1.11 Exposed conduits shall be installed, either parallel or perpendicular, to structural members and grouped together where possible. Conduits supported from building walls shall be installed with at least 1/4 in. clearance from the wall to prevent the accumulation of dirt and moisture behind the conduit. The contractor shall furnish and set in place all sleeves, etc., for exposed risers and inserts for raceway supports.

16D.1.12 Exposed conduit shall be supported at intervals as recommended by the latest edition of the National Electric Code.

16D.1.13 Supports for conduit runs shall be conduit straps, pipe hangers or structural steel members furnished by the Contractor. Conduits of 1-1/2 in. diameter and less may be supported by one-hole conduit straps on concrete, tile or steel work, but for larger size conduit, 2-hole straps shall be used. Clamps shall be galvanized malleable iron. Galvanized or aluminum unistrut bar and hangers shall be used as required for conduit supports. No painted mild steel unistrut. In general, conduit shall be run on top of unistrut or other supports. Angle iron brackets should be used for conduit supports around heavy vibration areas.

16D.1.14 Conduit rack shall be secured to concrete walls and ceilings by means of cast in place anchors in accordance with the structural section of these specifications. Individual conduit supports may be similar cast in place anchors, die cast, rustproof alloy expansion shields or cast flush anchors. Wooden plugs, plastic inserts or gunpower driven inserts shall not be used as a base to secure conduit supports.

16D.1.15 Welding, brazing or otherwise heating of the conduit will not be permitted. Plumber's perforated hanger iron shall not be used for any purpose.

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16D.1.16 Where required for ease of pulling and as necessary to meet code, the Contractor shall install cast junction or pull boxes even though not shown on the drawings.

16D.1.17 Expansion joints shall be installed every 300 ft of straight run, unless otherwise indicated on drawings, with bonding straps to assure ground continuity.

16D.1.18 Where conduits enter wall mounted control cabinets, safety switches, circuit breaker enclosures, or individual motor controllers, not having threaded hubs, a raintight hub having an insulated liner or Meyers "Scrutite" watertight fitting shall be used. Such fittings will not be required at motor control centers unless so indicated on applicable drawings.

16D.1.19 Where conduit enters outlet boxes, pull boxes or other enclosures not specified elsewhere, a double locknut and bushing assembly shall be used. Bushings shall be plastic insulating type for conduit of 2 in. diameter and smaller, larger sizes to have insulated metallic bushings. Grounding bushings, where required, shall be insulated metallic type with set screw and large lug connecting screw.

16D.1.20 Conduit encased in concrete shall be securely tied in place before any concrete is poured to prevent movement during pouring. Joining and other installation of conduit shall be in such a fashion to preclude any seepage of grout into the conduit system when the encasement is poured. A bitumastic compound shall be applied to all conduits leaving encasement from below ground. This application shall begin approximately 6 in. prior to being exposed and at least 3 in. beyond encasement.

16D.1.21 All conduit installed in concrete which is in contact with the earth shall be adequately separated from the earth by at least 3 in. of concrete.

16D.1.22 Conduit shall not be installed in concrete slabs or walls having a concrete thickness of 6 in. or less. Conduit installations in concrete slabs or walls having a concrete thickness of more than 6 in. shall be permitted only if the details of the installation are submitted to, reviewed by, and

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approved by the Owner's Representative. Details shall be sufficient to determine sizes and locations of all conduit involved in the embedded work.

16D.1.23 Conduit installed in concrete slabs or walls shall be placed in the middle third where possible. Clearances equal to the conduit trade diameter, but not less than 1-1/2 in., shall be maintained between conduits encased in slabs, unless otherwise shown on the drawings. Clearances of less than 1-1/2 in. at conduit crossings and terminating locations may be allowed by the Owner's Representative at his discretion. Runs in slabs shall be installed to avoid trapping wherever possible and with as few bends as possible.

16D.1.24 Conduit rising through a slab shall be protected by a dry pack concrete approximately 6 in. in diameter and 3 in. above the finished floor or the conduit shall come up through the equipment pad.

16D.1.25 All stub-ups when set shall be extended upward with one length of conduit until after encasement is poured to assure vertical alignment of elbow. All risers from underground shall be so installed that the upper side of a coupling is located 6 in. beyond the encasement with all empty conduits plugged.

16D.1.26 Below grade wall penetrations shall be made with O.Z./Gedney "Thruwall" seals or approved equal.

16D.1.27 Direct burial conduit shall be buried below the frostline and shall be given a heavy coating of bitumastic #50 coating compound prior to burial.

16D.1.28 Conduit carrying low energy (millivolt or milliamper) signal circuits shall be run a minimum of 2 ft from trays carrying power or control cable. When crossing power and control cable trays at right angles, there shall be a minimum separation of 1 ft.

16D.1.29 Each conduit passing from a hazardous or chlorine gas area into a nonhazardous area shall be provided with a sealing fitting located on either side of the boundary. The seal shall be installed at the boundary and in accordance with NEC requirements. The seal shall be UL approved and shall be filled with approved sealing compound of the same manufacture.

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16D.1.30 The Contractor shall exercise the necessary precautions to prevent the lodging of dirt, concrete, or trash in the conduit, fittings and boxes during the course of installation.

16D.1.31 Each conduit shall be identified at each end with a permanent brass or stainless steel marker, or other approved method. Designation shall be pressure stamped into tag.

16D.1.32 Liquidtight flexible metallic conduit shall be used for all motor connections. Where flexibility is required for electrical raceways on equipment, liquidtight conduit shall be used in accordance with JIC standards, these specifications, and the local inspection agency. The maximum length of flexible conduit shall be 24 in. and the terminating fittings and sealing shall be as shown in the motor details. Liquidtight flexible conduit shall not be depended on for equipment grounding. Internal ground conductors shall be installed throughout.

16D.2 Conduit Duct Encasement

16D.2.1 Concrete for duct encasement shall have 2500 psi strength, 6 to 9 in. slump, and shall be reinforced under railroads, roadways, etc., as detailed on applicable drawings. Concrete on top of duct bank shall be colored red by addition of iron oxide or suitable pigment.

16D.3 Conduit Trenches

16D.3.1 Trenches for conduit under roadways or tracks shall be backfilled with approved granular material and compacted to 100% of maximum density. Conduits shall be in concrete encasement with #4 rebars for additional strength.

16D.4 Cable

16D.4.1 The Contractor shall estimate and/or take off the quantities required for the installation and assure that the quantities and lengths required are ordered in time to maintain the work schedule.

16D.4.2 Conductor sizes shall be as indicated on applicable drawings but in no case shall be smaller than indicated below.

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Power circuits - #12 AWG
Lighting and receptacle circuits - #12 AWG
Motor Control - #14 AWG

16D.4.3 Wire and cable installation shall be in accordance with the following requirements:

a. All wire and cable, other than direct buried, shall be installed in conduit or other type raceway systems in accordance with the drawings and the National Electrical Code.

b. No wire or cable shall be installed in any section or area until the conduit system in that section or area is completed. Conduit shall be cleaned of all foreign matter before wire is pulled in.

c. The use of lubricants, other than talc or powdered soapstone or nonhardening compounds approved by the Underwriter's Laboratories and the cable manufacturer for pulling is not permissible.

d. Suitable slack shall be provided in wire or cable in boxes, outlets, and cabinets to insure that there is no binding at the bushing. Enough slack shall be provided on motor leads in starter to permit the use of a "clamp-on" ammeter on any leg.

e. All wires shall be continuous, having no splices from terminal to terminal, unless otherwise indicated on applicable drawings.

f. Branch circuit wiring to outlets, receptacles, and fixtures, shall conform strictly to the branch circuit numbers on each outlet on the drawings.

g. Portable cord feeding permanent installations such as sump pumps, and portable equipment shall have a wire mesh cord grip of flexible stainless steel to take the tension from the cable termination. Portable cord shall be heavy duty, Type SO construction. Weatherproof strain relief fittings shall be used for all connections. Forty-five degree and ninety degree connectors shall be used where applicable to

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prevent unnecessary strain on cords. Flexible cord feeding submersible motors shall be similarly protected, but the cord shall be of nonwicking neoprene construction.

16D.5 Terminations

16D.5.1 600 volt and below

a. Power and control conductors shall be terminated in terminal blocks with solderless box lugs. Terminal blocks for power leads shall be of ample size and capacity to handle the required loads. All control terminal boards shall be of ample size to accept two No. 12 AWG field conductors per point. All terminal blocks shall be numbered and provided with white fiber markings.

b. Signal leads shall be terminated in terminal blocks with saddle type pressure connectors capable of receiving two No. 16 AWG or smaller conductors on each point.

c. Stranded wire and cable connections shall be made expertly in an approved manner with solderless tinned copper compression type connectors. Connectors shall be formed, high conductivity copper, securely fastened with tools recommended by connector manufacturer.

d. Control connections shall be made with compression type fork tongue lugs with insulating sleeve.

e. Splices in power wiring shall be made with two compression lugs bolted together. Splices in stranded control wiring or lighting circuits may be made with compression connectors. Splices in signal wiring shall be soldered. Splices shall be made only in junction boxes.

f. Solid wire shall not be lugged nor shall electrical spring connectors be used on any wiring except for lighting circuits. Lugs and connectors shall be installed with a compression tool recommended by the lug manufacturer for the particular lug used.

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g. All wiring splices or taps shall be insulated. For 600 volt THW insulated wire and rubber insulated, #4/0 and smaller, a minimum of 4 half-lapped layers of Scotch #33 plastic tape shall be used. For wire larger than #4/0, rubber tape with protective cover tape shall be used per manufacturer's recommendations. For 480v power and lighting circuits, rubber tape shall be applied over the splice so as to exceed the thickness of the wire insulation. Protective cover tape shall be applied over the rubber tape.

16D.6 Wire Identification

16D.6.1 All wire and cable other than lighting branch circuits, shall be identified at termination and splice points and shall carry the same wire number or circuit number as shown on the drawings. All wires and cables shall be identified with a permanent marker.

16D.6.2 Three phase system power cables shall be tagged at each termination with legible permanent marking tape showing phase designation by the letters ABC. The tagging shall be consistent throughout. The sequence shall correspond to the actual positive sequence phase rotation with phase 1 being the A phase, phase 2 the B phase, and phase 3 the C phase.

16D.6.3 Control circuit conductors shall be tagged at each end in motor control centers, control panels and control stations with a legible permanent coded wire marking sleeve. Sleeves shall be white PVC tubing with machine printed black marking. Markings shall be in accordance with the wire numbers and prefixes as shown in the control diagrams. Field control conductors shall be similarly tagged at each end except that each conductor termination shall have its marking sleeve imprinted with the terminal identification for both ends of the conductor. A schedule shall be provided with the as-built drawings correlating these wire markings.

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16D.7 Wiring Devices and Outlet Boxes

16D.7.1 Outlet boxes shall be located to provide ample clearance between fixtures and pipes, beams and ducts. The location of all outlets shown is approximate. The exact location shall be verified on the job to avoid conflict with other work. Boxes shall be accurately placed and independently and securely supported. Wooden plugs inserted in masonry or concrete shall not be used as a base to secure boxes. Boxes shall be secured by galvanized brackets, expansion bolts, toggle bolts, or machine or wood screws depending on the type of construction. Unless otherwise indicated, receptacle boxes shall be mounted 12 in. above the floor in offices and similar areas and 48 in. above the floor in all other areas. Switch boxes shall be mounted 48 in. above the floor, except in Blower Room, Wetwell Pump Room and Scrubber Room, mounting height shall be 72" above the floor. Blank covers shall be provided for all unused openings.

16D.7.2 Unless directed otherwise all receptacles located outdoors, wet locations, and below grade locations shall have ground-fault circuit-interrupter protection for personnel.

16D.7.3 All Ground Fault Circuit Interrupters (GFCI) receptacles shall be wired as a "End-of-Line" device which protects itself only. A separate ground wire shall be installed for GFCI receptacles. Conduit shall not be used as a ground for GFCI receptacles.

16D.7.4 All receptacles installed at outdoor locations, wet locations and below grade locations shall be equipped with weather proof covers unless indicated otherwise.

16D.8 Control Equipment and Systems

16D.8.1 The Contractor shall install and complete all electrical control systems associated with equipment being installed and provided with power under the general Scope of Work. All connections shall be made and equipment shall be ready to operate at time of acceptance.

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16D.8.2 Placement of control panels, consoles, switchboards, control cubicles, etc. shall be accomplished as indicated on applicable drawings. All units shall be properly aligned, leveled, and plumbed, and shall be attached to floor or building structure as indicated on applicable drawings. Manufacturer's installation instructions shall be followed throughout.

16D.8.3 The Contractor will ready all control systems for functional tests and will provide craft assistance as required for operational testing of control systems by Owner's Representative. Minor reconnections or adjustments to the system and all corrections of faulty Contractor furnished work or material shall be accomplished by the Contractor at no additional expense to the Owner.

16D.9 Equipment

16D.9.1 Care shall be exercised in the installation of all equipment to avoid damage or disfigurement of any kind. All equipment shall be protected from dust and moisture prior to and after installation. The panels and motor control centers shall be covered with a heavy polyethylene plastic sheet or laminated kraft paper having a moisture barrier during all stages of construction.

16D.9.2 Equipment which is stored in unheated or open areas on the job shall be provided with thermostatically controlled heating units of sufficient size to keep the temperature of the equipment above the dew point.

16D.9.3 Equipment shall be covered by the manufacturer to protect it during delivery.

16D.9.4 The Contractor shall repair by spray painting, after properly preparing the surface, all scratches or defects in the finish of the equipment. Only identical paint furnished by the equipment manufacturer shall be used for such purposes.

16D.9.5 Failure of the Contractor to protect the equipment as outlined herein shall be grounds for rejection of the equipment.

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16D.9.6 Free-standing panels shall be mounted on channel iron sills embedded in 4 in. concrete pads as shown on the drawings. They shall bear evenly over full length and be installed perfectly plumb. The sills shall be installed prior to the erection of the panel at the time the concrete pad is cast. Sills shall be secured with hook anchor bolts 1/2 by 8 in., 6 in. in concrete for each 20 linear in. of sill, or in old concrete as approved by the Owner's Representative.

16D.9.7 Sills shall bear evenly and be shimmed as required to prevent strain and deformation from being induced in the panel structure.

16D.9.8 Doors and access panels shall close and open smoothly and easily. Securing bolts and machine screws for doors and accesses shall fit perfectly to the extent that all screws and bolts may be turned down by hand without use of tools until all mating surfaces are in contact.

16D.9.9 Alternately, free-standing panels may be mounted on concrete which has been leveled by an approved grout. The concrete must be level enough to prevent any binding of compartment doors or misalignment or structural deformation of panel sections.

16D.10 Fixtures

16D.10.1 Install lighting fixtures of types indicated where shown and at indicated heights in accordance with lighting fixture manufacturer's written instructions and with recognized industry practices, to ensure that fixtures comply with requirements and serve intended purposes. Comply with NEMA standards and requirements of National Electrical Code pertaining to installation of lighting fixtures.

16D.10.2 Fixtures shall be carefully and neatly installed as required for ceiling conditions. The fixtures shall be supported with formed channels, angles, rods, clamps, washers, etc., of sufficient size and strength to support weight of fixtures from the building structure.

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16D.10.3 The Contractor shall be responsible for furnishing, at no additional cost to the Owner, all the required accessories and hardware for a complete installation of lighting fixtures in various types of ceiling construction such as plaster, exposed grid, concealed spline or any other type of ceiling construction. These accessories shall include such items as plaster frames, support arms, etc. He shall be responsible for ordering the proper fixtures with hardware for installation in or on the specified ceiling.

16D.10.4 All inoperable lamps shall be replaced with new lamps during the course of construction, up to and including the date of final acceptance of the building by the Owner's Representative.

16D.10.5 All labels and marks except UL label shall be removed from the exposed parts of the fixtures. Fixtures shall be cleaned when the job is completed. All fixtures shall be relamped one week prior to acceptance of the work. Protect installed fixtures from damage during remainder of construction period.

16D.10.6 Upon completion of installation of interior lighting fixtures, and after building circuitry has been energized, apply electrical energy to demonstrate capability and compliance with requirements. Where possible, correct malfunctioning units at site, then retest to demonstrate compliance; otherwise, remove and replace with new units and proceed with retesting.

16D.10.7 At date of substantial completion, replace lamps in interior lighting fixtures which are observed to be noticeably dimmed after Contractor's use and testing as judged by the Engineer. Furnish stock or replacement lamps amounting to 15% (but not less than one lamp in each case) of each type and size lamp used in each type fixture. Deliver replacement stock as directed to Owner's storage space.

16D.11 Grounding

16D.11.1 The Contractor shall furnish and install, complete, system and equipment grounding systems, including all conductors, connectors, ground electrodes, etc., for grounding of electrical equipment, or other items, as specified herein and indicated on applicable drawings.

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16D.11.2 Underground connections and connections to building steel shall be crucible weld process unless otherwise noted on applicable drawings. Exposed connection to equipment shall be by bolted compression type lugs.

16D.11.3 Motors having power supplied by nonarmored multi-conductor cable shall be grounded by an insulated conductor, green in color, integral with the cable, when the phase conductors are AWG #10 or #12; and by bare grounding conductors run in the interstices of the cable when phase conductors are larger.

16D.11.4 Motors having power supplied by single conductor wire in conduit shall be grounded by an insulated (green) wire run in the conduit with the phase conductors.

16D.11.5 In addition to any other required provision for grounding, all ac, 460 volt motors of 50 hp and above shall have a bare copper ground connection directly to the main ground grid system. Grounding conductor sizes will be as follows.

hp (460v)	AWG
50 - 200	#2

16D.11.6 All ac motor grounds shall provide a low impedance direct path to the ground bus of the appropriate controller.

16D.11.7 Connections from the main ground grid system (when required) shall be made to the rear leg on the conduit side of the motor.

16D.11.8 Grounding connections shall be made only to surfaces that are clean and dry. Steel surfaces shall be ground or filed to remove all scale, rust, grease, and dirt. Copper and galvanized steel shall be cleaned to remove oxide before making welds or connections.

16D.11.9 All raceway and conduit terminating at switchboard, motor control centers, and panelboards shall be bonded together and permanently grounded to the equipment ground bus. Connection to conduit may be by grounding bushing or ground clamp. Excepted from the above are conduits containing only control

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wire which enter the equipment sheet metal enclosure and are terminated there with double locknuts or hubs making an effective ground connection to the enclosure.

16D.11.10 All raceway at pump control panels or other low voltage control equipment shall be bonded and grounded except that any conduit which is effectively grounded to the sheet metal enclosure by double locknut or hub need not be otherwise bonded.

16D.11.11 Flexible "jumpers" shall be provided around all raceway expansion joints and between metallic conduits in manholes, handholes and utility vaults. Bonding straps for steel conduit shall be copper.

16D.11.12 It is the intent of these specifications that the ground grid system shall provide a low resistance earth ground. The resistance between the ground grid and the nearest water line shall be no greater than five ohms. In order to assure a low resistance path, the electrical contractor shall take a ground grid resistance reading with a Megger Null Balance Earth Tester. The reading shall be forwarded to the Engineer as soon as they are taken. If the reading exceed five ohms, the Engineer shall submit corrective measures to insure an acceptable ground resistance level. The electrical contractor shall not use the water system to ground any electrical equipment.

16D.12 Rotating Equipment

16D.12.1 The motor will be furnished by others unless indicated otherwise in these specifications or on the drawings.

16D.12.2 The Contractor shall receive, unload, and store all motors and other rotating electrical machinery shipped separately from driven equipment.

16D.12.3 The Contractor shall set and align all electric motors shipped separately from driven equipment.

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16D.12.4 All electrical machines shall be set true and plumb and with proper alignment with shafts or pulleys of apparatus to be driven. All motors are to be connected to the conduit system with flexible conduit as described herein under "Conduit" and "Grounding". Unless otherwise detailed on the drawings, conduit shall enter the side or bottom of terminal boxes and shall be so installed that liquids will tend to run off the supports rather than toward the motor fitting.

16D.12.5 The Contractor shall make all electrical connections to motors and other rotating equipment as specified herein and as shown on the applicable drawings. All motors shall be tested for proper phase and rotation and necessary reconnections made. No motor connected to pumps, blowers or other driven equipment shall be checked for rotation with the equipment connected. Permission shall be obtained from the Owner's Representative prior to the starting any motor for test.

16D.13 Instrumentation

16D.13.1 Contractor will furnish and install instruments as shown on the drawings. Instrument power shall be 120 volts from an lighting and distribution panelboard. Most electronic signal circuits will be low energy type with a milliamperere or millivolt signal.

16D.13.2 Instrument cables shall be run in conduit to be furnished and installed as specified herein under "Scope of Work", "Conduit" and as indicated on applicable drawings.

16D.13.3 Where the signal cable is the shielded type, the shield shall be carried continuously through to the panel where all shields shall be connected to a ground. Shields shall be grounded only at this point.

16D.14 Hazardous Location Installation

16D.14.1 All material, equipment, and installation work done in Hazardous Locations shall be strictly in accordance with Chapter 5 of the National Electrical Code and applicable standards of the National Fire Protection Association for the class, group, and division (as defined in the National Electrical Code)

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of hazardous conditions indicated herein or on applicable drawings.

16D.14.2 The special requirements for installations in Hazardous Locations as described in the National Electrical Code, the standards of the National Fire Protection Association and as detailed on applicable drawings shall take precedence over specifications for material, equipment or work specified herein for general application. All work, material and equipment specified elsewhere in this specification is for general application and is not necessarily suitable for Hazardous Location installations.

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16E -- TESTING AND START-UP

16E.1 Scope

16E.1.1 The tests, start-up and associated work required to be performed under this Contract are as specified below.

16E.2 General

16E.2.1 The Contractor shall provide all the necessary labor and equipment to perform all the testing required by this specification. The Contractor shall submit test reports for approval to the Engineers as required by this specification.

16E.2.2 All equipment shall be demonstrated as operating properly prior to the acceptance of the work.

16E.2.3 All protective devices shall be operative during all testing of operations.

16E.2.4 Tests shall be conducted during the construction period, and the completion of records covering such work shall be the responsibility of the Contractor. All such tests and checks shall be made in strict accordance with applicable manufacturer and instructions of the Owner or his representative.

16E.2.5 Where conditions are found during the work which require correction or change, the Contractor shall proceed promptly with the necessary work as directed by the Engineers.

16E.3 Tests Performed by the Contractor

16E.3.1 The Contractor shall furnish all the necessary labor and equipment for testing in accordance with this specification. The Contractor shall be responsible for all tests and test records. Testing shall be performed by, and under the immediate supervision of, the Contractor and shall be performed by qualified personnel fully experienced in this type of testing.

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16E.3.2 The Contractor shall provide all the necessary test equipment and shall be responsible for setting up all test equipment and other preliminary work in preparation for the tests.

16E.3.3 All testing shall be done in the presence of the Owner and/or his designated representative.

16E.3.4 Records of all tests and inspections, with completed data of all readings taken, shall be made and incorporated into a report for each piece of equipment tested. Individual reports shall be bound together with all test reports associated with the facility. The reports shall be indexed and grouped in a logical sequence.

16E.3.5 The tests specified herein apply to all equipment installed by the Contractor. Any mechanical or electrical defects or damage in the Contractor's furnished equipment shall be immediately reported to the Owner or his designated representative and shall be replaced or repaired as soon as practical by the Contractor at no additional cost to the Owner.

16E.3.6 Prepurchased items and equipment supplied by others damaged by careless or improper use of testing equipment, shall be replaced or repaired as soon as practical by the Contractor at no additional cost to the Owner.

16E.3.7 No equipment shall be energized without the prior written approval of the Owner's Representative.

16E.3.8 Test forms shall be generated by the Contractor to document test results. These forms shall be standardized for all tests of the specific type. Additional test forms shall be approved by the Owner's Representative.

16E.3.9 After the visual inspection of joints and connections and the application of tape and other insulating materials, all sections of the complete system or wiring shall be thoroughly tested for shorts and grounds. The Contractor shall correct all defects.

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16E.3.10 The Contractor shall test the grounding system, as required by this specification. If the ground system fails this testing, additional ground rods shall be driven and connected to the system as directed by the Owner's Representative. The system shall then be retested until satisfactory results are obtained. The Contractor shall include one ground test in his proposal; additional labor, materials, and testing will be priced on a unit basis.

16E.3.11 Tests of ground resistance shall be made after underground installation and connections to building steel are complete. Tests shall be made using a "megger" type ground tester and "fall of potential" test method. The ground bed shall have a maximum resistance of 5 ohms.

16E.3.12 Acceptance tests for cables utilized in systems below 600 Volts.

Perform wire and cable tests prior to connecting to equipment, as follows:

a. Control and Instrument Service

- (1) Continuity tests of cable shield, when applicable.
- (2) Continuity and ground test of conductors, prior to connecting to equipment: shield, if any, grounded at only 1 point.
- (3) Continuity tests may be performed with circuit test ringers or telephone sets, except megger (500 V) all cables 50 ft or longer in underground ducts, conduits or direct burial. Conductors may be connected together and measured to ground; apply 500 V for 10 sec. Minimum reading in megohms = rated cable insulation kV + 1.

b. Power Service

- (1) Continuity tests of cable shield, sheath, or armor, when applicable.

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- (2) Insulation resistance tests, following completion of terminations and the grounding of any shield, sheath, or armor, and prior to connection to equipment.
- (3) Megger each conductor to all others connected together and to ground, applying 1,000 V for 60 seconds. Minimum reading in megohms = rated cable insulation kV + 1. For power cables in underground systems, the above tests should be conducted immediately following pull-in, prior to terminating, and repeat tested following termination.

16E.3.13 Phase Rotation

- a. Phasing and identification of 3-phase, 60 Hz circuits, conductors, and terminal shall be:

ABC from top to bottom in vertical arrangement
ABC from left to right in horizontal arrangement

- (1) Facing front of 3-phase panels.
- (2) Facing low voltage side of power transformers.
- (3) Facing right end of panel or primary control cubicle (right end determined from 1).
- (4) Facing right end of transformer bank (right end determined from 2).

- b. Phase rotation is to be counterclockwise. (This refers to electrical rotation only, and not to mechanical rotation of machines).

16E.3.14 Motors

- a. Rotating machinery shall be given the following visual and mechanical inspections.

- (1) Inspect for physical damage. Compare equipment nameplate information with single-line diagram.

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(2) Inspect for proper anchorage, mounting, grounding and connection. Also check for proper alignment and lubrication in accordance with the manufacturer's recommendations. Lubrication or realignment shall be performed by the Mechanical Contractor.

(3) The Contractor shall compile for each motor the following data in a neatly tabulated form:

- (a) Motor Number
- (b) Drive Title
- (c) Horsepower
- (d) Volts
- (e) Nameplate Amperes
- (f) Code Letter
- (g) RPM
- (h) Service Factor
- (i) Enclosure
- (j) NEMA Design Letter
- (k) Insulation Resistance
- (l) Overload Heater
- (m) Power Factor

This information shall be filed with the Engineer prior to start-up of any equipment.

b. All three-phase rotating machines shall be given an insulation test from winding to frame. Megger test voltages and acceptable resistance values are given below.

Machine Type & Voltage	Megger Voltage	Minimum Megohms	Time
480 V ac	1000	50	60 sec.

16E.4 Final Installation Check

16E.4.1 Prior to operational testing, and after Contractor's test, final checking of equipment, raceways, circuits, and connections is required. Such checking will be done under the direction of the Owner's Representative. The Contractor shall provide all necessary labor and, where requested, supervision

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to accompany, advise, and assist the Owners' personnel in making such checks and in recording the results. Improper or defective items discovered during the checking processes shall be listed and shall be corrected, as soon as possible.

16E.4.2 The requirements for preoperational checking include, but are not limited to, the following items:

- a. Phase rotation and voltage of power interconnections
- b. All fuse and circuit breaker ratings correct as specified or shown on drawings.
- c. All instrumentation circuits correctly wired
- d. Pump controllers installed, connected, clean, and ready for operations
- e. Thermal overload relays in motor starters of correct ratings and properly installed
- f. All equipment properly grounded
- g. Integrity of grounding system verified, including all ground connections tight
- h. Power and control circuit connections completed and tight
- i. All motors checked for rotation, properly lubricated, tested, clean, and ready for operation, with driven equipment connected or positively and safely disconnected, as may be required
- j. All tests performed by the Contractor complete in accordance with this specification
- k. Conduits properly installed in accordance with applicable documents and drawings
- l. All metal raceway systems electrically continuous and correctly grounded.

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16E.5 Operational Check

16E.5.1 All equipment and all power, control, and instrument circuits will be operated and checked to ensure that operation conforms to the requirements of the elementary diagrams, wiring diagrams, and specifications. Each component or subsystem shall be operated, checked out, and necessary corrections made and rechecked before operation of major systems is attempted.

16E.5.2 The Contractor shall be responsible for the testing and calibration of all control devices and circuits.

16E.5.3 The Contractor shall provide all necessary labor and, where requested, supervision to assist the Purchaser's designated personnel with the required operational checking and to correct at once, as directed, any defective conditions disclosed by such preliminary operation.

16E.5.4 Where checking, testing, and operation reveal defects, errors, or misoperation of equipment installed by others, the Contractor shall notify the Engineers at once and shall cooperate with other Contractors or trades to correct such conditions.

16E.6 Testing Equipment

16E.6.1 Testing equipment, in sufficient numbers, to be provided by the Contractor shall include, but shall not be limited to, meggers, ground tests sets, timers, motor rotation indicator, and instruments. All equipment shall be in good operating condition and shall be properly maintained and calibrated. The calibrations will be checked at intervals by the Owners' Representative, and recalibration will be done whenever necessary.

16E.6.2 Upon completion of testing, checking, and preliminary operation of each item of equipment, circuit, or system, the Contractor shall be responsible for any necessary maintenance and protection until the item is turned over to and accepted by the Purchaser's operating personnel. Where periodic testing is a part of prescribed maintenance, the Contractor shall continue to make

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such tests and to record results according to established procedures.

16E.7 Inspection

16E.7.1 The following are mandatory hold points for which prior notification is required:

All grounding systems, direct buried conduits, and other work which will be concealed in concrete or backfilled with earth shall be inspected and released by the Owner's Representative before concrete is poured or backfill is completed.