

SECTION 16010
GENERAL REQUIREMENTS – ELECTRICAL

PART 1 GENERAL

1.1 DESCRIPTION

A. Work Included

1. All items of labor, materials, and equipment, not specified in detail or shown on drawings but necessary for complete installation and proper operation of work described or implied, shall be furnished and installed.
2. Test all electrical conductors, after completion of installation of wiring and apparatus, to ensure continuity, proper splicing, freedom from grounds, except "made grounds" and those required for protection and insulation resistance. Use testing instruments, i.e. megger. Activation of each circuit will be required as final test. Testing shall be done at no additional expense to the Owner.
3. Drawings are indicative of work to be installed but do not indicate all bends, fittings, boxes, etc. that will be required in this Contract. The structural and finished conditions of the project shall be investigated prior to construction.
4. Coordinate work with other trades to avoid interference between piping, ducts, equipment, architectural or structural features. In case of interference, the Engineer decides which work is to be relocated, regardless of which is first installed.
5. Visit the site to determine actual conditions. No extra compensation will be allowed by failure to determine existing conditions.

1.2 QUALITY ASSURANCE

A. Regulations, Standards and Publications

1. ANSI American National Standards Institute, Inc.
2. ASTM American Society for Testing and Materials
3. BOCA Building Officials and Code Administrators
4. IEEE Institute of Electrical and Electronic Engineers
5. IPCEA Insulated Power Cable Engineers Association
6. ISA International Society of Automation
7. NEC National Electrical Code of National Fire Protection Association
8. NEMA National Electrical Manufacturers Association
9. NESC National Electrical Safety Code
10. NFPA 70E Standard for Electrical Safety in the Workplace
11. UL Underwriters' Laboratories

B. Electrical Requirements

1. The installation shall comply with all Federal and State, municipal or other authority's laws, rules and/or regulations.
2. Inspections by the required authorities shall be made. Original final wiring certificates with two copies shall be submitted to the Owner.

3. The electrical inspections shall be made by the County.
4. All electrical equipment and its components and materials shall meet all applicable UL criteria and bear the appropriate label of the Underwriters' Laboratory.
5. All electrical equipment or apparatus of any one system shall be of the same quality as produced by one or more manufacturers, suitable for use in a unified system. The term "manufacturer" shall be understood as applying to a reputable firm who assumes full responsibility for its products.

1.3 SUBMITTALS

A. Shop Drawings

1. All shop drawings shall be submitted to the Engineer for review. All shop drawing submittals shall clearly indicate, using arrows and/or highlighting on all copies, which item(s) are being submitted and that each item being submitted is in compliance with all requirements on the drawings and in these specifications. All pertinent specification and drawing requirements shall be indicated on the shop drawings. If incorrect, they shall be resubmitted in quantity according to Contract conditions until satisfactory. Work shown on shop drawings shall not be executed until such drawings are approved. Electrical items shall not be installed until final approval of the shop drawings has been given by the Engineer.
2. See specific sections for a breakdown of shop drawing items.
3. Submit certification that all equipment is UL listed.
4. Shop drawings shall indicate adequate clearance for operation, maintenance and replacement of operating equipment devices.
5. The Engineer reserves the right to request additional shop drawings.

B. Installation, Operation and Maintenance Manuals

1. Submit required number of installation, operation and maintenance manuals for all equipment being provided for the electrical system. These manuals shall be submitted in 3-ring loose-leaf binders and shall be complete, neat, orderly and indexed.
2. The installation, operation and maintenance manuals shall include a copy of the approved shop drawings for all electrical items installed on the project.

1.4 PRODUCT DELIVERY, HANDLING AND STORAGE

A. Product Handling

1. Deliver all materials in good condition. Store in dry place, off ground, and keep dry at all times.

B. Protection of Installation

1. All unfinished installations, construction materials and equipment shall be protected during construction.

PART 2 PRODUCTS

2.1 SEE SPECIFIC SECTIONS FOR PRODUCTS

PART 3 EXECUTION

3.1 INSTALLATION

A. Protection of Installation

1. All equipment shall be protected during construction. All damaged equipment caused by noncompliance with this requirement shall be repaired at no expense to the Owner.

B. Openings and Chases

1. Determine locations of chases and openings prior to construction so that same may be provided where required. If openings or chases are made after building construction is accomplished, such cutting and repairing of the building shall be made by this Contractor in complete coordination with other trades on the job site to match original conditions in quality, color and type of materials used, and at no additional expense to the Owner.

C. Position of Outlets

1. The Engineer shall determine the position of all relocated outlets and equipment if the required location differs from that indicated on the drawings.

D. Moving Outlets

1. The Owner reserves the right to move any outlet a distance of ten feet before roughing in, at no additional expense.

E. Methods and Materials

1. All work shall be installed in a first-class, neat and workmanlike manner by skilled mechanics. All materials shall be new. Firmly support all materials and equipment.

F. Cutting, Repairing and Finishing

1. All cutting, repairing, finishing and painting required for the installation of work under this Contract shall be performed under this Contract.
2. All disturbed surfaces shall be repaired and finished to match adjacent surfaces by skilled mechanics working in their respective fields.

G. Excavation and Backfilling

1. Excavation and backfilling shall be in accordance with the requirement of Division 2 and as required to complete the work according to details on drawings.

- H. Concrete
 - 1. Concrete work shall be in accordance with the requirements of Division 3 and as required to complete the work according to details on drawings.
- I. Cutting and Patching of Concrete Areas
 - 1. Openings in concrete required for Electrical construction shall be made by taking extreme precautions to prevent excessive damage to existing facilities. Prior to completion, all disturbed areas shall be closed, restored to normal and finished to match surrounding areas.
- J. Access
 - 1. Install all conduit, wire, cable, wiring devices and equipment to preserve access to all equipment installed under this Contract.
- K. Layout of Wiring
 - 1. The layout of wiring as shown on the drawings shall not be considered as absolute. It shall be subject to changes where necessary to overcome obstacles in construction. Where a major deviation from the plans is indicated by practical consideration, shop drawings shall be submitted showing all deviations in detail to clearly indicate the necessity or desirability for the change.
- L. Miscellaneous Supports
 - 1. Furnish and install all necessary angles, beams, channels, hanger rods or other supports for equipment and piping furnished under this Contract requiring support or suspension from building structure.
- M. Continuity of Service
 - 1. Uninterrupted electrical service shall be maintained during the entire time required for complete installation of the work proposed in the Drawings and in the specifications.
 - 2. Temporary equipment, cable, and whatever else is necessary shall be provided as required to maintain electrical service to all facilities. Temporary service facilities, if required at any time, shall not be disconnected or removed until new services are placed in proper operation.
 - 3. If any service or system must be interrupted, the Contractor shall request permission in writing stating the date and time the service will be interrupted, and the areas affected. This request shall be made in sufficient time for proper arrangements to be made. Written permission shall be obtained from the Owner before interrupting electrical service to any facility.

N. Clean Up

1. Upon completion of all work under the electrical specifications, furnish labor, materials, and incidentals to accomplish the following: remove all dirt, foreign materials, stains, fingerprints, etc. from all lighting fixtures, glassware, panelboards, wall plates, system equipment, floors, walls and ceilings adjacent to the above equipment and leave the electrical work in such a condition that no cleaning will be required by the Owner. The complete system shall be subject to inspection and approval by the Owner.

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SECTION 16050
BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 GENERAL

1.1 DESCRIPTION

- A. This Section includes requirements for basic electrical materials and methods. It includes requirements for the following listed materials:
 - 1. Raceway and Fittings
 - 2. Wire and Cable – 600Volt and below
 - 3. Wire connections and Connecting Devices
 - 4. Boxes
 - 5. Wiring Devices
 - 6. Panelboards
 - 7. Grounding Materials
 - 8. Disconnect Switches
- B. This Section applies to all sections of Division 16 and to other sections that include electrical equipment requirements except when in these individual sections' requirements are otherwise specified.
- C. Electrical systems shall be complete including all miscellaneous materials and be ready for operation as indicated in accordance with the Contract Documents.
- D. Classifications of areas shall be as shown on the Drawings.

1.2 QUALITY ASSURANCE

- A. Electrical work shall be performed, and all materials shall be in accordance with the National Electrical Code. Above code shall be minimum requirements for electrical work and if there is a conflict between the requirements specified in the Contract Documents and the code, the more stringent shall apply as determined and approved by the Engineer.
- B. Unless approved otherwise, provide electrical materials and equipment that are the standard products of manufacturers regularly engaged in the production of such materials and equipment. Provide the manufacturer's latest standard design that conforms to these Specifications. When two or more units of the same class of material and equipment are required, these units shall be the products of the same manufacturer.

1.3 SUBMITTALS

- A. Submit the following Contractor's Drawings in accordance with Section 01300:
 - 1. Complete list of electrical materials to be furnished showing manufacturer.
 - 2. Complete schedule and listing of system and equipment identification labels with legends.

3. Conduit Layout

1.4 JOB CONDITIONS

- A. The Drawings indicate the extent and general arrangement of the principal electrical elements, outlets, and circuit layouts. It is the intent that all electrical elements and devices provided under this, and other sections be properly connected and interconnected to form a workable system as required by the Contract Documents whether the connections and interconnections are specifically stated in the Specification or shown on the Drawings. Additional circuits shall be installed wherever required to conform to the specific requirements of the furnished equipment and for proper installation of the work without additional cost to the Commission.

1.5 IDENTIFICATION FOR SYSTEM AND EQUIPMENT 600 VOLTS AND BELOW

- A. General
 - 1. Identify and label each raceway, piece of equipment and conductor.
 - 2. Develop a schedule for labels showing the legend of each as shown on the Drawings, schedules and by the nature of the system. In the absence of specific data, the Contractor shall develop legends from the nature of the service or system and submit for approval by the Engineer. The schedule shall be arranged to produce a legible comprehensive identification system.
- B. Raceway Identification
 - 1. Exposed raceways shall be identified at each end within 12 inches of point of termination.
 - 2. Identifying labels shall be factory manufactured with colored paper machine printed with an identifying legend laminated between two sheets of vinylite plastic formed to completely encircle the raceway. Sizes shall match the raceway on which they are to be applied. Labels shall be installed in accordance with manufacturer's instructions.
 - 3. Legends to be used in the labels shall indicate the system voltage and what it serves or type of service. The legend shall appear in a minimum of one-inch-high white letters on a black background for raceways 2½ inch and smaller diameter and two-inch-high letters for raceways larger than 2½ inch diameter.
- C. Equipment Identification
 - 1. Nameplates shall be attached to inside surfaces with adhesive and to the outside surface with round head, self-tapping metal screws.
 - 2. Nameplates shall be two-color laminated plastic not less than 1/16 inch thick, machine engraved to show white letters not less than ¼ inch high on a black background. Legend shall identify the enclosure or piece of equipment.

D. Conductor Identification

1. Power conductors terminating in panelboards, cabinets, motor control centers and special service outlets shall be identified at each end and in intervening junction and pull boxes. Where feeder conductors pass through a common box, tag the feeder to indicate the electrical characteristics, circuit number and panelboard designation. Labels shall be located near the conductor ends for terminals and on exposed portions of conductor within pull and junction boxes.
2. Control wiring shall be identified at each end of each wire by a number conforming to the following:
 - a. Wiring for Pump No. 1 shall be labeled with numbers from 100 to 199. Wiring for Pump No. 2 shall be labeled with numbers from 200 to 299, and so forth. Wiring for auxiliary equipment shall use wire numbers not used for the pumping units. Where it is impractical to maintain the same wire numbers throughout, a terminal block shall be installed at the junction of the different numbered wires. On each side of the terminal block each associated wire number shall be typed or written in with permanent ink.
3. Labels shall be plastic slip-on ferrule type with durable machine printed letters, numerals and other identifying characters.

PART 2 MATERIAL

2.1 RACEWAY AND FITTINGS

A. General

1. Minimum size shall be $\frac{3}{4}$ inch.
2. Fittings shall be of the same material and match the raceway.

B. Raceways

1. Rigid steel, heavy wall, hot-dip galvanized meeting requirements of UL-6 and ANSI C80.1.
2. PVC coated rigid galvanized steel shall meet the requirements for rigid galvanized steel raceway herein and have 40 mils bonded PVC jacket meeting requirements of NEMA RN-1 type A-40.
3. Rigid non-metallic shall be Schedule 40 PVC and Schedule 80 PVC meeting requirements of UL-651 with solvent cement joints.
4. Liquid-tight flexible shall be single strip steel, hot-dip galvanized with PVC jacket meeting requirements of UL-t. Conduit sizes $1\frac{1}{4}$ inch and smaller shall include a continuous copper bonding conductor wound spirally between convolutions on the inside of the conduit meeting requirements of UL-360.
5. Electrical metallic tubing (EMT) shall meet requirements of UL-797 and ANSI C80.3.
6. Intermediate metal conduit (IMC) shall meet requirements of UL-1242 and ANSI C80.6.

7. Rigid aluminum meeting requirements of UL-6 and ANSI C80.5.
- C. Fittings
1. Fittings shall be of the same material and finish as the raceways and shall meet requirements of UL-514 and ANSI C80.4. Threaded connectors shall be used for all rigid metal conduits.
 2. For enclosures, cabinets and boxes in dry areas use nylon insulated bushing and lock-nut.
 3. For enclosures, cabinets and boxes in wet areas use PVC coated watertight hub fitting with gasket.
 4. Connectors for liquid-tight flexible conduit shall have factory installed liner of plastic in areas of contact with conductor insulation. Neoprene sealing rings shall be provided when conduit is installed in knockout.
- D. Miscellaneous Specialty Fittings
1. For exterior walls, roof and where water tightness is required, provide watertight sealing sleeves for raceway penetrations consisting of a steel sleeve with pressure ring and clamps or an assembly of molded rubber links with pressure plates and through bolts which may be tightened at any time. Seal between raceway and concrete shall withstand 25 feet of water head without leaking.
 2. For interior walls, floors and where water tightness is not required provide schedule 40 galvanized steel pipe sleeves and plastic expandable sealant.
 3. Provide raceway expansion fittings where raceway crosses building or concrete expansion joints. Provide bonding jumper with each expansion fitting.
- E. Hazardous Locations
1. Conform with NEC Articles 501 and 502 for areas identified as "Hazardous Areas."
 2. Provide threaded cast boxes and fittings for junction boxes and pull boxes in Class I areas. Boxes and fittings shall be UL listed for installation in Class I, Division 2, Groups A, B, C, and D.
 3. Provide Conduit seal at conduits leaving the "Hazardous Areas".
- F. Raceway Supports
1. Support raceway at intervals and at locations as required by the NEC. Do not use perforated straps or plumbers' tape for conduit supports. Independently support raceways from the structure, except as may be approved by the Engineer.
 2. Supports and hangers shall be steel, hot dip galvanized after fabrication, except stainless steel supports shall be provided for PVC and PVC coated raceways, and aluminum supports provided for use on aluminum raceways.
 3. Fasteners for concrete shall be expansion bolts or inserts, toggle bolts for hollow masonry or frame construction and preset inserts for pre-stressed concrete.

4. For raceways supported on surface, provide straps with holes for one or two fasteners and shaped to fit raceway size.
5. At structural steel members support raceway with hot dip galvanized beam clamps. Drilling or welding may be used only where indicated on the Drawings or as approved by the Engineer.
6. For suspended raceways, provide galvanized hanger rods not less than $\frac{3}{8}$ inch diameter for raceways up to 2-inch diameter and $\frac{1}{2}$ inch diameter rods for raceways larger than 2-inch diameter. Rods shall be threaded a minimum of $1\frac{1}{2}$ inch on each end to permit adjustment.
7. For multiple suspended raceways, the horizontal channel shall not be less than $1\frac{1}{2}$ inches square by 12 Gauge. Weld two or more together when greater strength is required to limit deflection to $1/2000$ of span. Hanger for the horizontal channel shall be sized for the number and size of raceways supported as shown on the drawings or if not shown as approved by the Engineer.
8. Exposed raceways on walls below grade, in damp, wet or corrosive locations shall be installed with standoff brackets provided a minimum of $\frac{1}{4}$ inch air space between the raceway and the mounting surface.
9. Where area or room is identified as "Corrosive, wet or hazardous area", supports, hangers, preformed channels and clamps shall be type 304 stainless steel. Bolts and nuts shall be Type 304 stainless steel.
10. Where raceway may be affected by dissimilar movements of the supporting structures or medium provide flexible or expansion devices.
11. Fasteners for concrete shall be SST expansion bolts or inserts, toggle bolts for hollow masonry or frame construction and preset inserts for pre-stressed concrete.
12. Exposed raceways on walls below grade, in damp, wet, corrosive or hazardous locations shall be installed with standoff brackets providing a minimum of $\frac{1}{4}$ inch air space between the raceway and the mounting surface.

2.2 WIRE AND CABLE - 600 VOLTS AND BELOW

A. General

1. Conductors shall be copper, 98 percent conductivity, soft annealed copper meeting requirements of ASTM B33. No.12 and No.10 AWG shall be solid, and No.8 AWG and larger gauge stranded. All wiring shall be stranded with the exception of b. below.
2. Minimum conductor sizes shall be as follows:
 - a. Power and lighting branch circuits shall be No.12 and No.10 AWG as needed and be copper and solid.
 - b. 120volt ac control circuits shall be No.14 AWG and be copper and stranded.
 - c. Low energy control and signal circuits as indicated on Drawings.

- B. Insulation
1. Unless approved otherwise, wire and cable shall be insulation type THWN or THHN. No.6 AWG and larger gauge shall be XHHW-2.
- C. Identification
1. Wire cable shall have the following information surface printed at regular intervals throughout the entire length. No.6 AWG above shall be XHHW-2.
 2. Manufacture or trade name.
 3. Size of conductor.
 4. Type of insulation
 5. Voltage classification
- D. Color Coding
1. Color coding shall be provided throughout the entire network for service, feeder, branch, control, and low energy signal circuit conductors. Color coding of conductors No.6 AWG and smaller shall have factory impregnated color throughout its entire length. Conductors No.4 AWG and larger gauge may be marked with color coding tape a minimum of 0.004 inch in thickness. Color coding tape shall be applied to cover at least three inches of the conductor length, one-third lapped. The color of conductors for different voltage systems shall be as follows:

SYSTEM	PHASE A	PHASE B	PHASE C	NEUTRAL N	GROUND
240/120Vac Single Phase	Black	Red	N/A	White	Green
208/120Vac Three-Phase	Black	Red	Blue	White	Green
480/277Vac Three-Phase	Yellow	Brown	Orange	Gray	Green
Control and Low-Energy Signal	Red	N/A	N/A	White	Green

- E. Instrumentation signal cables shall be shielded pairs or triads with polyvinyl jackets and overall shield over the multiple pairs or triads. The instrumentation cable shall be rated 300volts at 90°C or better. The size of the instrumentation cable shall be AWG No. 16 with seven strands minimum, unless approved otherwise. Instrumentation cables shall meet all the requirements of ICEA S-61-402 and shall be UL listed.
- F. All Control and Instrumentation wire intended and designed for use with 24 VDC or less shall be considered Low Voltage. To prevent electrical interference and provide isolation from higher voltages, all Low Voltage wire shall be installed in separated and dedicated rigid conduit or cable trays that provide segregation.

- G. 120volt ac control wiring shall be AWG No.14 THHN. Main power (120volt ac) to the panels shall be wired using color coded AWG No.12. Supply power to any panel component shall be accomplished using molded 3-wire plug cords.

2.3 WIRE CONNECTIONS AND CONNECTING DEVICES

- A. Splice and Termination Components
 - 1. Splice connectors for conductors No.10 AWG and smaller gauge solid conductors shall be insulated pressure twist-on nut type.
 - 2. Splice connectors for No.8 AWG and larger gauge conductors shall be split bolt or compression type for making parallel or butt splices. Provide companion preformed plastic insulating covers or tape equivalent to conductor insulation.
 - 3. Provide solderless terminal lugs for stranded and multiple solid conductors at connection to terminals or use UL listed crimp tool compression style lugs.
 - 4. Control conductor connection terminations shall be either spade lug or pressure type.

2.4 BOXES

- A. General
 - 1. Boxes on conduit raceways shall be made of the same material as the conduit except on PVC conduit use PVC coated galvanized steel boxes.
- B. Outlet, Junction and Pull Boxes
 - 1. Outlet, junction and pull boxes for use in dry areas shall be one-piece galvanized sheet steel knock-out type (unless otherwise noted) a minimum size of four inches square or octagonal and 1½ inches deep. Provide appropriate and compatible cover for each box.
 - 2. Boxes for use in damp and wet areas shall meet requirements of NEMA 4X, be PVC coated cast steel or cast iron with threaded external hubs for conduit entrance a minimum size as stated for boxes in dry areas. Boxes shall have gasketed cover plates and be PVC coated with stainless steel hardware.
 - 3. Boxes for use in corrosive areas shall meet requirements of NEMA 4X, Stainless-steel with external hubs and extended ears for conduit entrance, minimum size as stated for boxes in dry areas. Boxes shall have gasketed cover plates and stainless-steel hardware.
 - 4. Boxes for use in hazardous areas shall meet NEC requirements for Class 1, Division 2, Groups C and D.

2.5 WIRING DEVICES

- A. Switches
 - 1. Wall switches shall be rated at a minimum 20 amperes.

- B. Outlet Receptacles
 - 1. General utility duplex convenience receptacles shall be rated at a minimum 20 amperes, specification grade.
 - 2. Provide special purpose receptacles of the type, rating and number of poles as shown on the Drawings.
- C. Device Plates
 - 1. Device plates for outlets shall be one piece suited for the device installed. Plates on unfinished walls shall be zinc-coated sheet steel or cast metal with rounded edges. Plates on finished walls shall be satin finish stainless steel. Screws shall be countersunk heads with color and finish to match plate.

2.6 PANELBOARDS

- A. General
 - 1. Panelboards shall meet requirements of UL-67 and in addition, those used as service disconnects shall meet requirements of UL-869. Panelboards shall be factory assembled, dead front, safety type equipped with circuit breakers and designed so individual bolt-in-type breakers can be removed and replaced without disturbing adjacent units or without loosening or removing insulation supplied to obtain clearances as required by UL. Panelboards shall be sized to accommodate the number of single, double and three pole breakers as shown on the Drawings. Unless approved otherwise, provide for a minimum of six single pole spare spaces in each Panelboard for future installation of breakers.
 - a. Cabinet for the Panelboard shall be equipped with a continuous piano-hinged door trim covering. Inside the door, mount a removable directory behind a transparent protective covering to indicate and identify the different circuit breakers. Panelboard door shall be provided with a lock with two keys provided per lock. Unless approved otherwise, door locks shall be keyed alike. The panelboard cabinet shall be shop primed and finish-painted inside and outside with manufacturer's standard paint system.
 - b. Each panelboard shall be provided with main and neutral buses insulated from the cabinet and a ground bus bonded to the cabinet. Buses shall be copper with ampere rating as shown on the Drawings. Support bus bars on bases independent of the circuit breakers. Buses shall be designed so circuit breakers may be changed with simple tools without machining, drilling or tapping. Make complete provisions for mounting future circuit breakers throughout the entire length of the bus regardless of the number of units and spaces specified. Provide solderless main lugs for main, neutral and ground bus bars.

- c. Circuit breakers shall be molded-case type. Provide quick-make and quick-break toggle mechanism, inverse time trip characteristics, and trip-free operation on overload or short circuit. Automatic tripping shall be indicated by a handle position between the manual OFF and ON position. Provide trip ratings and number of poles as indicated in the drawings. Provide provisions for padlocking external disconnect handles in the OFF position.

2.7 GROUNDING MATERIALS

- A. Ground rods shall be copper clad steel minimum $\frac{3}{4}$ inch diameter and not less than ten feet long.
- B. Ground conductors for connection to the ground rods shall be stranded, bare, soft drawn, copper cable or bar with gauge not lighter than 12 AWG. Green insulated conductors for installation in raceways.
- C. Ground clamps shall be copper alloy multi-bolt type, saddle clamp or compression type assembled with bronze bolts, nuts, and washers.
- D. All welded connections for the grounding system shall be the exothermic process.

2.8 DISCONNECT SWITCHES

- A. Disconnect safety switches shall be fusible or non-fusible with ampere rating, voltage rating, number of poles and enclosure type as shown on the Drawings. All switches shall be heavy duty type. Mechanisms shall have quick-make, quick-break operating handles with provisions for padlocking in the OFF position, interlock to prevent unauthorized opening of the cover when the switch is in the ON position and to prevent closing the switch mechanism with the cover open.

PART 3 EXECUTION

3.1 GENERAL

- A. Install electrical equipment and material of the size, type and general routing as shown on the Drawings or on approved Contractor's Drawings. No splices shall be allowed unless approved by the Engineer.
- B. Install metallic raceway, fittings, boxes, and cabinets free from direct contact with reinforcing steel.
- C. Provide fasteners, anchor bolts, anchorage items and supports as required to insure proper and rigid alignment. Attach equipment with fasteners sized according to size and weight of equipment and thickness of supporting surface.
- D. Where aluminum is placed in contact with dissimilar metal or concrete, separate contact surfaces with gasket, non-absorptive tape, or coating to prevent corrosion.

- E. Make metallic conduit, raceways, and cable trays electrically and mechanically continuous and ground as required. Conduits shall be continuous between outlets, boxes, cabinets, and panels, and shall enter and be secured to each box.
- F. Provide ground conductor in each conduit run.
- G. No more than one 3-phase circuit or feeder circuit in a conduit run, unless shown otherwise on the Drawings
- H. Provide electrical equipment and material per the following schedule, unless noted otherwise on the Drawings:

CONDUIT USE SCHEDULE

AREA	ENCLOSURE	CONDUIT
Dry Location		
Control Room	NEMA 1 or 12	PVC Schedule 80
Generator Room		
Drywell (Pump Room & Intermediate Levels)	NEMA 4X	PVC Schedule 80
Above suspended ceiling, concealed in walls (not concrete encased)	NEMA 1	EMT
Underground Vaults	NEMA 4X	PVC Schedule 80
Outdoors		
Subject to physical damage		Aluminum
Not subject to physical damage		PVC Schedule 80
Direct Buried		PVC Schedule 80
Encased in Concrete		PVC Schedule 80
Wetwell and Areas Class 1, Division 2	NEMA 7, Explosion Proof	PVC Coated R.G.S.

NOTES:

- Minimum size conduit ¾”.
- Minimum ¼” spacing off walls.
- All Stub-ups to 3'-0” A.F.F., rigid galvanized steel (R.G.S.) conduits, except PVC coated rigid galvanized steel as required. Use full length of conduit for stub-up.

3.2 CONDUIT RACEWAYS

A. General

1. Unless approved otherwise, conceal conduits within finished walls, ceiling and floors. Install conduits parallel or perpendicular to building floors, ceilings and walls, and to avoid interference with other work. Cut conduits square and debar cuts to the same degree as conduit manufacturer. Fasten conduit securely to outlets, junction, pull and terminal boxes. Provide caps and seals to prevent entrance of foreign material and moisture during installation and before wire pulling.
2. Keep conduit at least six inches away from high temperature piping, ducts, flues and surfaces. For mounting on concrete and masonry surfaces provide a minimum of ¼ inch standoff support. Support and fasten conduit to building structural members using pipe straps, wall brackets, hangers or ceiling trapeze spaced in accordance with electrical codes. Support conduit at least every eight feet and within three feet of every box, panel, and enclosure.
3. When two or more exposed conduits are in the same general routing, provide parallel installation with symmetrical bends. For three or more provide channel racks. Provide channel rack space for 25 percent additional conduits.
4. Make changes in direction with bends and fittings. Field-made bends and offsets shall be made with a hand bender or conduit-bending machine. Conduit runs shall have no more than the equivalent of three 90 degree bends within 75 feet between boxes or two 90 degree bends within 125 feet. Pull boxes shall be provided where shown, specified, or wherever required to pull conductors and to meet the above requirement. Install expansion fitting when conduit crosses building structural expansion joint. Unless otherwise approved, conduits shall cross perpendicular to building structural expansion joints.

B. Conduit Connections

1. Final connections to motors or vibrating equipment shall be liquid-tight flexible conduit. Unless approved otherwise, flexible conduit shall not be less than one foot nor more than three feet in length.
2. Conduit fittings, connectors and boxes shall be of the same material and be compatible with the conduit material.

C. Underground Conduits

1. For conduits buried in earth, provide minimum 30 inches of cover and minimum of one foot clearance between other utility crossings and parallel runs. Maintain a grade of at least four inches per 100 feet run either from one manhole or pull box to the next or from a high point between them. Drain conduits away from building, if this is not possible, provide watertight seal at building.
2. Provide detectable warning tape approximately 18 inches above and directly over centerline of buried conduit.

D. Conduit Penetrations

1. Concealed penetrations for conduits shall be made not more than $\frac{1}{4}$ inch larger than the diameter of the conduit. Penetrations through walls, ceiling and floors other than concrete for exposed conduits shall be not more than $\frac{1}{4}$ inch larger than the diameter of the conduit and void around conduit filled with non-hardening caulking compound receptive to painting and surface finished same as wall, ceiling or floor.
2. Where a conduit enters through a concrete roof or membrane waterproofed wall, floor or ceiling, provide a watertight sealing sleeve that can be tightened from one side. If the sealing sleeve is not placed with the concrete, core-drill proper size hole to provide a mechanically watertight installation.
3. Where a conduit enters through a concrete non-waterproofed wall, floor or ceiling, provide a galvanized steel sleeve, schedule 40, and fill the space between the conduit and sleeve with plastic expandable compound or an oakum and lead joint. If the sleeve is not placed with the concrete, drill hole not less than $\frac{1}{2}$ inch nor more than one inch larger than sleeve, center sleeve and grout sleeve total depth of penetrated concrete with non-shrink grout, polyurethane, or silicone sealant.

E. Conduit Damage Correction

1. Repair cuts, nicks and abrasions or replace damaged conduit as approved by the Engineer.

F. Conduit Seals

1. Provide a conduit seal for each conduit leaving a hazardous area.

G. Spare Conduits

1. Provide spare conduits for future use as shown on the Drawings. Provide a minimum 200-pound strength nylon pull line in each spare conduit and identify at each end the origin and termination of the conduit. Terminate spare conduits in equipment, boxes or by couplings plugged flush with building surfaces.

3.3 BOXES

A. General

1. Each box shall be of the proper size for the number of conductors enclosed in the box.
2. For boxes mounted on steel, concrete and masonry surfaces provide minimum $\frac{1}{4}$ inch spacer to hold box away from surface or provide non-corrosive coating between surfaces.
3. Provide separate support for boxes and bolt units to building with expansion anchors, toggle bolts or appropriate screws. For lighting fixture outlet boxes, provide supports adequate to support weight of fixture to be mounted on the box.

4. Remove debris including dust, dirt, wire clippings and insulation from interior of boxes. Boxes with open conduit holes are not permitted and shall be replaced at no cost to the Commission. Damaged boxes shall be repaired, as approved by the Engineer, or replaced.
 5. Where boxes are shown on each side of a common wall, do not mount back-to-back but offset horizontally at a minimum of six inches.
 6. In underground locations, conduit entrance into equipment and fixtures shall be made from side or bottom of box. Top penetrations shall not be permitted.
- B. Outlet Boxes
1. Unless approved otherwise, mount boxes flush with finished wall or ceiling.
 2. Unless approved otherwise, mounting heights measured from the finished floor to centerline of the outlet box shall be as follows:
 - a. For switches four feet and in addition for lighting switches mount on strike side of door.
 - b. Duplex convenience outlets 18 inches for dry locations, and 48 inches for wet & damp locations.
 - c. For fixtures and equipment four feet or as shown on the Drawings.
- C. Junction and Pull Boxes
1. Provide pull boxes where required to facilitate conductor installation and to limit conduit runs to less than 150 feet.
 2. Install pull and junction boxes in accessible locations with working space in front of and around the installation. Boxes are not permitted in finished areas without approval of the Engineer.

3.4 CONDUCTORS

- A. Install conductors as shown on the Drawings in raceways with no splices between boxes. Install complete raceway system and clear debris and moisture before conductor installation.
- B. Pull conductors using proper equipment without exceeding manufacturer's recommendation for maximum pulling tension. Protect conductor insulation jacket at all times from kinks, scrapes, punctures and other damage. Replace damaged conductors. Use lubricating compound to reduce pulling force as required. Lubricating compound shall be UL listed compatible with the conductor insulated jacket and with the raceway.
- C. Support conductors in vertical risers with woven grips to prevent loading on conductor connectors.
- D. In conduits entering buildings or from areas where temperature change may cause condensation or moisture, provide seal between conductors and conduit after conductors are put in place.

- E. When using color-coding tape apply with overlapping turns for a minimum length of two inches starting two inches back from the termination point.
- F. Leave a minimum of six inches of free conductor at each connected outlet and a minimum of nine inches at unconnected outlets.

3.5 WIRE CONNECTIONS AND CONNECTING DEVICES

- A. Connect circuit conductors of the same color to the same phase throughout the installation.

3.6 WIRING DEVICES

- A. Switches and receptacles shall be installed in accessible locations and so that the long dimension is vertical.
- B. Provide a bonding jumper between the grounded box and the switch or receptacle ground terminal.

3.7 CABINETS AND ENCLOSURES

- A. Mount cabinets and enclosures so there is a minimum of 1½ inch air space all around.
- B. Arrange conductors in cabinets, panels and enclosures in a neat arrangement, cut to proper length and with surplus conductor removed.
- C. Identify each circuit in the enclosure.
- D. Provide terminals and connectors for the type of material being used.

3.8 PANELBOARD

- A. Secure panelboard rigidly to walls and floors to mounting pads with anchor pads with anchor bolts or Phillips Drill Company concrete anchors. Anchor bolts or concrete anchors shall be Type 316 stainless steel.

3.9 GROUNDING

- A. Unless approved otherwise, ground all exposed non-current carrying metallic parts of electrical equipment, raceway systems, and the neutral of all wiring systems in accordance with the NEC and other applicable codes.

- B. Grounding system shall be bonded to one or more grounding rods driven a minimum of nine feet in the ground. The ground connection to the metal pipe shall be not more than one foot inside the building. Ground conductor for connection to ground rod shall be stranded copper and connected by the exothermic welding process. Earth buried ground conductors shall not be insulated. File or sand surfaces before connecting ground to ensure good metal to metal contact.
- C. Bond the grounding conductors to metallic enclosures at each end and to all intermediate metallic enclosures. Where equipment contains a ground bus, extend and connect grounding conductors to that bus. Run ground conductors inside conduits enclosing the power conductors.
- D. Make connections of grounding conductors to circuits 20 amps or above by a solderless terminal and a 5/16-inch minimum bolt tapped to the motor frame or equipment housing. Ground connections to smaller equipment may be made by fastening the terminal to a connection box. Connect junction boxes to the equipment grounding system with grounding clips mounted directly on the box or with $\frac{3}{8}$ inch machine screws. Remove all paint, dirt or other surface coverings at grounding conductor connection points so that good metal to metal contact is made.

3.10 FIELD QUALITY CONTROL

- A. Perform Testing in accordance with Section 16950.

END OF SECTION

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SECTION 16130
ELECTRICAL BOXES AND FITTINGS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Provide junction boxes, pull boxes, covers, and miscellaneous hardware as indicated, in accordance with the Contract Documents.

1.2 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
 - 1. National Electrical Manufacturers Association (NEMA).
 - 2. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
 - 3. Underwriters Laboratory Inc. (UL):
 - a. 508, Industrial Control Equipment.
 - b. 698, Industrial Control Equipment for Use in Hazardous (Classified) Locations.
 - c. 886, Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations.

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the production of the required materials and equipment.
 - 1. The manufacturer shall be responsible for the design, construction and proper operation of all components.
- C. Comply with applicable codes and standards.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Submit the following in accordance with Section 01330, Submittal Procedures.
 - 1. Product data.
 - 2. Shop drawings.
 - 3. Special shipping, storage, protection, and handling instructions, if any.
 - 4. Manufacturer's installation instructions.
- B. Submit manufacturer's certificates in accordance with the Section 01450, Quality Control.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Outlet Boxes:
 - 1. Steel City.
 - 2. Appleton Electric Co.
 - 3. Raco.
 - 4. Carlon.
 - 5. Or equal.
- B. Pull and Junction Boxes:
 - 1. Crouse-Hinds Co.
 - 2. OZ Electrical Manufacturing Co.
 - 3. Hope Co.
 - 4. Or equal.
- C. Fittings:
 - 1. Crouse-Hinds Co.
 - 2. Appleton Electric Co.
 - 3. Robroy Industries.
 - 4. OZ Electrical Manufacturing Co.
 - 5. Carlon.
 - 6. Or equal.

2.2 OUTLET BOXES

- A. Provide outlet boxes for use with IMC raceway as follows.
 - 1. Galvanized case metal type.
 - 2. With tapped hubs for conduit entrance.
 - 3. Having galvanized cast metal covers with rubber gasket.
- B. Provide non-metallic outlet boxes for use with concealed PVC raceway. Procure from same manufacturer as raceway.
- C. Provide non-metallic single- and two-gang outlet boxes with integral mounting feet, for use with PVC raceway. Provide non-metallic blank covers with stainless steel mounting screws. Carlon FS or FD, or equal.
- D. For use with PVC coated RMC provide PVC coated galvanized cast metal type outlet boxes with tapped hubs for conduit entrance. Provide covers of PVC coated galvanized cast metal with rubber gasket. Provide minimum 40 mil-thick polyvinyl chloride jacket on exterior surfaces of box bodies and covers.
- E. Provide PVC coated cast outlet boxes in hazardous areas (as defined by NEC), as follows
 - 1. Suitable for Class, Division and Group location as indicated.
 - 2. Conform to UL 886.

3. Bearing UL label as suitable for intended application.

2.3 PULL AND JUNCTION BOXES

- A. Provide junction or pull boxes where indicated, and where required to facilitate wire pulling and connection.
- B. Provide pull and junction boxes less than 100 cubic inches as specified for outlet boxes:
 1. Flush NEMA 4 junction boxes – watertight outside flanged with recessed cover type “YR” as manufactured by OZ/Gedney, or equal.
- C. Provide pull and junction boxes 100 cubic inches and larger for use with PVC raceway, fabricated from PVC, or equal non-metallic product, and:
 1. Equipped with screw cover unless otherwise noted.
 2. Adequately support the boxes to maintain shape.
 3. Provide NEMA 4X boxes with watertight gasketed covers and external mounting feet.
- D. Pull and junction boxes 100 cubic inches and larger installed in hazardous areas, as defined by NEC, shall be suitable for Class, Division and Group as indicated and comply with following:
 1. Provide neoprene gasket.
 2. Provide stainless steel hinges and natural stainless-steel finish.
 3. Confirming to UL 886 and bearing UL label as suitable for intended application.
- E. Boxes shall be supported to maintain shape. Larger boxes shall be formed of structural bracing into rigid assembly to maintain alignment in shipment and installation
- F. Provide drain fittings in NEMA 4X boxes. Crouse-Hinds, Type ECD 11, Killark No. KDB-1, or equal.

2.4 PAINTING

- A. Clean and shop prime all non-galvanized, non-stainless steel metal surfaces in accordance with Section 09900, Painting and Coating, System No. 3.
- B. Use ANSI 61 light gray as the final exterior color for the pull boxes.

PART 3 EXECUTION

3.1 GENERAL

- A. Size boxes in accordance with NEC, or as indicated.

- B. Provide suitable box at outlets especially designed to receive type of fixtures and devices to be mounted thereon, except where otherwise noted for recessed fluorescent fixtures.
- C. Provide fixture outlets with fixture supports of size and type required for fixture to be hung. Fixture studs, generally, shall be 3/8-inch.
- D. Provide boxes of type approved for particular purpose intended.
- E. Recessed wall outlet boxes shall be at least 4-inches square.
- F. In finished areas, provide box covers to fit outlet box installed of required depth so that the edge of ring is flush with finished material.

3.2 INSTALLATION

- A. Securely support each box at two or more points and two or more sides to prevent movement in all directions.
- B. Use boxes to support devices and face plates. Do not use face plates and devices to support boxes.
- C. Where box is concealed in stud wall, securely attach it to full depth stud (or section of stud) on each side of box.
- D. Provide labels in accordance with Section 16195, Electrical Identification.

3.3 FIELD QUALITY CONTROL

- A. Perform field inspection and testing in accordance with Section 16950, Testing.
- B. Adjusting and Cleaning: Clean surfaces after installation.
- C. Grounding:
 - 1. Provide grounding in accordance with Section 16450, Grounding.
 - 2. Tighten connections to comply with tightening torques specified by the manufacturers and UL Standard 486A to assure permanent and effective grounding.

END OF SECTION

SECTION 16143 WIRING DEVICES

PART 1 GENERAL

1.1 DESCRIPTION

- A. Provide plugs, plug connectors, device covers, and switches as indicated on drawings and as specified herein. This section includes the following:
 - 1. Receptacles.
 - 2. Ground fault circuit interrupter receptacles.
 - 3. Switches.
 - 4. Mounting hardware.

1.2 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
 - 1. National Electrical Manufacturers Association (NEMA).
 - 2. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
 - 3. Underwriters Laboratory Inc. (UL).

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the production of the required materials and equipment.
 - 1. The manufacturer shall be responsible for the design, construction, and proper operation of all components.
- C. Comply with applicable codes and regulations.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Submit the following in accordance with Section 01330, Submittal Procedures:
 - 1. Product data.
 - 2. Drawings.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Toggle Switches:

1. Arrow-Hart, Inc.
 2. General Electric Co.
 3. Harvey Hubbell, Inc.
 4. Or equal.
- B. Corrosion Resistant Switch:
1. Appleton Electric Co.
 2. Crouse-Hinds Products ECM.
 3. Or approved equal.
- C. Receptacles:
1. Arrow-Hart, Inc.
 2. General Electric Co.
 3. Harvey Hubbell, Inc.
 4. Or equal.
- D. Corrosion Resistant Receptacles:
1. Appleton Electric Co.
 2. Or equal.
- E. Dry Type Transformers:
1. Square D
 2. Or equal.

2.2 SWITCHES

- A. Single pole ac toggle switch, quiet type, 120/277Vac, 20 ampere, ivory, specification grade, provide:
1. Arrow-Hart, Inc.; Catalog No. 1991-I.
 2. General Electric Co.; Catalog No. GE5951-2.
 3. Harvey Hubbell, Inc.; Catalog No. 1221-I.
 4. Or equal.

2.3 CORROSION RESISTANT SWITCH

- A. Single gang, dead end, one pole, 3-way, 4-way, 120/277Vac, 20 amperes, in areas classified as NEC Class I, Division 2 hazardous areas, provide:
1. Appleton Electric Co.; EFS Series.
 2. Crouse-Hinds Products ECM; EFS Series.
 3. Or equal.

2.4 RECEPTACLES

- A. Duplex grounding receptacles, corrosion resistant, 2-pole, 3-wire, 125Vac, 20 ampere, NEMA 5-20R configuration, provide:
1. Arrow-Hart, Inc.; Catalog No. 5739CR.
 2. General Electric Co.; Catalog No. GE0526-C.
 3. Harvey Hubbell, Inc.; Catalog No. 53CM62.

4. Or equal.
- B. Single grounding receptacle, corrosion resistant, 2-pole, 3-wire, 125Vac, 20 ampere, NEMA 5-20R configuration, provide:
1. Arrow-Hart, Inc.; Catalog No. 5361-CR.
 2. General Electric Co.; Catalog No. GE0520-C
 3. Harvey Hubbell, Inc.; Catalog No. 53CM61
 4. Or equal.

2.5 CORROSION RESISTANT RECEPTACLES

- A. Install in areas classified as NEC Class 1, Division 2 hazardous locations, receptacles as below:
1. Meltric DNX Decontactors, as indicated on Drawings.
 2. Or equal.

2.6 GROUND FAULT INTERRUPTER (GFI) RECEPTACLES

- A. Provide ground fault interrupter receptacles of following types and rating.
1. “Feed-thru” type ground fault circuit interrupter, with integral heavy duty NEMA 5-20R duplex receptacles arranged to protect connected downstream receptacles on same circuit.
 2. Provide unit designed for installation in a 2-3/4-inch-deep outlet box without adapter, grounding type, Class A, Group 1, in accordance with UL Standard 94.3.
 3. Explosion proof, 20A, 125Vac, 5 MA trip setting ground fault circuit interrupter with explosion proof receptacle in areas classified as NEC Class I, Division 2 hazardous locations.
 4. Snap Switches: Quiet type AC switches. Comply with UL 20 and NEMA WD1.
 5. Wall Plates: Single and combination of types, sizes and with ganging and cutouts as indicated.
 - a. To mate and match with wiring devices to which they are attached.
 - b. Use metal screws for securing plates to devices with screw heads colored to match finish of plates.
 - c. Color to match wiring devices except as otherwise indicated.
 - d. With engraved legend where indicated. Conform to requirements of Section 16195, Electrical Identification.
 - e. Possessing the following additional construction features:
 - f. Material and Finish: 0.04 inch thick, Type 302 satin finished stainless steel in wet and/or corrosive area.
 - g. Material and Finish: Plastic.
 6. Plugs: Watertight, solderless, long plug housing and suitable for activating explosion proof receptacles and areas classified as NEC Class I, Division 2 hazardous locations.
 7. Mounting Hardware: Stainless steel.

2.7 DRY TYPE TRANSFORMERS

1. 1. Transformers shall be size and voltage as indicated on the Drawings, dry type, ventilated, floor mounted, 115°C temperature rise with 220° C insulation system.
2. 2. Transformers shall have aluminum windings, and shall be energy efficient, DOE 2016 compliant.
3. 3. Transformer enclosure shall be painted steel, unless noted otherwise on the Drawings.
4. 4. Transformers shall be Square D.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Comply with following installation requirements for wiring devices:
1. Install wiring devices and accessories as indicated, in accordance with manufacturer's written instructions, applicable requirements of NEC and in accordance with recognized industry practices to fulfill project requirements.
 2. Coordinate with other work, including painting, electrical boxes and wiring installations, as necessary to interface installation of wiring devices with other work.
 3. Install wiring devices only in electrical boxes, which are clean, free from building materials, dirt and debris.
 4. Install stainless steel wall plates in unfinished spaces.
 5. Install wiring devices after wiring work is completed.
 6. Install wall plates after painting work is completed.
 7. Tighten connectors and terminal, including screws and bolts, in accordance with equipment manufacturer's published torque tightening values for wiring devices. Where manufacturer's torquing requirements are not indicated, tighten connectors and terminals to comply with tightening torques specified in UL Standard 486A. Use properly scaled torque indicating hand tool.
 8. Mount receptacles 18 inches above finished floor in office areas, control rooms, conference rooms and similar above grade areas unless shown otherwise. Mount all other receptacles 4 feet -2 inches above finished floor unless approved otherwise.
 9. Securely fasten equipment to walls or other structural surfaces on which they are mounted. Provide independent, factory applied PVC coated steel or stainless-steel supports and accessories where no wall or other vertical surface exists.
 10. Provide field applied PVC coating for cut ends of PVC coated supports.
 11. Space at least 1/4 inch from wall. Spacers shall be stainless steel, PVC or nylon.
 12. Mount wall switches 4 feet -2 inches above finished floor unless approved otherwise.

13. Install bonding jumpers between the receptacle ground screws and the outlet boxes on all receptacles.

3.2 FIELD QUALITY CONTROL AND TESTING

- A. Perform field inspection and testing in accordance with Section 16950, Testing.
- B. Testing: Prior to energizing circuits.
 1. Test wiring for electrical continuity, and for short-circuits.
 2. Ensure proper polarity of connections is maintained.
 3. Test ground fault interrupter operation with both local and remote fault simulations in accordance with manufacturer recommendations.
- C. Subsequent to Energizing: Test wiring devices and demonstrate compliance with requirements, operating each operable device at least six times.

END OF SECTION

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SECTION 16186
VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.1 DESCRIPTION

- A. Furnish all variable speed, variable frequency drives (VFDs) called for herein. These drives shall be coordinated with the driven equipment to ensure that the entire system is compatible and coordinated properly.

1.2 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
 - 1. Institute of Electrical and Electronics Engineers (IEEE).
 - 2. National Electrical Manufacturers Association (NEMA).
 - 3. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
 - 4. Underwriters Laboratories Inc. (UL).

1.3 QUALITY ASSURANCE

- A. Reference Standards: Comply with all federal and State of Maryland laws or ordinances, as well as all applicable codes, standards, regulations and/or regulatory agency requirements.
- B. The complete VFD shall be UL listed and bear the UL label in accordance with UL 508A.
- C. The VFD shall meet the harmonic distortion limits specified in the IEEE 519 standard, as measured at the drive input terminals. The base drive shall include an AC line reactor and/or DC link choke for harmonic filtering. If basic filtering is insufficient to meet IEEE 519 limits, then the VFD supplier shall furnish a passive harmonic filter (<200 HP), or 18-pulse converter with auto transformer (>200 HP), or active front end (>250 HP) as needed. The horsepower ranges suggested here are general guidelines based on cost effectiveness and shall not be used as the sole criterion in determining a solution for harmonic distortion.

1.4 SUBMITTALS

- A. General: Submittals shall be in accordance with Section 01330, Submittal Procedures.
- B. Shop Drawings:
 - 1. Wiring diagrams, front and side views of enclosures, overall dimensions, conduit entrance locations and requirements, nameplate legends, and enclosure details.

2. Datasheets depicting voltage, ratings, and size of switching and overcurrent protective devices, short circuit ratings, and weight.
3. Specific description of harmonic mitigation provisions being made to ensure proper system operation and compliance with IEEE 519.

C. VFD/Equipment Compatibility:

1. Submit in writing that each VFD supplied shall be compatible with equipment to which it is connected. The VFD supplier shall obtain the actual torque requirements (breakaway, accelerating, running, peak and holding torques) continuous current rating and overload current rating from the equipment manufacturers and submit in writing that each VFD is sized correctly and fully compatible for any equipment. Each VFD shall be sized in accordance with the equipment's motors maximum current requirements under peak torque demands.
2. Also submit in writing documentation showing VFD/equipment compatibility across the entire speed range of the motor for each VFD. Ensure the VFD is of sufficient size to maintain a speed setpoint as low as 5 Hz without being limited by the torque output of the motor relative to the load torque at that speed.
3. Each VFD shall be rated for constant torque or variable torque as required for the equipment which speed is being varied and the continuous output current rating shall be at least as required by the equipment manufacturer's approved shop drawings.
4. Submit in writing that the VFD supplier has reviewed each installation for motor lead length restrictions. Review the motor, cable type, length of cable, conduit type, and all other motor lead length constraints. Submit that the proposed VFD for each application has been checked for any problems and is acceptable to be installed as shown on the Drawings.
5. Passive filters on generator power shall be equipped with a dropout contactor for the filter capacitors in order to limit leading power factor during no-load operation.

D. Harmonic Distortion Analysis:

1. Perform harmonic distortion analysis for each VFD to be installed under this project. Provide calculations, results, and report for harmonic distortion analysis performed including specific recommendations for harmonic mitigation measures to comply with requirements of IEEE 519.
2. Perform analysis considering the following two points of common coupling (PCC) locations to ensure adequate power quality conditions within the facility:
 - a. 480V MCC Bus directly supplying the VFD.
 - b. 480V Switchgear bus at substation, if applicable.
3. Perform a system analysis to demonstrate not more than 5% total harmonic distortion (THD) voltage and current distortion level in accordance with the IEEE 519 at all identified distribution buses.

4. Where calculations yield THD-voltage is greater than 5% or THD-current is greater than the IEEE 519 recommended level, provide specific recommendations to reduce distortion by the addition of filters, reactors, or other means.
- E. Submit in writing evidence of a factory authorized service engineer within 100 miles of the plant and that spare parts for each VFD are available at a local distributor within 100 miles of the plant.
- F. Service Manuals: Provide service manuals.
- G. O&M Training: Comply with requirements of Section 01330, Submittal Procedures and as specified herein.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Approved VFD manufacturers:
 1. ABB / General Electric
 2. Allen-Bradley by Rockwell Automation
 3. Benshaw
 4. Siemens
 5. Toshiba
 6. Danfoss
 7. Eaton

2.2 VFD

- A. The VFD shall be completely solid state. The drive shall convert 460 volts 3-phase ac input power into frequency and voltage controller 3-phase output suitable to provide positive speed control to standard induction motors. The adjustable frequency control shall have an input designed to provide a high-power factor that remains constant regardless of load or operating speed and creates no line notching or other disturbances of the power line. Power transistors shall be utilized for high reliability in the output power switching circuit.
- B. Each VFD shall be suitable for operation of standard NEMA Design B motors. The VFD shall not require modification to accommodate any replacement NEMA Design B motor of equal or lower horsepower as long as the output current requirement is not increased. VFD shall include the following features:
 1. PC boards with standard conformal coated for additional protection.
 2. Real time clock with time-of-day functionality.
 3. Data capture, event logs, and reminder warnings system.
 4. USB port for memory stick plug-in for data storage and drive reflashing.
 5. Wireless programming capability using PDA-trAC+ system.
 6. Ethernet IP communication protocol.

- C. The VFD shall be furnished with an integral NEMA-1 rated enclosure equipped at the factory with fans, blowers, heat exchangers, or air conditioner as needed to maintain ambient operating temperature within factory limits.
- D. Drive Disconnect Switch:
 - 1. A main disconnect switch shall be provided for each variable frequency drive to disconnect power to the drive. The disconnect switch shall be sized for the full output current rating of the drive. Each disconnect switch shall have a lockable handle.
- E. Each VFD shall have the following features:
 - 1. Input Power:
 - a. The drive shall operate from 460 V, 3-phase, 60-Hz.
 - b. Variations of up to plus or minus 15 percent of line voltage and plus or minus 2 Hz of line frequency shall be permitted without the drive shutting down on a fault.
 - c. Power line interruptions of up to 0.5-second shall be permitted without the drive shutting down on a fault.
 - d. The drive input circuitry shall not generate line notches or large voltage transients on the incoming line.
 - e. The drive shall present a displacement power factor of 0.95 or better to the ac line at any speed or load.
 - f. The drive control efficiency at rated load and frequency shall be 97.5 percent or better.
 - g. The drive shall have input transient protection. The drive shall withstand line transients up to 6,000 volts peak in accordance with IEEE C62.41.1991. It shall also have control logic noise immunity up to 1,500 volts peak.
 - h. The drive shall be designed to operate on an ac line which may contain line notching and up to 10 percent harmonic distortion. The drive shall not require an input isolation transformer.
 - i. The drive shall not be sensitive to supplied power that has one phase grounded (delta) or referenced to earth ground (wye).
 - j. The drive shall have minimum 42 kA RMS short circuit rating without the use of additional input fusing.
 - k. Control circuit voltage shall be 120V ac provided by an individual control power transformer with both legs fused on the primary side and one leg fused and one leg grounded on the secondary side. See the Drawings for control schematics.
 - l. Inverter section shall be the latest generation IGBT. It shall not require commutation capacitors.
 - m. All drives 5 HP and above shall be furnished with an integral AC line reactor and/or DC link choke in order to smooth current flow and limit current spikes at the input rectifier section.

2. Output Power:
 - a. The VFD shall convert 3-phase, 60Hz input power to 3-phase adjustable voltage, adjustable frequency output power using sinusoidal Pulse Width Modulation (PWM) switching techniques and Insulated Gate Bipolar Transistor (IGBT) outputs. Fast switching SCRs shall not be used in the inverter output section.
 - b. The drive output frequency shall be adjustable from 0- to 120-Hz.
 - c. The VFD shall have selectable or programmable modes of operation including, but not limited to: Linear V/Hz, V/Hz with Quadratic (parabolic) characteristic, V/Hz with programmable characteristic, and Sensorless Vector Control (SVC).
 - d. In linear V/Hz mode, drive output shall vary from 0 to 460 VAC at 60 Hz and maintain a constant V/Hz ratio equal to 7.6. Above 60Hz the output voltage shall be limited to 460 VAC. When operating on generator power, the output may vary from 0 to 460 VAC at nominal frequency.
 - e. The volts-per-hertz output of the drive shall not be affected or require readjustment when other drive adjustments (such as maximum speed) are changed.
 - f. The drive shall have an adjustable programmable microprocessor controlled PWM carrier frequency within a range of 2-8 kHz to reduce noise at the motor and guard against interference with other sensitive electronic equipment.
 - g. The drive shall be capable of restoring motor operation after 0.5 second line loss without shutting down on a fault.
 - h. The drive shall be capable of operating output open circuited with no fault of damage.
 - i. The drive regulator section shall be microprocessor based in order to achieve digital control of output voltage, current, and frequency.
 - j. Each VFD shall have a common mode core or output choke to reduce noise at the motor and guard against interference with other sensitive electronic equipment. No drives shall be approved without this feature.
 - k. Each drive 60 hp and less shall have software to limit the reflected wave due to long cable lengths to a maximum of 2 times bus voltage. Larger drives shall have designs to minimize reflected wave.
 - l. Each VFD shall be suitable for use on heavy duty loads. Heavy duty ratings are rated for the FLA of the equipment continuously, 120 percent of the rated FLA for up to 60 seconds, and 180 percent of the rated FLA for instantaneous duration.
3. Drive Protection Features:
 - a. Overcurrent protection.
 - b. Short circuit protection.
 - c. Fast acting supply fuses.
 - d. Supply voltage phase loss.

- e. dc bus undervoltage protection.
 - f. dc bus overvoltage protection.
 - g. Overtemperature protection.
 - h. Power semiconductor protection.
 - i. Dynamic brake overload
4. Drive Diagnostics:
- a. The diagnostic system shall continuously monitor all systems and indicate faults and all shutdown causes. Provide single-pole double-throw (SPDT) dry contact outputs for fault alarms as shown on the Drawings. As a minimum, the following drive diagnostics shall be monitored, indicated on the drive, and alarmed:
 - (1) Overload (overcurrent).
 - (2) Ground fault.
 - (3) Overvoltage.
 - (4) Undervoltage.
 - (5) Overtemperature.
 - (6) Dynamic brake overload.
 - (7) Semiconductor fault (each leg).
 - (8) Power supply fault.
 - (9) Motor over-temperature/shutdown.
 - (10) Motor stalled.
5. Control Features:
- a. The VFD shall have a door-mounted keypad/display that can be used for drive setup and programming, command and control, and fault and status annunciation.
 - b. The drive shall produce an output without external feedback.
 - c. For all analog speed commands, the drive shall maintain set frequency to within 0.6 Hz during power line fluctuations or changes in ambient temperatures.
 - d. For digital speed commands, the drive shall maintain set frequency to within 0.01 Hz during power line fluctuations or changes in ambient temperatures.
 - e. Within the drive rating, the drive shall maintain set frequency and not require readjustment due to changes in load.
 - f. To control the rate of change of output frequency for a step change in input reference, the drive shall have two independently adjustable acceleration and deceleration rates.
 - g. The drive shall have a foldback current limiting circuit. During acceleration, the circuit shall automatically reduce the acceleration rate to a slower rate if the load inertia causes excessive currents.
 - h. The drive shall have a selectable deceleration voltage limiting circuit. The circuit shall extend the set deceleration ramp if the bus voltage approach high limits due to regeneration.

- i. The drive shall have incremental adjustable IR compensation boost. A selectable range for offsetting motor losses at low frequency operation shall be used to optimize motor torque for starting high inertia and high friction loads.
 - j. All drive set-up operations and adjustments shall be digital and stored in a nonvolatile memory (EEPROM). No analog or potentiometer adjustments shall be allowed.
 - k. It shall be possible to program the VFD to automatically restart after a power outage and to specify the number of restart attempts, as well as the time between restart attempts.
 - l. The VFD shall have bi-directional automatic speed search (flycatcher) for starting into rotating loads. The VFD shall be able to catch a motor spinning in either direction and bring the motor to the desired speed in the proper direction without stopping the motor or tripping the drive.
- 6. Speed Control:
 - a. The VFD shall be capable of accepting an analog input (4-20 mA) speed command that can be scaled, inverted, and/or offset. Unless approved otherwise, the analog speed command shall be scaled: $4-20\text{ mA} = 0 - 100\% = 0 - 60\text{ Hz}$. This scaling is required for drives that are to be controlled by the plant Distributed Process Control System (DPCS).
 - b. The system shall have field adjustable minimum speed (0 to 65 percent), maximum speed (45 to 100 percent), acceleration rate, deceleration rate, continuous current limit (range 50 to 150 percent of inverter capacity), V/Hz ratio, and IR compensation adjustments to insure proper motor performance.
 - c. The VFD shall have an analog output (4-20 mA) that can be configured to report back actual motor speed. Unless approved otherwise, the analog speed feedback shall be scaled: $4-20\text{ mA} = 0 - 100\% = 0 - 60\text{ Hz}$.
 - d. Three programmable preset speeds shall be provided.
 - e. Selectable stopping modes of coast, ramp to stop, or DC brake to stop shall be available.
 - f. Three adjustable skip frequencies shall be provided.
- 7. Drive Control Interface:
 - a. Control Transformers:
 - (1) Provide a control power transformer for each drive control circuit. Control transformers shall be 480 volts to 120 volts and shall be provided with primary and secondary fusing.

- b. Selector Switches:
 - (1) Selector switches shall be non-illuminated. Switches shall be 30.5 mm, heavy-duty, oil tight. Switches shall have double-break silver contacts. All switches shall be maintained contact type unless otherwise indicated on the Drawings. Provide auxiliary contact blocks as indicated on the Drawings or in the Description of Operation. Provide a legend plate for each switch with white engraving as indicated on the Drawings.
 - (2) Selector switches shall be Allen-Bradley Bulletin 800T, NEMA Type 4/13, or equal by Square D.
- c. Push Buttons:
 - (1) Push buttons shall be momentary type, 30.5 mm, heavy-duty, oil tight with silver contacts. Provide a legend plate for each push button with white engraving as indicated on the Drawings.
 - (2) Push buttons shall be Allen-Bradley Bulletin 800T, NEMA Type 4/13, or equal by Square D.
- d. Pilot Lights:
 - (1) Pilot lights shall be 30.5mm, heavy-duty, push to test, transformer type with LED lamps. Voltage rating shall be 120 volts. Color cap shall be green for "run" and red for fault". Provide a legend plate for each switch with white engraving as indicated on the Drawings.
 - (2) Pilot lights shall be Allen-Bradley Bulletin 800T, NEMA Type 4/13, or equal by Square D.
- e. Relays:
 - (1) Relays shall be heavy-duty general-purpose type with 10 amp contacts. Relays shall have terminals, which plug-in to a socket, mounted to the inside of the drive enclosure. Contact configuration shall be 3PDT. Relay coils shall operate on 120 volts AC, unless indicated otherwise on the Drawings. Relays shall have an indicator light to indicate the relay coil is energized.
 - (2) Relays shall be Allen-Bradley, or equal.
- f. Elapsed Time Meters:
 - (1) Elapsed time meters shall be time totalizer, non-resettable. They shall have a synchronous motor, which shall drive a set of digit readout wheels to indicate the total time the unit is energized. Readout shall be five-digit including 1/10 digit. Range shall be 0 to 9999.9 hours. Voltage rating shall be 120 volts.
 - (2) Elapsed time meters shall be ENM Company Series T50, or equal.

- g. Control Wiring:
 - (1) All 120 VAC control wiring shall be red. All 24vdc wiring shall be blue. All wiring in the VFD shall be labeled.
- h. Control Terminal Block:
 - (1) Provide a control terminal block in the MCC cubicle to terminate all control wiring from the field. All terminals shall be labeled with machine printed labels.
- i. The VFD shall have (2) independent, galvanically isolated analog inputs that can be configured for 4-20 mA or 0-10 VDC. (Note: WSSC standard is 4-20 mA). The bias and gain of each input shall be individually programmable.
- j. Digital Inputs:
 - (1) Provide a minimum of five multi-function input terminals, capable of being programmed to determining the function when their state is changed.
 - (2) These terminals shall provide various functions including, but not limited to remote/local selection, remote fault condition, remote reset, and start command.
- k. The VFD shall have (2) independent analog outputs that can be configured for 4-20 mA.
- l. Digital Outputs:
 - (1) Provide (3) programmable relay outputs, including at least (1) Form-C relay, for reporting drive operational status. For DPCS installations, unless approved otherwise, the relay output configuration shall include:
 - (2) Control Mode (1 = Remote, 0 = Manual)
 - (3) Run Status (1 = Running, 0 = Stopped)
 - (4) Fault Status (1 = No Fault, 0 = Fault)
 - (5) These contacts shall be rated at 1A at 250V ac.
 - (6) The outputs shall provide various functions including at-speed, drive healthy, drive fail, drive running, over-frequency, under-frequency, and over-torque, under-torque.
- 8. Control Features:
 - a. The condition or fault shall be annunciated on the diagnostic display panel. This display panel shall have a digital potentiometer to manually adjust the speed and be used for programming and other control features. The panel shall be mounted on the VFD enclosure and not behind a window. Provide all cables and other options to mount the panel on the VFD enclosure door.
 - b. The drive shall instantaneously shut down when a fault condition occurs.
 - c. Automatic shutdown in event of loss of input power and during single phasing. Automatic restart after power resumption.

9. Momentary Overload Protection Circuit:
 - a. The drive shall have an adjustable momentary overload protection circuit (MOPC), or equivalent current limiting feature, adjustable from 50 to 150 percent of drive rating.
 - b. The MOPC shall sense a motor load current exceeding the programmed amount of the drive rating. The circuit shall momentarily reduce the output voltage and frequency until the load is reduced to acceptable levels.
 - c. If the load is such that the motor is in a LOCKED ROTOR condition for more than 4 seconds, the drive shall attempt to protect the motor and shut down on a MOPC fault. The fault shall be annunciated on the digital display panel readout.
10. Motor Overload Protection:
 - a. The drive shall provide Class 10 motor overload protection.
 - b. The overload protection shall be adjustable from 50 to 150 percent of the drive full load current rating.
 - c. Motor overload protection shall meet NEC overload protection requirements and shall be tested in accordance with UL Standard 1991.
11. System shall be modular plug-in printed circuit board design with all components easily accessible from the front of the enclosure.
12. Provide all relays, indicating lights, fuses and any other features and options as shown or required on the Drawings. Control schematics are shown on the Drawings. The indicating lights shall be installed on the VFD control station enclosure.

F. Operational Features:

1. System Operation:
 - a. When in HAND mode, VFD Start/Stop and Speed Setpoint shall be controlled by the keypad/display. Start/Stop pushbuttons and speed pots shall not be installed on the VFD enclosure.
 - b. When in Remote mode, VFD Start/Stop and Speed Setpoint shall be controlled by drive digital and analog inputs.
 - c. If a remote Hand/Off/Remote switch is to be installed at the equipment powered by the VFD, then HAND/REMOTE mode control at the drive keypad/display shall be disabled. THIS IS A SAFETY REQUIREMENT AND SHALL BE OBSERVED.
2. Manufacturer's standard features, unless approved otherwise:
 - a. Sustained power loss.
 - b. Momentary power loss.
 - c. Power interruption.
 - d. Power loss ride through of 2 seconds.
 - e. Start on the fly.
 - f. Stall protection.
 - g. Slip compensation.
 - h. Automatic restart after power return (ability to enable/disable function).

- i. Critical frequency lockout (three selectable points minimum, by 1.5 Hz steps in 10 Hz bands, to prevent resonance of system).
 - 3. VFD maintenance system software for complete programming and diagnostics.
 - 4. Operate with no motor connected to output terminals.
 - 5. Carrier frequency:
 - a. Minimum of six settings to allow adjustment in field.
 - b. At or above 5 kHz without derating to satisfy conditions for current, voltage, and horsepower.
 - 6. Factory settings for all parameters, and capability for those settings to be reset.
 - 7. Capability to adjust the following functions, while VFD is running:
 - a. Forward/Reverse direction.
 - b. Acceleration adjustment from 0 to 3,600 seconds.
 - c. Deceleration adjustment from 0 to 3,600 seconds.
 - d. Minimum of six different preset speeds.
 - 8. Analog output gain to calibrate signal for the application used.
- G. Diagnostics:
 - 1. Comprehensive for drive adjustment and troubleshooting.
 - 2. Visual display of specific fault condition.
 - 3. Memory Battery Backup: 100 hours, minimum, during a power loss.
 - 4. Status messages shall not stop drive from running but shall prevent it from starting.
 - 5. Fault Condition Messages and History: First fault protection function to be activated, ability to store six successive fault occurrences in order.
 - 6. Minimum Faults Numerically:
 - a. Over-current (time and instantaneous).
 - b. Over-voltage.
 - c. Under-voltage (dc and ac).
 - d. Over-temperature (drive, motor windings, motor bearing, pump/fan bearing).
 - e. Serial communication fault.
 - f. Short-circuit/ground fault (motor and drive).
 - g. Motor stalled.
 - h. Semiconductor fault.
 - i. Microprocessor fault.
 - j. Single-phase voltage condition.
- H. Operator Interface at VFD Enclosure:
 - 1. VFD shall include a front mounted, sealed keypad, with illuminated LCD display.
 - 2. Keypad shall provide complete programming, operating, monitoring, and diagnostic capability with 10-key keypad with blue backlit LCD display.
 - 3. VFD display shall provide readouts of output frequency in hertz, output voltage in volts, output current in amps, output power in kilowatts, dc bus voltage in volts, interface terminal status, and fault codes.

4. Displays shall be viewed in easy-to-read illuminated LCD with English language as standard.

I. Enclosure Air Conditioner:

1. Provide a NEMA 12 steel air conditioner for the High Flow Pump VFD.
2. The air conditioner shall be thermostatically controlled, and it shall be mounted on the side of the enclosure.
3. The air conditioner shall be sized to maintain a temperature of 80°F inside the enclosure when all VFDs are operating, and the outside ambient temperature is 90°F.
4. The air conditioner shall operate at 208 volt, single phase power.

- J. Unless approved otherwise, the front mounted VFD controls shall be limited to the keypad/display and pilot light for indication of Drive Stopped, Drive Running, and Drive Fault conditions.

2.3 SPECIAL TOOLS, SPARE PARTS, AND MAINTENANCE MATERIALS

A. Spare Parts:

1. Provide one set of fuses for each drive furnished.
2. Provide one set of circuit boards for each horsepower class of drive.
3. Provide one set of power devices (includes power switching modules, bus capacitors, diode bridge, and MOV or snubber assembly) for each horsepower class of drive.
4. Provide additional spare USB adapter module for each type of VFD equipment furnished.

PART 3 EXECUTION

3.1 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Delivery and Handling:

1. Inspect all equipment and materials against approved Shop Drawings at time of delivery.
2. Equipment or materials damaged or not meeting the requirements of the approved Shop Drawings shall be immediately returned for replacement or repair.

B. Storage:

1. Carefully prepare for storage and label all equipment and materials after they have been inspected.
2. Store all equipment and materials in a dry, covered, ventilated location and protect from harm according to the Manufacturer's instructions.

3.2 FACTORY TESTING

- A. The Commission reserves the right to witness all factory tests. The Commission reserves the right to back charge the manufacturer if a second trip is needed to witness equipment due to problems or errors in fabrication and engineering.
- B. Provide 2 weeks written notice to the Commission so arrangements can be made to witness tests.
- C. Provide three copies of the final factory inspection tests to the Commission.
- D. VFDs:
 - 1. Visual and Mechanical Inspection:
 - a. Inspect for physical damage.
 - (1) If visual inspection reveals VFD damage, broken connections, inoperative breakers or switches; conduct internal inspections and tests as necessary to locate the damage.
 - (2) Submit a detailed report to the Commission. Identify the damage, cause of the damage, and corrective measures taken to assure the Commission of the quality of the VFD.
 - b. Compare equipment nameplate information with latest one-line diagram and record/report discrepancies.
 - c. Verify proper device operation such as breakers, starters MCPs, contact relays, and indicators.
 - d. Verify proper operation of elementary control diagrams and operating control equipment in accordance with drawing intent by simulating external signals.
 - 2. Electrical Tests:
 - a. Check automatic operation of breakers, starters, control relays, and MCPs for close and trip operation from protective relays and operators.
 - b. Perform insulation-resistance tests at 1,000V dc for 1 minute on all control circuit wiring and electromechanical components. Minimum acceptable values shall be in accordance with NETA.
 - c. Verify functions of harmonic correction units and associated devices.

3.3 INSTALLATION

- A. Installation shall be in accordance with the approved Shop Drawings and with the manufacturer's instructions and recommendations.
- B. Adjust all equipment to the best industrial standards. Check and adjust all alignment in the field in the presence of the Commission.

- C. In accordance with manufacturer recommendations to maintain 1,000 psi washdown from 6 inches, provide sealed conduits for all VFD connections to prevent water entry into the enclosure.

3.4 COMMISSIONING

- A. All programming, startup, and testing shall be done by the VFD manufacturer's factory trained and certified field service representative. The manufacturer's representative shall be familiar with and completely skilled in the operation, maintenance, and troubleshooting of VFD equipment. Submit the qualifications of the manufacturer's representative for approval. No programming, startup, or testing shall be allowed without prior approval of the representative.
- B. Each VFD shall be started-up and tested before it is scheduled to be online in the particular construction phase as shown on the Drawings. The following shall be done to each VFD when it is scheduled to be started-up with its associated equipment:
 - 1. Give the equipment a running test in the presence of the Commission to demonstrate compliance with this specification. All field adjustments shall be cycled through the complete range of their adjustments to prove compliance with these specifications.
 - 2. Demonstrate the diagnostic system and test instrument use to Commission personnel.
 - 3. Make and record all initial adjustments of the system. These adjustments are to be arrived at in consultation between the manufacturers' representative and the Commission.
 - 4. Prove to the satisfaction of the Commission that all equipment works as required and as specified and that all adjustments are properly set prior to placing any equipment into service.
 - 5. Furnish complete field installation report including the programming parameters for each drive.
- C. Harmonic Analysis Testing:
 - 1. As part of this scope, the VFD supplier shall provide the services of an independent testing agency certified in harmonic analysis testing. The testing agency shall test the system at each of the points of common coupling (PCC) as described below before installation of any new electrical equipment and when all electrical equipment is fully operational. This testing is to assure that all new electrical equipment complies with IEEE 519.
 - 2. The following information shall be submitted in each test report as a minimum for each PCC:
 - a. Isc: Available short circuit current at the PCC.
 - b. Il: Maximum demand load current.
 - c. Isc/Il: The ratio of the available short circuit current to the maximum demand line current.

- d. TDD: Total demand distortion based on the maximum demand load current for each odd harmonic up to the 35th harmonic.
 - e. THD: Total harmonic distortion.
 - f. Provide wave forms of each measurement sample.
- D. Manufacturer's Commissioning Services:
 - 1. The Contractor shall not directly complete work included in this Article unless approved by the Commission. This work shall be completed by the manufacturer's representative.
 - 2. For bidding purposes, the manufacturer shall provide the services of qualified technical personnel to perform duties and tasks as listed below. Additionally, the manufacturer may be responsible to perform tasks at any time period at the plant and shall not assume that work will be completed during normal daytime business hours. Such services are in addition to the services included in other Articles of this section, such as submittals, training, lesson plans, service manuals and maintenance services, etc.
 - 3. The Commission reserves the right to reject any manufacturer's personnel that are unqualified to complete each duty or task.

3.5 FIELD QUALITY CONTROL AND TESTING

- A. Perform field inspection and testing in accordance with Section 16950, Testing.
- B. Adjusting and Cleaning: Adjust operating mechanisms for free mechanical movement.
- C. Grounding: Provide equipment grounding in accordance with Section 16450, Grounding.

3.6 MANUFACTURER'S FIELD SERVICES

- A. Provide manufacturer's field services in accordance with Section 01640, Manufacturers' Field Services. Manufacturer's field services shall respond to the Commission's request for correction of problems during startup and warranty power within 4 hours.
- B. Training:
 - 1. Provide training to instruct representatives of the Commission and Engineer as follows:
 - a. VFD: 4 hours.

END OF SECTION

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SECTION 16195
ELECTRICAL IDENTIFICATION

PART 1 GENERAL

1.1 DESCRIPTION

- A. Provide electrical identification products and components for identification of electrical materials, equipment, and installation, including but not limited to the following:
 - 1. Buried electrical line warnings.
 - 2. Conduits, raceways, cables, and conductors.
 - 3. Electrical manhole and handhole covers.
 - 4. Operational instruction signs.
 - 5. Warning and caution signs.
 - 6. Equipment labels and signs.

1.2 REFERENCES

- A. The following is a list of codes and standards that may be referenced in this section:
 - 1. American National Standards Institute (ANSI): A13.1, Scheme for the Identification of Piping Systems, with regard to type and size of lettering for raceway and cable labels.
 - 2. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the product of the required materials and equipment.
- C. Comply with applicable codes and standards.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Submit the following in accordance with Section 01330, Submittal Procedures.
 - 1. Product data.
 - 2. Schedule of identification nomenclature to be used for identification signs and labels.
 - 3. Samples of each color, lettering style, and other graphic representation required for identification materials, samples of labels and signs.

PART 2 PRODUCTS

2.1 ELECTRICAL IDENTIFICATION PRODUCTS

- A. Provide Adhesive Marking Labels for Raceway and Metal-Clad Cable:
 - 1. Pre-printed.
 - 2. Flexible.
 - 3. Self-adhesive labels with legend indicating voltage and service (emergency, lighting, power, light, power dc, air conditioning, communications, control, and fire, etc.)
- B. Colored Adhesive Marking Tape for Raceways, Wires, and Cables: Provide self-adhesive vinyl tape not less than 3 mils thick by 1 inch to 2 inches in width.
- C. Pre-tensioned Flexible Wraparound Colored Plastic Sleeves for Raceway and Cable Identification: Provide flexible acrylic band, sized to suit the raceway diameter and arranged to stay in place by pre-tensioned gripping action when coiled around the raceway or cable.
- D. Underground Line Marking Tape:
 - 1. Provide permanent, bright-colored, continuous-printed, plastic tape compounded for direct-burial service not less than 6 inches wide by 4 mils thick.
 - 2. Provide printed legend, indicative of general type of underground line below.
- E. Wire/Cable Designation Tape Markers: Provide vinyl or vinyl-cloth, self-adhesive, wraparound, cable/conductor markers with preprinted numbers and letters.
- F. Aluminum, Wraparound, Cable Marker Bands:
 - 1. Provide bands cut from 0.014-inch thick, aluminum sheet, fitted with slots or ears for securing permanently around wire or cable jacks or around groups of conductors.
 - 2. Make arrangement for applying legend with stamped letters or numbers.
- G. Plasticized Card Stock Tags:
 - 1. Provide vinyl cloth with preprinted and field-printed legends to suit the application.
 - 2. Use orange background, except as otherwise indicated, with eyelet for fastener.
- H. Brass or Stainless-Steel Tags:
 - 1. Provide metal tags with stamped legend punched for fastener.
 - 2. Dimensions: 2 inches by 2 inches by 19 gauge.

- I. Engraved, Plastic-Laminated Labels, Signs, and Instruction Plates:
 - 1. Provide engraving stock melamine plastic laminate, 1/16-inch minimum thick for signs up to 20 square inches, or 8 inches in length: 1/8-inch thick for larger sizes.
 - 2. Provide engraved legend in white letters on black face and punched for mechanical fasteners.
- J. Baked-Enamel Warning and Caution Signs for Interior Use: Provide preprinted aluminum signs, punched for fasteners, with colors, legend, and size appropriate to the location.
- K. Fasteners for Plastic-Laminated and Metal Signs: Provide self-tapping stainless-steel screws or number 10/32 stainless steel machine screws with nuts and flat and lock washers.
- L. Cable Ties:
 - 1. Provide fungus-inert, self-extinguishing, one-piece, self-locking nylon cable ties, 0.18-inch minimum width, 50-pound minimum tensile strength, and suitable for a temperature range from minus 50 to 350 degrees F.
 - 2. Provide ties of specified colors when used for color coding.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Lettering and Graphics:
 - 1. Coordinate names, abbreviations, colors, and other designations used in electrical identification work with corresponding designations specified or indicated.
 - 2. Install numbers, lettering, and colors as approved in submittals and as required by code and as specified in Section 16050, Basic Electrical Materials and Methods.
- B. Install identification devices in accordance with manufacturer's written instructions and requirements of NEC.
- C. Sequence of Work: Where identification is to be applied to surfaces that require finish, install identification after completion of finish work.
- D. Conduit Identification.
 - 1. Identify Raceways of Certain Systems with Color Banding:
 - a. Provide bands for exposed or accessible raceways for identification.
 - b. Provide pre-tensioned bands, snap-around colored plastic sleeves, colored adhesive marking tape, or a combination of the two.
 - c. Make each color band 2 inches wide, completely encircling conduit, and place adjacent bands of two-color markings in contact, side by side.

- d. Install bands at changes in direction, at penetrations of walls and floors, and at 40-foot maximum intervals in straight runs.
- E. Identify Junction, Pull, and Connection Boxes
 - 1. Provide code-required caution sign for boxes, with pressure-sensitive, self-adhesive type label, indicating system voltage in black, preprinted on orange background.
 - a. Install label on outside of box cover.
 - b. Label box covers with identity of contained circuits.
 - c. Use pressure-sensitive plastic labels at exposed locations.
 - d. Provide similar labels or plasticized card stock tags at concealed boxes.
- F. Underground Electrical Line Identification:
 - 1. During trench backfilling, for exterior underground power, signal, and communications lines, install continuous underground plastic line marker, located directly above line at 6 to 8 inches below finished grade.
 - 2. Where multiple lines are installed in a common trench or concrete envelope, do not exceed an overall width of 16 inches; install a single line marker.
- G. Electrical Manholes and Handholes:
 - 1. Provide identification on all new electrical manhole and handhole covers.
 - 2. Identification shall consist of metal tags with stamped legend punched for fastener. Dimensions shall be 2 inches by 2 inches by 19 gauge.
- H. Install line marker for underground wiring, both direct-buried and in raceways.
- I. Use conductors with factory-applied color on the entire length of the conductors except as follows:
 - 1. Use following field-applied color-coding methods in lieu of factory-coded wire for sizes larger than No. 10 AWG.
 - a. Apply colored, pressure-sensitive plastic tape.
 - (1) Provide half-lapped turns for a distance of 6 inches from terminal points and in boxes where splices or taps are made.
 - (2) Apply the last two laps of tape with no tension to prevent possible unwinding.
 - (3) Use 1-inch-wide tape in colors as specified.
 - (4) Do not obliterate cable identification markings by taping.
 - (5) Adjust tape locations slightly to prevent obliteration.
 - b. Use of colored cable ties in lieu of pressure-sensitive tape.
 - (1) Apply three ties of specified color to each wire at each terminal or splice point starting 3 inches from the terminal and spaced 3 inches apart.
 - (2) Apply with a special tool or pliers, tighten for snug fit, and cut off excess length.

2. Power Circuit Identification:
 - a. Securely fasten identifying metal tags or aluminum wraparound marker bands to cables, feeders, and power circuits in vaults, pull boxes, junction boxes, manholes, and switchboard rooms.
 - b. Use 1/4-inch steel letter and number stamps with legend to correspond with designations on drawings.
 - c. Where metal tags are provided, attach them with approximately 55-pound test monofilament line or one-piece self-locking nylon cable ties.
- J. Tag or label conductors as follows.
 1. Future connections: Indicate cable for future connection or connection under another contract, with identification indicating source and circuit numbers.
 2. Multiple Circuits: Where multiple branch circuits or control wiring or communications/signal conductors are present in the same box or enclosure (except for three-circuit, four-wire home runs):
 - a. Label each conductor or cable.
 - b. Provide legend indicating source, voltage, circuit number, and phase for branch circuit wiring.
 - c. Indicate phase and voltage of branch circuit wiring by means of coded color of conductor insulation.
 - d. For control and communications/signal wiring, use color coding or wire/cable marking tape at terminations and at intermediate locations where conductors appear in wiring boxes, troughs, and control cabinets.
 - e. Use consistent letter/number conductor designations throughout on wire/cable marking tapes.
 3. Match identification markings with designation used in panelboards shop drawings, Contract Documents, and similar previously established identification schemes for the facility's electrical installations.
- K. Apply warning, caution, and instruction signs and stencils as follows:
 1. Install warning, caution, or instruction signs where required by NEC, where indicated, or where reasonably required to assure safe operation and maintenance of electrical systems and of the items to which they connect.
 2. Install engraved plastic-laminated instruction signs with approved legend where instructions or explanations are needed for system or equipment operation.
 3. Install butyrate signs with metal backing for outdoor items.
 4. Emergency Operating Signs: Install engraved laminate signs with white legend on red background with minimum 3/8-inch-high lettering for emergency instructions on power transfer, load shedding, or other emergency operations.
- L. Install equipment/system circuit/device identification as follows:

1. Apply equipment identification labels of engraved plastic-laminate on each major unit of electrical equipment in building, including central or master unit of each electrical system. This includes communication/signal/alarm systems unless unit is specified with its own self-explanatory identification.
 2. Except as otherwise indicated, provide single line of text, with 1/2-inch-high lettering on 1-1/2-inch-high label (1-inch-high where two lines are required), white lettering in black field.
 3. Text shall match terminology and numbering of the Contract Documents and shop drawings.
 4. Apply labels for each unit of the following categories of electrical equipment.
 - a. Panelboards, electrical cabinets, and enclosures.
 - b. Access doors and panels for concealed electrical items.
 - c. Electrical substations.
 - d. Motor control centers.
 - e. Motor starters.
 - f. Pushbutton stations.
 - g. Contactors.
 - h. Remote and local annunciators.
 - i. Control devices.
 - j. Transformers.
 - k. Battery racks.
 - l. Disconnect switches.
- M. Apply circuit/control/item designation labels of engraved plastic laminate for disconnect switches, breakers, pushbuttons, pilot lights, motor control centers, and similar items for power distribution and control components above, except panelboards and alarm/signal components, where labeling is specified elsewhere.
- N. For panelboards, provide framed, typed circuit schedules with explicit description and identification of items controlled by each individual breaker.
- O. Install labels at locations indicated and at locations for best convenience of viewing without interference with operation and maintenance of equipment.

END OF SECTION

SECTION 16323
DRY TYPE TRANSFORMERS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Provide dry type general-purpose air-cooled transformers as shown on the Drawings and specified herein.
 - 1. Provide appurtenances as specified and as shown on the Contract Documents.

1.2 REFERENCES

- A. The following is a list of codes and standards that may be referenced in this section:
 - 1. American National Standards Institute (ANSI): C89.2, Dry-Type Transformers for General Applications.
 - 2. National Electrical Manufacturers Association (NEMA): ST 20- 86, Dry-Type Transformers for General Applications.
 - 3. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the production of the required materials and equipment.
 - 1. The manufacturer shall be responsible for the design, construction, and proper operation of all components.
- C. Comply with applicable standards.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Comply with Section 01330, Submittal Procedures. Include the following information:
 - 1. Product data.
 - 2. Shop drawings.
 - 3. Special shipping, storage, protection, and handling instructions.
 - 4. Manufacturer's installation instructions.
- B. Submit the following before transformer shipment:

1. Certified routine test reports (for each transformer) in accordance with ANSI/IEEE Standard C57.12.40 and Section 01330, Submittal Procedures.
 2. Certified production test reports (for each network protector) in accordance with ANSI/IEEE Standard C57.12.44 and Section 01330, Submittal Procedures.
 3. Certified sound level test report.
 4. Installation, operation, and maintenance manuals.
- C. Submit manufacturer's certificates in accordance with the Section 01330, Submittal Procedures.
- D. Submit operation and maintenance manuals in accordance with Section 01330, Submittal Procedures.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Deliver, handle, and store the equipment in accordance with Section 01450, Quality Control.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Dry-Type General Purpose Transformers:
1. Square D Company.
 2. Eaton Electrical.
 3. General Electric.

2.2 DRY-TYPE GENERAL PURPOSE TRANSFORMERS

- A. Provide dry-type general purpose transformers that comply with the following:
1. Energy efficient, dry-type, designed for NEMA TP-1.
 2. kVA, primary voltage and connection, secondary voltage and connection, and number of phases, as specified in the Drawings.
 3. Constructed of highest quality low loss core materials to minimize power loss and vibration.
 4. Core and coil assemblies, mounted on rubber isolation pads to minimize and isolate sound transmission.
 5. Use copper windings.
 6. Provide an electrostatic shield between the windings to attenuate and isolate source line noise. Ground the shield to the enclosure.
 7. Maximum Temperature Rise above 40 Degrees C: 115 degrees C.
 8. Having four 2-1/2 percent taps, two above and two below nominal on primary windings.
 9. Sound Level: 3 dB below NEMA Standard.
 10. Insulation Class: 220 degrees C.

11. Size of Neutral: 100 percent.
12. Provide additional coil capacity to compensate for higher nonlinear load loss.
13. Heavy gauge ventilated indoor enclosure.
14. UL listed.

PART 3 EXECUTION

3.1 FACTORY TESTING

- A. Provide three copies of the final factory inspection tests to the Engineer.

3.2 INSTALLATION

- A. Install transformers as specified by Contract.
- B. Mount transformers with vibration isolators so that the vibrations are not transmitted to the structural parts of the building or to other equipments.
- C. Install conduit system to transformer enclosure using flexible couplings at the transformer to help prevent noise transmission.
- D. Adjust tap settings to provide proper voltage at panelboards with mean average loads energized and operating.
- E. Install transformers in conformance to NEC.
- F. Adjustment: Adjust transformer taps to provide optimum conditions at utilization voltage.
- G. Protection: Apply temporary heating accordance with manufacturer's recommendations within enclosure of each transformer throughout periods during which equipment is not in a space that is continuously under normal control of temperature and humidity.

3.3 FIELD QUALITY CONTROL AND TESTING

- A. Perform field inspection and testing in accordance with Section 16950, Testing.
- B. Grounding:
 1. Provide equipment grounding.
 2. Tighten connections to comply with tightening torques specified by the manufacturers and UL Standard 486A to assure permanent and effective grounding.

3.4 MANUFACTURER'S FIELD SERVICES

- A. Provide services in accordance with Section 01640, Manufacturers' Field Services. Manufacturer's field services shall respond to the Commission's request for correction of problems during startup and warranty power within 4 hours.
- B. Training:
 - 1. Provide training to instruct representatives of the Commission and Engineer as follows:
 - a. Dry Type Transformers: 2 hours.

END OF SECTION

SECTION 16375
UNDERGROUND DISTRIBUTION SYSTEM

PART 1 GENERAL

1.1 DESCRIPTION

- A. Furnish and install complete underground distribution system as indicated and specified.

1.2 REFERENCES

- A. The following is a list of codes and standards that may be referenced in this section:
 - 1. American National Standards Institute (ANSI): C2, National Electrical Safety Code.
 - 2. National Electrical Manufacturers Association (NEMA).
 - 3. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the production of the required materials and equipment.
 - 1. The manufacturer shall be responsible for the design, construction, and proper operation of all components.
- C. Comply with applicable standards.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Submit following in accordance with Section 01330, Submittal Procedures.
 - 1. Shop drawings of duct banks and manholes.
 - 2. One set of contract drawings showing:
 - a. Exact routing and elevation of all underground conduit, duct banks, and manholes.
 - b. Dimensions of all conduits duct banks, manholes, and bends from buildings or other fixed objects.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Encased Buried Conduit:
 - 1. Carlon Company.
 - 2. Or equal.
- B. Manhole Waterproofing Material:
 - 1. Tnemec Company, Inc.
 - 2. Mobil Chemical Company.
 - 3. Koppers Company, Inc.
 - 4. Or equal.
- C. Cable Supports:
 - 1. Continuous concrete inserts, 1-5/8 inches by 1-5/8 inches by 12 gauge stainless:
 - a. B-Line Systems.
 - b. Or equal.
 - 2. Cable brackets, 18 inches long, hot-dipped galvanized steel:
 - a. B-Line Systems.
 - b. Or equal.
 - 3. Insulators, porcelain cable rack saddle:
 - a. B-Line Systems; B4095.
 - b. Or equal.
 - 4. Columns, bases, braces, angles and other accessories and hardware: Compatible with “continuous concrete inserts” above as a minimum.
 - 5. Stainless steel anchor bolts and expansion anchors: Comply with ASTM 320, A151 Type 316.
- D. Frames and Covers:
 - 1. NEENAH; Cat. No. R-1640-D. (RCQ 4 9/30/13)
 - 2. Or equal.

2.2 ENCASED BURIED CONDUIT

- A. Provide Carlon EB-20.
- B. Or equal.

2.3 MANHOLE WATERPROOFING MATERIAL

- A. Provide heavy duty black, No. 46-449, Hi-Build Bituminous Coating, No. 35-J-10, Bitumastic Super Service Black.
- B. Or equal.

2.4 CABLE SUPPORTS

- A. Provide continuous concrete inserts, high-strength fiberglass nonmetallic supports by B-Line or T&B.
- B. Provide cable brackets of 18-inch long, high-strength fiberglass nonmetallic supports by B-Line or T&B.
- C. Provide insulated, porcelain cable rack saddle equivalent to B-Line type B4095 for use with brackets.
- D. Provide columns, bases, braces, angles and other accessories and hardware compatible with “continuous concrete inserts” above, as a minimum.
- E. Provide anchor bolts and expansion anchors of stainless steel, complying with ASTM 320, A151, Type 316.

2.5 FRAMES AND COVERS

- A. Provide heavy-duty gray cast iron, equivalent to NEENAH Cat No. R-1640-D. (RCQ 4 9/30/13)
 - 1. With lettering on the cover to read ‘ELECTRIC’ for electric system manholes.
 - 2. With lettering on the cover to read ‘COMMUNICATIONS’ for communication system manholes.
 - 3. With machine-finished seat to ensure perfect joint between frame and cover.

2.6 CONDUIT SPACERS

- A. Furnish conduit spacers in duct banks as follows:
 - 1. Made of plastic.
 - 2. Maintain spacing of 3 inches between conduits.
 - 3. Maintain spacing of 6 inches between power and communication conduits.

2.7 CONCRETE

- A. Provide minimum compressive strength, 4,000 psi.

2.8 REINFORCING

- A. Reinforcing steel in duct banks to comply with following:
 - 1. Minimum No. 5 bars at 12 inches O.C. longitudinally each face.
 - 2. No. 4 bars at 24 inches O.C. 12-inch overlapping half stirrups.

2.9 CONCRETE ELECTRICAL MANHOLES:

- A. Precast concrete manholes shall be manufactured under controlled conditions, not subject to the elements, using steel forms, internal and external vibrations of concrete, and subject to periodic testing and control of the Construction Materials Testing Institute.
- B. Concrete shall be produced on a performance basis using 7½ bag mix cement. The strength of the concrete shall be at or greater than 3500 psi in 28 days or at time of delivery. The design strength is determined by ASTM-C-94, Section 15, Table 1, with coefficient of variation of 15% and a required over design factor of 1.14.
- C. Basis for concrete strength is the 6 x 12 test cylinder made in conformance with ASTM-C-31 and tested in conformance with ASTM-C-39.
- D. Placing of the concrete shall be done under controlled conditions with temperatures varying not lower than 50°F nor higher than 85°F. Units are to be allowed to cure for 24 hours before removal to drying yards.
- E. Steel reinforcing shall be H-20 bridge loading proven by calculations drawn by a Registered Structural Engineer using new billet steel welded into cages and installed in steel forms before pouring of concrete.
- F. Manhole shall have heavy-duty frames and lids. Lids shall be self-sealing and shall be stamped "ELECTRIC" or "INSTRUMENTATION" as indicated on the Drawings.
- G. Manholes shall be provided with a fiberglass ladder leading to the bottom of the manhole.
- H. Manholes shall be provided with nonmetallic cable racks as required.
- I. All joints shall be sealed with plastic gaskets. All joints shall be sealed watertight.
- J. The manholes shall be waterproofed by applying two coats of Cooper-Black 760 top-service black protective coating to the outside surfaces of the manhole. The coating shall be applied in strict accordance with the manufacturer's recommendations. Final dry mils thickness shall be 12 mils.
- K. Manholes shall be manufactured by A.C. Miller, Penn Cast, or equal.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install conduit as follows:

1. Use concrete, spacers, reinforcing, etc., as specified, and as indicated for concrete encased conduits.
2. Follow routing on drawing and run conduits in straight lines as far as possible. Where deviation from a straight line becomes necessary, install bends of sufficient radius for proper pulling and installation of cable.
3. To accomplish changes in direction of runs exceeding total of 10 degrees:
 - a. Provide vertical or horizontal, by long sweep bends having minimum radius of curvature of 25 feet, with following exceptions:
 - (1) Use manufactured bends at ends of short runs of 100 feet or less.
 - (2) Use manufactured bends only at or close to end of run.
 - (3) Install manufactured bends with minimum radius of 36 inches where larger radius cannot be used.
 - b. Long sweep bends made up of one or more curved or straight sections and/or combinations thereof.
4. Lay duct lines to minimum slope of 4 inches per 100 feet and slope to manholes and handholes, as indicated. Duct lines are to slope away from buildings where possible.
5. Install spacers at intervals of approximately 4 feet and stagger between tiers of ducts to provide not less than 12 inches of longitudinal separation. Install base spacers to provide at least 3 inches between bottom of trench and underside of bottom conduits. Completely fill space with concrete. Firmly wire conduits and spacers together before concrete is placed.
6. Prior to placing of concrete, remove all dirt, sand, and any other debris from between conduits and from trench bottoms. Hold conduits in place to prevent floating or accidental movement.
7. Stagger joints in conduit at least 6 inches. Do not allow couplings to rest on bottom of trench. Install couplings for plastic conduit in accordance with manufacturer's recommendations.
8. Install concrete encasements so minimum clearance of 12 inches from concrete to parallel pipes, lines, structures, etc., is maintained. At duct crossings, minimum clearance of 6 inches shall be acceptable.
9. Top of concrete to be minimum 30 inches below finished grade or paving. Submit special conditions, which may require lesser clearances to Engineer for approval.
10. Do not use power-driven vibrators for spading of concrete around ducts. Use wooden slicing tool to eliminate voids in concrete envelope.
11. Roll and grade backfill and restore surface to condition at least equal to which it was found immediately before work was begun, or as otherwise indicated.
12. Provide duct bank markers at ends of all duct banks except at manholes or handholes as follows:

- a. Locate approximately every 200 feet along duct run, and at each change in direction of duct run.
 - b. Refer to specification section 16050 and drawings for duct bank installation details.
 - c. 6-inch square or round section by 3 feet long made of Class B concrete.
 - d. Imprint the letter "D" or cast it on top of the marker.
13. Keep conduits clean of concrete, dirt, and other substances during the course of construction.
- a. After the duct lines have been completed, pull a standard flexible mandrel not less than 12 inches long, having a diameter approximately 1/4-inch less than the inside diameter of the conduit, through each conduit.
 - b. After mandrelling, pull a brush with stiff bristles through each conduit to make certain that no particles of earth, sand, or gravel have been left in the line.
 - c. Replace conduit runs that do not allow the passage of the mandrel at no additional cost to the Commission.
 - d. Pneumatic rodding may be used to draw in the lead wire.
 - e. Plug and seal spare conduits after cleaning and installation of nylon pulling rope.

B. Install Manholes and Handholes as follows:

1. Construct manholes and handholes of Class 4000 concrete cast in place in accordance with Section 03300, Cast-in-Place Concrete.
2. Provide cable racks, hooks, insulators, and other features in manholes, as indicated.
3. Place a 6-inch crushed-stone base under each manhole and handhole.
4. Construct cast-in-place manholes and handholes with forms as follows:
 - a. Complete with centering cores and molds, to conform to shape, form, line and grade required, and maintain sufficient rigidity to prevent deformation under load.
 - b. Make all joints leak-proof and arrange horizontally or vertically.
 - c. Place forms on successive units for continuous surfaces and fit to accurate alignment, assuring a smooth completed surface, free from irregularities.
 - d. Provide sump in manhole floor as detailed on drawings.
5. At convenient point close to wall, drive 3/4-inch by 12-foot-long copper-clad steel ground rod into earth as indicated. Extend ground rod approximately 6-inch above finished manhole floor.
6. After completion of manhole, provide a ground loop of No. 4/0 AWG bare copper ground wire within manhole or handhole and Cadweld to ground rod.
7. Connect all conduit grounding bushings, other metallic parts, splices, ground wires run with each feeder and duct bank ground wire to ground loop. Duct bank ground wire shall be a separate No. 4/0 AWG bare copper wire that shall be run within the concrete encasement.

8. Size, space, and place reinforcing bars and ductwork ground wire as indicated and as specified.
9. Set manhole and handhole frames to the required grade, in full bed of concrete mortar to make watertight connection.
10. Install tops of manhole and handhole covers in unpaved areas approximately 1/2-inch above finished grade, and in paved areas install flush with finished surface of paving.
11. Install inserts in the manholes as indicated.
12. Provide two cable pulling irons in wall opposite each duct bank entrance into manhole.
 - a. Install one 12 inches above floor.
 - b. Install one 12 inches below the roof of manhole.
 - c. Where indicated on drawings, install additional pulling irons and features such as openings in manhole walls for future conduit entrances.
 - d. Seal future entrances with required courses of brick.
13. Where duct lines enter manholes, terminate conduits with PVC to non-metallic adapters.

C. Manhole and Handhole Waterproofing:

1. Apply two coats of bituminous waterproofing material to exterior surfaces of manholes and handholes:
 - a. Apply by brush or spray, in accordance with manufacturer's instructions.
 - b. Allow time between coats to permit sufficient drying.

3.2 FIELD QUALITY CONTROL AND TESTING

- A. Perform field inspection and testing in accordance with Section 16950, Testing.
- B. Grounding:
 1. Provide grounding in accordance with Section 16450, Grounding.
 2. Tighten connections to comply with tightening torques specified by the manufacturers and UL Standard 486A to assure permanent and effective grounding.

END OF SECTION

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SECTION 16400 PANELBOARDS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Furnish and install panelboards including circuit breakers and cabinets complete, in conformance with the latest NEMA Standards and Federal Specifications listed below as shown on Drawings and as specified herein.
- B. Related work specified elsewhere may include but is not limited to:
 - 1. Section 16050, Basic Electrical Materials and Methods.
 - 2. Section 16450, Grounding.
 - 3. Section 16950, Testing.

1.2 REFERENCES

- A. The following is a list of codes and standards that may be referenced in this section:
 - 1. National Electrical Manufacturers Association (NEMA):
 - a. AB1, Molded Case Circuit Breakers.
 - b. PB1, Panelboards.
 - 2. Federal Specifications (FS):
 - a. W-C-375a, b, Molded Case Circuit Breakers.
 - b. W-P-115a, b, c, Panelboards.
 - 3. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
 - 4. Underwriter's Laboratories, Inc.:
 - a. 50, Enclosures for electrical equipment.
 - b. 67, Panelboards.

1.3 QUALITY ASSURANCE

- A. Reference Standards: Comply with all federal and the State of Maryland laws or ordinances, as well as all applicable codes, standards, regulations and/or agency requirements.

1.4 SUBMITTALS

- A. Shop drawings of the electrical equipment will not be reviewed until the short circuit analysis, protective device coordination study, and arc flash study are approved by Engineer in accordance with the relevant specification section for Electrical System Protective Device Study and Arc Flash Analysis.

- B. General: Provide all submittals in accordance with Section 01330, Submittal Procedures.
- C. Shop Drawings:
 - 1. Drawings and data covering outlines, wiring diagrams and certified test data reports, shall be submitted in accordance with the Section 01330, Submittal Procedures.
 - 2. Submit time-current characteristic curves for each rating of circuit breaker supplied.
 - 3. Provide a separate circuit schedule with loads for each panelboard.
- D. Service Manuals: Submit in accordance with Section 01330, Submittal Procedures.
- E. O&M Training: Submit in accordance with Section 01330, Submittal Procedures.

1.5 DELIVERY AND HANDLING

- A. Shipping: Ship materials complete with identification and quantity of items.
- B. Acceptance at Site: Inspect and inventory items upon delivery to site.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. Contingent upon products' compliance with the specifications, acceptable manufacturers are as follows:
 - 1. 1. ABB / General Electric
 - 2. 2. Eaton

2.2 3. SQUARE D / SCHNEIDER ELECTRICMANUFACTURED UNITS

- A. All panelboards shall be completely factory assembled, deadfront type, with automatic branch circuit breakers.
- B. Furnish panelboards complete with branch circuit breakers and a main circuit breaker, or solderless main lugs only, as indicated on the Drawings.
- C. Furnish panelboards with full capacity separate ground bus and furnish panelboards connected to 3-phase, 4-wire service with an insulated neutral bus.
- D. All circuit breaker connections shall be in hole tapped by the manufacturer.

- E. Furnish the panelboard main, neutral and grounding buses, with minimum 98 percent conductivity rectangular tin-plated copper bars provided with bolted type lugs as necessary.
- F. Tin-plated copper buses, connectors and terminals shall conform to the latest standard requirements.
- G. Prevent terminal lugs from turning per NEMA standard PBI and ensure they are suitable for the conductor material and size.
- H. The design of the interior shall permit replacement of circuit breakers without disturbing adjacent units and without machine drilling or tapping.
- I. Install panelboard in motor control center (MCC) if shown on the Drawings. Panelboard shall be provided and installed by the MCC manufacturer when installed in the MCC.

2.3 EQUIPMENT

- A. Ratings:
 - 1. Voltage ratings listed below shall apply to each panelboard, as shown on the drawings.
 - a. 480 volt, 3-phase, 3-wire, 60-Hz.
 - b. 480/277 or 120/208 volt, 3-phase, 4-wire, 60-Hz.
 - c. 120/240 volt, 1-phase, 3-wire, 60-Hz.
 - d. 125 volts, 2-wire, dc.
 - 2. Provide main bus-bracing for each ac panelboard adequate for 22,000 amperes rms symmetrical short circuit for 120/208 volts 60-Hz panelboards and 65,000 amperes rms symmetrical short circuit for 480 volts 60-Hz panelboards.
 - 3. Provide main bus-bracing for each dc panelboard adequate for 10,000 amperes rms symmetrical short circuit at 125V dc, unless approved otherwise.
- B. For all circuit breakers:
 - 1. Furnish bolt-on type branch and main circuit breakers. Furnish frame sizes, trip settings and number of poles as indicated. Clearly and visibly mark circuit breakers with ampere trip rating.
 - 2. Furnish all breakers with quick-make, quick-break, toggle mechanisms and thermal-magnetic, inverse time-limit overload and instantaneous short circuit protection on all poles, unless approved otherwise. Automatic tripping shall be indicated by the breaker handle assuming a clearly distinctive position from the manual ON and OFF position. Furnish breaker handle that is trip free on overloads. Multi-pole breakers shall be common trip.

3. Do not use single pole breakers with handle ties or bails in lieu of multi-pole breakers.
4. Furnish non-padlocking type handle lock device on breakers where indicated on schedules to prevent the manual opening of the selected breakers, unless approved otherwise.
5. Furnish padlocking device on breakers as indicated to prevent the opening of indicated breakers.
6. Ensure that voltage and interrupting rating of all breakers in a panelboard is not less than voltage and short circuit rating of the panelboard main buses, as indicated. Furnish breakers suitable to operate satisfactorily at the frequency indicated.
7. Furnish ground fault interrupter circuit breakers for certain circuits as indicated on the Drawings.
8. Furnish single pole breakers with full module size. Do not install two pole breakers in a single module.
9. Provide solderless lug type breaker terminals.
10. Where schedules indicate space for future breakers, provisions shall be such that no additional connectors will be required to add breakers.

C. Branch Circuit Breakers:

1. 480-volt rating, 225- and 100-ampere frame, minimum interrupting rating 65,000 rms symmetrical amperes at 480 volts, or as shown on the Drawings.
2. 120/240-volt, 60Hz, 100-ampere frame, minimum interrupting rating 22,000 rms symmetrical amperes at 120 volts, or as shown on the Drawings.
3. 125V dc, 100-ampere frame minimum interrupting rating 10,000 rms symmetrical amperes volts, or as shown on the Drawings.
4. 1 pole, 2 pole, and 3 pole with trip settings as shown on the Drawings.

D. Main Circuit Breakers:

1. 480-volt rating, 225-ampere frame, minimum interrupting rating 65,000 rms symmetrical amperes at 480 volts, or as shown on the Drawings, whichever is greater.
2. 240-volt rating, 100-ampere frame, minimum interrupting rating 22,000 rms symmetrical amperes at 240 volts, or as shown on the Drawings, whichever is greater.
3. 125V dc, 100-ampere frame minimum interrupting rating 10,000 rms symmetrical amperes or as shown on Drawings, whichever is greater.
4. 2- or 3-pole with trip settings as shown on the Drawings.

2.4 COMPONENTS

A. Cabinets:

1. Provide NEMA 12 cabinets, unless approved otherwise, without knockouts. Drill cabinets only for the exact conduit entrances and mounting bolts.
2. Finish cabinet fronts, trims, and surface-mounted boxes in ANSI 61 light-gray enamel over a rust-inhibitive primer. Attach the fronts (exterior trims) to the boxes or interior trims, by quarter-turn, indicating trim clamps. Design cabinets for surface or flush mounting as indicated.
3. Unless approved otherwise, construct panelboard cabinets of code-gauge galvanized, sheet steel and equip with gutters of size in accordance with NEC for the risers and outgoing circuits. Ensure that the cabinets do not exceed 78 inches in height.
4. Panelboards shall have dead-front shield to provide access to wiring gutters with front removed, without exposing bus compartment.
5. Furnish fronts with adjustable trim clamps for attachment to front of panelboard enclosure.
6. Complete fronts with doors, catches, and spring-loaded door pulls. Catch and door pull assembly not to extend beyond front of door. Three-point catch, and vault-type handle provided on all doors over 48 inches high, doors over 24 inches wide, and on all double doors. No door locks to be provided.
7. Attach doors to fronts with semi-concealed or concealed hinges.
8. Continuous piano hinges provided on all doors over 36 inches high.
9. Identify each circuit by typewritten directory with transparent tough plastic cover, fastened to inside surface of door.
10. Install panelboard in MCC if shown on the Drawings.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Mount all panelboards such that the height of the top operating handle does not exceed 6 feet 6 inches from the floor. Install all conduit, wiring, and grounding as indicated.
- B. All circuit breakers installed in existing panelboards shall be manufactured by the original panelboard manufacturer and shall be fully compatible with the panelboard.

3.2 FIELD QUALITY CONTROL

- A. Make required continuity and operational tests. Provide directory card filled-out.

3.3 MANUFACTURER'S FIELD SERVICES

- A. Provide services in accordance with Section 01640, Manufacturers' Field Services. Manufacturer's field services shall respond to the Commission's request for correction of problems during startup and warranty power within 4 hours.
- B. Training:
 - 1. Provide training to instruct representatives of the Commission and Engineer as follows:
 - a. Panelboards: 1 hour.

END OF SECTION

SECTION 16450 GROUNDING

PART 1 GENERAL

1.1 SCOPE

- A. Furnish and install a single, complete, electrically continuous grounding system, including all conductors, raceways, and connections, specified, and indicated.
- B. Install and connect the ground system, in order to furnish an adequate ground for the electronic and electrical equipment, in conformance to the National Electrical Code and as shown on the Drawings and described herein.
- C. Electronic equipment and wiring grounding directions shall be closely adhered, to prevent ground loops and stray signal generation.

1.2 QUALITY ASSURANCE

- A. Reference Codes, Standards and Applicable Provisions:
 - 1. National Electrical Code (NEC).
 - 2. National Fire Protection Association (NFPA).
 - 3. American National Standards Institute (ANSI).
 - 4. National Electrical Manufacturers Association (NEMA).
 - 5. Institute of Electrical and Electronic Engineers (IEEE).
 - 6. Insulated Cable Engineers Association (ICEA).
 - 7. American Society for Testing and Materials (ASTM).
 - 8. Underwriters' Laboratories, Inc. (UL).
- B. Tests
 - 1. Measure ground grid resistance with earth test megohmmeter
 - 2. Install additional ground rods and conductors as required until resistance to interconnected ground system is 5 ohms or less.
 - 3. Measure ground resistance in normally dry conditions and not less than 48 hours after rainfall.

1.3 SUBMITTALS

- A. Shop and working drawings shall be provided in accordance with Sections 01300 and 16050.

PART 2 MATERIALS

2.1 ACCEPTABLE MANUFACTURERS

- A. Contingent upon products compliance with the specifications.
- B. Ground rods:

1. Copperweld Corporation, 2 Oliver Plaza, Pittsburgh, PA.,
 2. ITT Blackburn Company,
 3. Approved Equal.
- C. Exothermic Welding.
1. Erico Products Inc., Cleveland, Ohio.
 2. American Brass Mfg. Co.
 3. Therm-O-Weld by Burndy Corporation
 4. Approved Equal.
- D. Connecting Hardware.
1. American Brass Mfg. Co.
 2. Anderson Electric Corp.
 3. Burndy Corporation
 4. O.Z./Gedney, Division of General Signal Corporation
 5. Approved Equal.

2.2 CONDUCTORS

- A. Cables or wire shall be Class A bare or insulated copper, sizes as indicated on the Drawings or as required by the National Electric Code. All conductors shall be protected if physical damage would result from exposure.
- B. Main grounding conductors, grounding electrode conductors and main bonding jumpers shall be no smaller than #4/0 stranded bare copper cable, annealed, with no less than nineteen (19) strands in the cable unless approved otherwise.
- C. Furnish bare conductors where buried in earth or where embedded in concrete.
- D. In buildings run insulated grounding conductors with green insulation only.
- E. Furnish insulated grounding conductors with insulation rated at 600 volts.
- F. Furnish grounding conductors for installation in all non-metallic raceway in addition to, and not to be considered as, the neutral wire of the systems.

2.3 CONNECTIONS

- A. Make all buried and concealed ground connections by exothermic welding.
- B. Make accessible connections to structural members by exothermic welding process or by bolted connectors. Make connections to equipment or ground bus by acceptable bolted connectors suitable for and matching grounding provisions furnished.
- C. All clamps, connectors, lugs, bolts, washers, and nuts shall be silicone bronze and shall be Everdur.

- D. In manholes, for buried ground grid connections, and were indicated on the Drawings, ground cable connections shall be made by Cadweld exothermic welding process.
- E. Apply grounding bushings on both ends of conduit run and intermediate enclosures.

2.4 GROUND RODS

- A. Ground rods shall be copper clad steel ground rods 3/4-inch in diameter of a single 10-foot length.
- B. Rods shall have a rolled scar-resisting surface, with both ends of the rod receiving the same heavy coating of copper as the body of the rod.
- C. The end of the driving rod shall be chamfered, and the point shall be machined smooth, to aid in driving.

PART 3 EXECUTION

3.1 INSTALLATION OF GROUNDING CONDUCTORS

- A. Install grounds conductors so not exposed to physical damage.
 - 1. Install connections firm and tight.
 - 2. Arrange conductors and connectors so no strain on connections.
- B. Bury equipment grounding conductors 24-inch deep. Bring loops or taps up for connections to equipment or other items to be grounded.
- C. All grounding conductors shall be installed in conduit except the grounding electrode conductor or were shown otherwise.
- D. Connect building steel to the station ground system using bonding cable with exothermic welds.
- E. Install loop type, low impedance, grounding system interconnecting all components so at least two ground connections are provided for each major item of electrical equipment. Ensure that severing of any single grounding conductor in this system does not remove grounding protection on any major item.
- F. Perform exothermic welding with properly sized molds in good conditions.

3.2 INSTALLATION OF GROUND RODS

- A. Install ground rods at manholes, substations and buildings whether indicated on drawings or not.
- B. Make connection to overall grounding system as indicated.

- C. Ensure that final resistance of interconnected ground system is 5 ohms, or less. Measure ground resistance in normally dry conditions and not less than 48 hours after rainfall.

3.3 EQUIPMENT GROUNDING

- A. Ground all electrical equipment by means of a grounding conductor installed in raceway feeding that equipment with copper wire sized in accordance with National Electric Code. Grounding conductors installed in conduit shall be furnished with green, 600-volt insulation.
- B. Connect transformer cases and neutrals to grounding system.
 - 1. Connect neutral ground connection at transformer terminal as shown on drawings.
 - 2. Provide two separate, independent, diagonally opposite, connections for power transformers so removal of one connection will not impair continuity of other unless approved otherwise.
- C. Connect two separate ground connections from ground grid to ground bus of switchgear assemblies and all outdoors substation equipment. Ensure that each connection for the item of equipment is from different section of ground grid.
- D. Install a separate grounding conductor from ground system to all 480-volt motors and equipment, in addition to raceway system.
 - 1. Ground motor ground connection to motor frame, independent of mounting bolts or sliding base.
 - 2. Ground motor to nearest point on grounding system, unless approved otherwise.
- E. Scrape bolted surfaces clean and coat with oxide-resistant conductive compound.
- F. All conduit and armored cables leaving the service equipment and/or motor control centers shall be grounded to the service equipment and/or motor control center ground bus.
- G. Ground each lightning mast to ground rod driven near base of mast, in accordance with requirements of UL.
- H. Where lightning arresters are furnished with electrical equipment and ground connections are not inherently provided, ensure that suitable separate grounding conductor connects lightning arresters with system ground.
- I. Ground wire fences when used to enclose electrical equipment. Unless approved otherwise, provide minimal grounding by buried outside peripheral ground loop; connections to each corner fence post and nearby ground rod; flexible connections to each gate; and at least two connections to grounding system from approximately opposite positions of fence.

- J. Also connect the ground rods to the grounding conductor run with the direct burial cable.

3.4 INSTRUMENTATION GROUNDING

- A. Install separate main ground conductors for all DC circuits and instrumentation panels and instruments.
- B. Connect DC and instrumentation grounds to the main station grounding system at a properly selected point as shown on the Drawings or as recommended by the instrumentation supplier.
- C. Shielded cable shall be grounded at one location only in accordance with the recommendation of the instrumentation manufacturer/supplier.

3.5 FIELD QUALITY CONTROL

- A. Field inspection and testing shall be performed in accordance with Section 16950.

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SECTION 16480
MOTOR CONTROL CENTERS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Provide 600V rated motor control centers (MCCs) complete for operation on a 480V, 60 Hz system, as indicated on the Drawings and as specified herein.
 - 1. Include motor circuit protectors, circuit breakers, fuses, variable frequency drive, non-reversible motor starters, and other protective equipment as shown on the drawings to form a complete and fully assembled unit. Provide all components therein to be standard products of one manufacturer, except where specifically required or approved otherwise.
 - 2. Provide appurtenances as specified and as shown in the Contract Documents.
- B. Products Installed in MCC but Specified in Other Sections
 - 1. Section 16323 – Dry Type Transformers
 - 2. Section 16400 – Panelboards

1.2 REFERENCES

- A. The following is a list of codes and standards that may be referenced in this section:
 - 1. American National Standards Institute (ANSI):
 - a. C39.1, Electrical Analog Indicating Instruments.
 - b. C57.13, Standard Requirements for Instrument Transformers.
 - c. ANSI/IEEE C62.41-1991, Surge Withstand Capacity.
 - 2. Canadian Standards Association (CSA): 22.2, No. 14 and No. 66 – CSA Requirements for Power Electronics.
 - 3. Federal Commerce Commission (FCC); Part 15, Sub Part J, Class A – RFI/EMI Emission Standards.
 - 4. International Code Council (ICC): ICBO Building Code, Section 16, Seismic Zone 4 – Vibration Standard.
 - 5. National Electrical Manufacturers Association (NEMA):
 - a. ABI, Molded Case Breakers.
 - b. EI2, Instrument Transformers.
 - c. ICS, Industrial Controls and Systems.
 - d. II2, Electrical Indicating Instrument-Relays.
 - e. KSI, Enclosed Switches.
 - 6. Underwriter's Laboratories Inc. (UL):
 - a. 508C, UL Requirements for Power Conversion Equipment.
 - b. 845, Motor Control Centers.

1.3 QUALITY ASSURANCE

- A. Comply with applicable portions of Section 16050, Basic Electrical Materials and Methods.
- B. Provide components that are the standard product of a manufacturer regularly engaged in the production of the required materials and equipment.
 - 1. The manufacturer shall be responsible for the design, construction, and proper operation of all components.
 - 2. The Motor Control Center and all components shall be designed, manufactured, and tested in accordance with the latest applicable standards of NEMA, ANSI and UL 845.
- C. Comply with applicable standards.
- D. Design to provide satisfactory performance under the specified operating conditions.

1.4 SUBMITTALS

- A. Shop drawings of the electrical equipment will not be reviewed until the short circuit analysis, protective device coordination study, and arc flash study are approved by the Owner in accordance with the specification section for Electrical System Protective Device Study and Arc Flash Analysis.
- B. Submit the following in accordance with Section 01330, Submittal Procedures.
 - 1. Front view elevation
 - 2. Floor plan
 - 3. Top view
 - 4. Unit wiring diagrams
 - 5. Nameplate schedule
 - 6. Starter and component schedule
 - 7. Conduit entry/exit locations
 - 8. Assembly ratings including:
 - a. Short-circuit rating.
 - b. Voltage
 - c. Continuous current
 - 9. Major component ratings including:
 - a. Voltage
 - b. Continuous current
 - c. Interrupting ratings
 - 10. Cable terminal sizes
 - 11. Product data sheets
- C. Where applicable the following information shall be submitted to the Owner:
 - 1. Busway connection
 - 2. Connection details between close-coupled assemblies
 - 3. Key interlock scheme drawing and sequence of operations.

4. Special shipping, storage, protection, and handling instructions.
 5. A list of manufacturer's recommended parts required to maintain the equipment for a period of one year, with current price information.
 6. A list of special tools, materials, and supplies furnished with the equipment for use prior to and during startup, and for future maintenance.
 7. Manufacturer's installation instructions.
- D. Submit the following before MCC shipment:
1. Final as-built drawings and information for items listed in Paragraph 1.4, B & C and shall incorporate all changes made during the manufacturing process.
 2. Unit wiring diagrams
 3. Installation information
 4. Seismic certification and equipment anchorage details as specified.
 5. Certified Routine Test reports in accordance with NEMA Standard and Section 01450, Quality Control, for tests including but not limited to following:
 - a. Continuity checks of each conductor against the schematic or elementary diagram, not against the connection diagram.
 - b. Proper sequence of operation of the control circuit.
 - c. Dielectric test performed as follows:
 - (1) Test voltage equal to 1,000 volts plus twice the rated voltage of the equipment applied for a period of 60 seconds, between each terminal and all other terminals with breakers and contactors open.
 - (2) Apply same test voltage between each terminal and grounded metal part, with breakers and contactors closed.
 - d. Above tests are in addition to tests required in accordance with Section 16950, Testing.
 6. Certified Production Test reports in accordance with ANSI/IEEE Standard and Section 01450, Quality Control.
 7. Submit operation and maintenance manuals before providing training to Commission personnel in accordance with Section 01450, Quality Control.
 8. A list of special tools, materials, and supplies furnished with the equipment for use prior to and during startup, and for future maintenance.
- E. Submit manufacturer's certificates in accordance with the Section 01330, Submittal Procedures.

1.5 SPECIAL TOOLS AND SPARE PARTS

- A. Provide spare parts recommended by the manufacturer. At a minimum, provide the following spare parts.
1. Four standard packages of each size of control fuse furnished under this Contract.
 2. Four LED lamps of each color for indicating lights.

3. One spare overload heater for each size furnished under this Contract, up to a maximum of six for any one-size overload heater.
 4. One spare current limiter for each size current limiter supplied per MCC.
 5. Two sets of covers which can be used to close all openings in doors when a unit is removed. Cover to match finish.
 6. One spare unit for each ten or less of each size or type of each of the following components furnished under this Contract.
 - a. Elapsed time meters.
 - b. Control power transformers.
 - c. Switch contact blocks.
 - d. Control relays.
 - e. Control coils for each size starter.
 - f. Starter contact kits including moving contacts, stationary contact springs, screws, etc. for each size starter or contactor.
 - g. Timers, time delay relays and meter relays
- B. Furnish one complete set of special tools required to disassemble, service, repair and adjust the equipment.

PART 2 PRODUCTS

2.1 MANUFACTURERS

- A. MCCs:
1. ABB / General Electric.
 2. Eaton.
 3. Square D / Schneider Electric

2.2 MCC

- A. Provide MCCs of Advantage model as manufactured by Eaton Electrical, or Model 6 as manufactured by Square D.
1. Provide overall dimensions of the MCC to accommodate within the space assigned.
- B. Having the following operating characteristics:
1. Suitable for 480 volt, 60-Hz, 3-phase, 4-wire, AC supply.
 2. Designed to withstand symmetrical short circuit amps as given on drawings.
- C. NEMA Class II, Type C.
- D. Having the following constructional features:
1. Totally enclosed, self-supporting and free-standing type, NEMA 12 structure.
 2. Dead front, consisting of 20 inches deep (nominal) by 20 inches wide by 90 inches high vertical sections bolted together to form a unit assembly, with the front forming a continuous lineup of a uniform height.

3. Obtain Owner's approval for oversized equipment as long as MCCs can be accommodated in the designated room in compliance with the NEC.
4. Each structure fabricated of steel sheets with heavy-formed steel uprights, top and bottom structural angle frames, and removable top plate.
5. Steel uprights carrying guide rails and steel clips of the quick fastener type for the support of removable starter units.
6. Each structure designed for easy removal or addition of units, as required in future.
7. Each structure designed to provide proper ventilation and to permit mounting of unit starters anywhere within the structure without any change in overload heater ratings.
8. Units of modular design, having minimum height of 12 inches and constructed in multiples of 6 inches plus or minus 1/2 inch, arranged as shown on the drawings.
 - a. Size No. 1 or 2 starters designed to fit into 12-inch or 13-inch units.
 - b. Each single vertical stack suitable to accommodate minimum of six size No. 1 or 2 starter units, each 12 or 13 inches high.
 - c. Units, front mounted only unless approved otherwise.
9. Each structure having removable gasketed top cover plates provided for conduit entry to the top of the horizontal wireway.
10. End sections having gasketed cover plates to close off horizontal bus and wireway openings; removable for adding vertical sections in future.
11. All provisions and spaces to have barriers, buses, doors, etc., so future use requires only the addition of divider pans and guide rail units.
12. All removable covers and pans, not larger than 48 inches high and 24 inches wide and including proper closure strips.
13. All components including bolts for bus connections and bus supports, front accessible.
14. Provide lifting angles securely bolted to the top of the structures for ease of handling in shipment. Defected or distorted structures shall be rejected. Remove the angles and seal the holes after the control centers are placed in permanent locations.
15. Furnish 3-inch galvanized steel base channels with bolt holes, for anchoring the control center to the concrete base. Extend the steel side sheets and the bottom wiring trough doors to the concrete base, covering all exposed metal. Supply a base channel for the front and for the rear of each MCC stack. Ship these channels in advance of the MCC for embedding in the concrete pad or floor slab. Include accurate templates and dimensions with the base channels.
16. Ensure electrical continuity between all metal non-conducting parts.

E. Having wiring troughs as follows:

1. Each structure provided with top and bottom horizontal wiring troughs and vertical wiring troughs, with all troughs accessible through outside doors.
2. All wiring troughs, isolated by barriers from starter and circuit breaker units and from buses.

3. Each top and bottom horizontal wiring trough, having adequate conduit entrance space, free of interference from the bus barriers and the structural members, for the largest conduit required.
 4. Vertical wiring troughs, equipped with cable tie supports to hold cables and wiring in place.
 5. Vertical wiring troughs, having a separate hinged door, with maximum of two doors per section.
 6. Vertical wiring troughs, fully enclosed except for openings into horizontal wireways and openings into structure units.
 7. All openings having rounded edges or grommets to protect wiring entering wireway. Provide removable covers for all unused openings.
 8. Access to the wiring troughs available without opening the unit door.
- F. Provide bus system as follows:
1. Main horizontal three-phase bus:
 - a. Tin-plated over entire length to minimum thickness of 0.1 mil.
 - b. Use hard drawn, high conductivity copper bar.
 - c. Continuous current rating, as shown on the drawings, UL rated. Maximum current density for copper limited to 1,200 amps per square inch.
 - d. Busbars extending the full length of the structure across the top of each structure and supported by bus supports of a noncarbonizing material, resistant to moisture, acid, and alkali, braced for short circuit current stresses caused by currents of a magnitude as shown on the Drawings.
 - e. Provide one-piece busbars without splices, except where necessary for shipping.
 - f. Provide drilling at both ends of the bus for future extension.
 - g. Provide uniform phase sequence of busbars throughout each structure, in accordance with industry standard and identify and label on the front and rear in each structure to indicate phase sequence.
 - h. Arrange bus phase bars edge to edge and stack vertically one above the other.
 2. Vertical Bus:
 - a. Rising to the full height of structure, supported by insulators of the same material as the horizontal bus supports, for distribution of power from the main bus to the starter units.
 - b. Braced for same rating as the main horizontal bus.
 - c. Use extra hard drawn adequately sized rectangular high conductivity copper bars, round edged and tin-plated to minimum thickness of 0.1 mil over its entire length, and providing a lubricated low resistance contact for the stab bus connectors.
 - d. Rated to carry the full load current of all circuit breakers installed in that section, but in no case less than 300 amperes capacity.
 - e. All bus joints, tin-plated.

- f. Provide uniform phase sequence throughout each structure, in accordance with the industry standard and label on the front and rear in each structure to indicate phase sequence.
 - g. Provide ganged shutters or insulating plugs for each starter compartment including all compartments shown as PROVISION or SPARE or SPACE. Provide means for closing shutters or installing the plugs from the front of structure without the necessity of removing nuts, bolts, brackets, etc.
 - 3. Grounding Bus:
 - a. Extending the full length, mounted across the bottom, without splices, except where necessary for shipping.
 - b. Adequately sized hard drawn, high conductivity copper completely tin-plated to a minimum thickness of 0.1 mil.
 - c. Drilled with lugs of appropriate capacity as required.
 - d. Having provisions for future addition at either end.
 - e. Bolted to each vertical structure with paint removed at point of contact.
 - 4. Busbar connections easily front accessible with simple tools. Provide stainless steel everdure or cadmium-plated steel bolts, nuts, washers and locking devices.
 - 5. All horizontal bus joints, easily accessible from the front for inspection and maintenance and isolated from the wireway by sliding polyester doors or removable steel barriers.
 - 6. All busbars except ground bus, isolated and insulated with polyester barriers in front of, rear of and between phase bars. Also furnish horizontal barriers below vertical bus to prevent accidental contact with wire snake.
- G. Furnish Unit Compartments as follows:
 - 1. Removable unit enclosures constructed from not less than 14-gauge sheet steel, with construction providing isolation and baffling of each unit from the other units.
 - 2. Provide unit compartments as part of the enclosure. Include plug-in stabs, fabricated of high spring strength, high conductivity copper alloy, silver-plated and mounted on an insulating base of the same material as used for the main bus supports, for connection to the vertical bus for circuit breakers 400-amp trip and less. Provide bolt-in arrangement for higher rated breakers.
 - 3. Across the line starter, NEMA 4 and smaller, draw out or plug-in type.
 - 4. Having guide rails for accurate alignment both horizontally and vertically within the structure, to eliminate possible damage to the bus.
 - 5. Provide units with a latch lever for padlocking in the tilt-out position (stabs disengaged from the bus) isolating the unit from the power circuit.

6. Having individual gasketed dust tight front door for each unit compartment. Provide formed pan or rolled edge type doors with closed corners designed to open at least 90 degrees. Each door having at least two hinges. Doors more than 35 inches high shall have at least three hinges and doors over 48 inches high shall have at least four hinges. Provide self-aligning type door closing fasteners that cannot be pulled out of the door. Removable covers over 6 inches high shall have at least four fasteners. Provide accurate three-dimensional alignment for all doors.
7. During unit removal, the doors remain in place to permit closing and fastening.
8. Unit doors, interlocked to inhibit opening of the door until the breaker is in "OFF" position. Provide an interlock defeat mechanism for maintenance bypass.
9. Drawout or plug-in units of the same size and same type to be interchangeable where possible. Use identical wiring numbers for all wiring of components in similar units. Connect wires to the same terminals on their respective terminal blocks. Include nameplates on each unit to define the compartments into which the unit is installed. When required to deter phase reversal, mark the units "Front Only" or "Back Only," as applicable.
10. Provide components as follows:
 - a. Use circuit breakers and combination type motor starters in the control centers.
 - b. Mount disconnect operating mechanism on the disconnect, not on the unit door, with "locking" feature available in both, the open and closed positions.
 - c. Include all control units and accessories as indicated on the schematic control circuits on the Drawings.
 - d. Mount all components of a given unit, inside the unit.
11. Provide terminal blocks as follows:
 - a. 30-ampere disconnect type, mounted on drawout or plug-in units for all external control and indicating wiring.
 - b. Rated 600-volt for power wiring with current rating as required by loads. Use disconnect type, for loads through size No. 2.
 - c. Having marked strips on fixed and removal section.
 - d. Provide a minimum of two spare terminals.
 - e. Accessible from the front to provide easy control unit installation and removal and to facilitate field wiring.
 - f. Factory wired, such that disconnection of any wiring is not necessary for unit withdrawal.

H. Circuit Breakers:

1. Type:
 - a. Thermal-magnetic, molded case, with each pole of the breaker providing inverse time delay overload protection and instantaneous short-circuit protection.

- b. Magnetic only, molded case motor circuit protectors, for three phase combination motor controllers.
 2. Minimum interruption ratings at least equal to the available short circuit at the line terminals, and in no case less than 42,000 amperes. All poles open, close and trip simultaneously.
 3. Operated by a toggle type handle and having a quick-make, quick-break over center switching mechanism that is mechanically trip free from the handle.
 4. Tripping due to overload or short circuit clearly indicated by the handle automatically assuming a position mid-way between the manual ON and OFF positions.
 5. Terminals listed with UL, suitable for use with aluminum or copper cable.
 6. Completely enclosed in a molded case, listed with, meet the appropriate classifications of Federal Specifications WC375, and conform to the National Electrical Code.
 7. Frame sizes and trip settings as shown on the Drawings. Minimum frame size, 100 amps.
 8. Circuit breakers with a 400-ampere frame and larger having removable, interchangeable trip units and adjustable magnetic trip elements lockable in the open position.
 9. Provide relays internally mounted within associated breaker cubicle.
 10. Lead all interconnecting wiring to terminal strips on individual devices.
 11. Provide indicating lights, amber-LED and white-microfilament cluster type, R. Stahl Inc. Model 8415. All indication lights shall be LED push-to-test type.
- I. Provide Motor Circuit Protectors and Current Limiters, Additional Features:
1. Sealed trip unit.
 2. Clearly marked ampere rating.
 3. Nonwelding silver alloy contacts.
 4. Individual instantaneous short circuit protection provided by single, adjustable, magnetic only element.
 5. All poles adjusted simultaneously by single adjusting screw.
 6. Motor circuit protector (MCP) and starter with minimum interrupting rating as indicated on the drawings at 480V ac based on NEMA test procedures.
 7. Suitable for use with current limiters; provided where indicated on the Drawings.
 8. Motor circuit protector, limiter and starter with minimum interrupting rating as indicated on the drawings at 480V ac based on NEMA test procedures.
 9. Limiters completely enclosed in a molded case with built-in trip indicator.
 10. Limiters fully coordinated with MCP such that protector clears all low-level faults without limiter reacting and on high faults, opens all three phases if limiter operates.
 11. Select ratings to provide complete protection of, and coordination with, starter overload relays and heaters and comply with following:

- a. Verify motor horsepower.
 - b. Install ratings as required by the NEC for nameplate full load currents of the motors actually installed.
 - c. Furnish proof of coordination to the Owner.
- J. Motor Starters:
- 1. Type, rating and features:
 - a. Magnetic coil operated.
 - b. Horsepower rated.
 - c. Equipped with three overload elements.
 - d. Equipped with a fused epoxy encapsulated control power transformer for 120-volt pilot control.
 - 2. Starter coils suitable for 120 volts, single phase, and 60-Hz operation and having under voltage release.
 - 3. All controllers of combination MCP type.
 - 4. All combinations of motor size, fuse size, circuit breaker size, overload size and contactor size conforming to the National Electrical Code.
 - 5. Of following functional types as shown on the drawings:
 - a. Full voltage.
 - b. Single or two speed.
 - c. Reversing or non-reversing.
 - d. Reduced voltage, wye-delta.
 - 6. Reduced voltage, wye-delta starters to be closed transition type with all contactors fully rated to the starter size. Provide size No. 5 starter with all size No. 5 contactors.
 - 7. Minimum starter size, NEMA Size 1.
 - 8. Include a separate 480/120-control power transformer in the starter enclosure, as follows:
 - a. Dry type, 2 winding, epoxy encapsulated, and single-phase unit.
 - b. Having large enough capacity to furnish power to all equipment connected to it, including devices external to the starter, and having an additional 25 percent spare capacity.
 - c. Provide 2 primary legs fused and one secondary leg fused and the other grounded for each starter.
 - d. Primary leg fuses of Bussman Type FNQ or approved equal.
 - e. Secondary leg fuses of Bussman Type FRN or approved equal.
 - 9. Submit a list of loads on each control power transformer, with the MCC shop drawings.
 - 10. Where additional fusing of control circuits is indicated on the Drawings, coordinate all the fuses in each control circuit.
 - 11. Provide individual layout sketches and post unit wiring diagrams and copies of applicable overload heater tables inside each door or wireway.
 - 12. Furnish auxiliary devices and contacts for motor space heaters, remote status signals and interlocks as shown on the drawings, complete and wired to the terminal blocks in each controller enclosure.

- a. Provide minimum number of auxiliary contacts, as shown on the drawings, plus two spare normally open and two spare normally closed contacts.
- 13. Provide overload relays as follows:
 - a. Manually reset from outside the enclosure by means of an insulated bar or button.
 - b. Of the bimetallic, ambient compensating type.
 - c. Use standard heater elements selected for actual motor nameplate full load amps.
 - d. Do not use on starters used only as contactors.
- K. Pilot Control Devices:
 - 1. Pushbuttons and Selector Switches:
 - a. Type: Round, heavy duty oil tight, NEMA A300 of Allen-Bradley Bulletin 800T, General Electric Type CR104, Square D Type K, Cutler-Hammer Type 10250 T, 30 mm size or equal.
 - b. Operator Legend Plates: Custom lettered, jumbo size as designated on the Drawings.
 - c. All pushbutton switches having full guard and button color to match associated indicating light.
 - d. Contact Blocks: Heavy-duty type.
 - e. Screw terminals for wire connections.
 - 2. Pilot Lights:
 - a. Indicating lights, LED having 100,000 hours half-life, 120V ac, R. Stahl Inc., Type 8415, or approved equal.
 - b. Lens color as shown on the Drawings.
 - 3. Relays:
 - a. All relays sized for the load conditions specified.
 - b. Coil Voltages: 120V ac.
 - c. Light duty relays:
 - (1) General-purpose plug-in type mounted on heavy-duty sockets, of Potter Brumfield, Type KUP14A35 or equal.
 - (2) Built-in neon indicating lamp.
 - (3) Relay sockets having barrier protected screw terminals.
 - d. Heavy duty relays:
 - (1) For motor control circuits and similar duty, use Allen-Bradley Bulletin 700 Type N, Square D Class 8501 Type GO-40, or equal.
 - (2) Having 10-ampere rated 300V ac convertible contacts.
 - e. Time delay relays:
 - (1) Pneumatic type with calibrated dial adjustment, of Agastat Series 7000 Pneumatic, or equal.
 - (2) Having heavy-duty convertible contacts.
 - 4. Provide timers as follows:
 - a. Adjustable, with range as shown on the Drawings.
 - b. On or off delay.
 - c. Power input: 120V ac.

- d. Contact rating: Compatible with current of devices simultaneously operated by contact.
 - e. Plug-in type mounted on heavy-duty octal sockets with barrier protected screw terminals.
- 5. Elapsed Time Meters:
 - a. Power input: 120V ac.
 - b. Size: 3-1/3-inch square.
 - c. Nonreset Type.
 - d. Display: 99,999.9 hours.
- L. Transient Voltage Surge Suppression: Provide transient voltage surge suppression devices as shown on Drawings and in accordance with Section 16289, Transient Voltage Suppression.
- M. Meters and Instrument Transformers:
 - 1. Provide instrument transformers according to IEEE C57.13 and the following:
 - a. Potential Transformers: Secondary-voltage rating of 120V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.
 - b. Current Transformers: Ratios as indicated; burden and accuracy class suitable for connected relays, meters, and instruments.
 - c. Control-Power Transformers: Dry type, mounted in separate compartments.
 - 2. Power Circuit Monitoring, Metering, Communication, and Control System:
 - a. Provide standard monitoring and display device of the manufacturer.
- N. Provide wiring to comply with following:
 - 1. Conductor size suitable for loads and insulation.
 - 2. Insulation to be Types SIS, MTW or THWN.
 - 3. Color-coded as follows:
 - a. For ac control:
 - (1) Red.
 - (2) Or as recommended by the manufacturer.
 - b. For Power: Black.
 - 4. All wiring and cable, identified at all terminations by Brady or T&B wire markers or equivalent.
 - a. Use inscribed plastic sleeve type wire markers.
 - b. Indicate circuit numbers, terminal numbers, wire numbers, etc., for each conductor.
 - 5. Terminate with heavy-duty, long ferrule, wire insulating crimp-type terminals having maximum two terminals per terminal screw where pressure type terminals are not provided.
 - 6. Tie internal and external wiring with separate close ties.
 - 7. Regularly fasten and support wiring in vertical wireways.
 - 8. Use minimum No. 14 AWG stranded wires for control wiring.

9. Wire all spare starter auxiliary contacts to terminal strips:
 - a. Provide one set of the two spare normally open and normally closed contacts for each starter.
 - b. Wire these contacts to a common terminal strip for future connection.
 10. Provide incoming and outgoing cable size and location as indicated on the Drawings.
- O. Provide nameplates as follows:
1. Black laminated nameplates with engraved white letters and beveled edge, for each unit compartment door.
 - a. Use nameplate descriptions as determined and approved under the shop drawing submittal.
 2. One large, laminated identification plate:
 - a. To identify the MCC by large letters.
 - b. With following inscribed below in smaller letters and blanks filled in as applicable:
 - (1) 480 volts, 3-phase, 4-wire.
 - (2) Fed from _____ circuit _____.
 3. Manufacturer's nameplate providing information to identify the order, date of manufacture, etc.
 4. Exterior nameplates fastened by stainless-steel screws.
 5. Small nameplate, decal, or similar marking, to identify each fuse block with its proper fuse rating.
 6. Small nameplate for each unit stating "This unit to be used in compartment _____" as previously specified under unit compartments.
- P. Provide MCC layouts as shown on the drawings. Obtain the Commission's approval for any deviations required by the manufacturer.

2.3 PAINTING

- A. Clean and shop prime all non-galvanized, non-stainless steel metal surfaces in accordance with Section 09900, Painting and Coating.
- B. Use ANSI 61 light gray as the final exterior color for the MCC.

PART 3 EXECUTION

3.1 FACTORY TESTING

- A. The Commission reserves the right to witness all factory tests. The Commission reserves the right to back charge the manufacturer if a second trip is needed to witness equipment due to problems or errors in fabrication and engineering.
- B. Provide 2 weeks written notice to the Commission so arrangements can be made to witness tests.

- C. Motor control centers shall have been tested in a high-power laboratory to prove adequate mechanical and electrical capabilities.
- D. All factory tests required by the latest ANSI, NEMA and UL standards shall be performed.
- E. A certified test report of all standard production tests shall be provided to the Owner.
- F. Provide three copies of the final factory inspection tests to the Commission.
- G. MCCs:
 - 1. Visual and Mechanical Inspection:
 - a. Inspect for physical damage.
 - (1) If visual inspection reveals MCC damage, broken bushings, inoperative breakers, or switches; conduct internal inspections and tests as necessary to locate the damage.
 - (2) Submit a detailed report to the Commission. Identify the damage, cause of the damage, and corrective measures taken to assure the Commission of the quality of the MCC.
 - b. Compare equipment nameplate information with latest one-line diagram and record/report discrepancies.
 - c. Verify proper device operation such as breakers, starters MCPs, and indicators.
 - 2. Electrical Tests:
 - a. Check automatic operation of breakers, starters and MCPs for close and trip operation from protective relays and operators.

3.2 INSTALLATION

- A. Install the MCCs and appurtenances in accordance with the instructions of the manufacturer and in accordance with the Contract Documents.
- B. Moving of Units: Use qualified riggers experienced in handling large equipment to move the MCCs.
- C. Connections: Set MCC assemblies in place and connect as shown on the approved shop drawings and in accordance with manufacturer's written instructions.

3.3 FIELD PAINTING

- A. Prepare and paint required surfaces as specified in Section 09900, Painting and Coating.

3.4 FIELD QUALITY CONTROL AND TESTING

- A. Perform field inspection and testing in accordance with Section 16950, Testing.

- B. Provide the services of a qualified factory-trained manufacturer's representative to assist the contractor in installation and startup of the equipment specified under this section. The manufacturer's representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained therein.
- C. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative:
 - 1. Rig the MCC assembly into final location and install on level surface.
 - 2. Check all removable cells and starter units for easy removal and insertion.
 - 3. Perform insulation tests on each phase and verify low-resistance ground connection on ground bus.
 - 4. Connect all power wiring and control wiring and verify basic operation of each starter from control power source.
 - 5. Torque all bolted connections made in the field and verify all factory bolted connections.
 - 6. Calibrate any solid-state metering or control relays for their intended purpose and make written notations of adjustments on record drawings. Perform startup of any solid-state starters and adjustable frequency drives
- D. Adjusting and Cleaning: Adjust operating mechanisms for free mechanical movement.
- E. Grounding
 - 1. Provide equipment grounding in accordance with Section 16450, Grounding.
 - 2. Tighten connections to comply with tightening torques specified by the manufacturers and UL Standard 486A to assure permanent and effective grounding.
- F. The Contractor shall perform field adjustments of the short circuit and overload devices as required to place the equipment in final operating condition. The settings shall be in accordance with the approved short-circuit study, protective device evaluation study, protective device coordination study, manufacturer's instruction leaflets, and the contract documents.
- G. Contractor is responsible for generation of a field report on tests performed, test values experienced, etc., and make the report available to the Commission.
- H. The Contractor shall provide three (3) copies of the manufacturer's field startup report to the Commission.

3.5 MANUFACTURER'S FIELD SERVICES

- A. Provide services in accordance with Section 01640, Manufacturers' Field Services. Manufacturer's field services shall respond to the Commission's request for correction of problems during startup and warranty period within 4 hours.

3.6 MANUFACTURER'S CERTIFICATION

- A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations. Equipment shall be inspected prior to the generation of any reports.
- B. The Contractor shall provide three (3) copies of the manufacturer's representative's certification report to the Commission.
- C. Training
 - 1. Provide training to instruct representatives of the Commission as follows:
 - a. MCCs: 3 hours.

END OF SECTION

SECTION 16500 LIGHTING FIXTURES

PART 1 GENERAL

1.1 DESCRIPTION

- A. Work Included
 - 1. Furnish all labor and materials to complete lighting fixture installation and associated items indicated, specified herein or both. Fixtures of size and type specified herein shall be supplied, installed, and connected for each fixture indicated on the Drawings.

1.2 QUALITY ASSURANCE

- A. Regulations, Standards and Publications
 - 1. FM Factory Mutual Engineering Corp.
 - 2. NEC National Electrical Code of National Fire Protection Association
 - 3. NFPA 70E Standard for Electrical Safety in the Workplace
 - 4. UL Underwriters' Laboratories
- B. Fixtures shall be CSA certified to US and Canadian standards.
- C. Where appropriate fixtures shall be UL listed for hazardous and severe environments.
- D. All fixtures shall meet all Federal, State, and local required criteria.
- E. All light fixtures shall be mounted in accordance with manufacturer's recommendations.
- F. LED drivers shall be Electrical Testing Laboratories, Inc. (E.T.L.) - Certified Ballast Manufacturers Association (C.B.M.) certified.
- G. The installation must comply with the amended National Electrical Code of the National Fire Protection Association.

1.3 QUALIFICATION

- A. When more than one name of manufacturer of fixture is listed in these specifications, the first manufacturer and number determine the style and quality.

1.4 SUBMITTALS

- A. Shop Drawings
 - 1. Submit manufacturer's latest publication of each fixture, including ballast information, construction details, light distribution details and/or coefficients.

PART 2 PRODUCTS

2.1 MATERIALS

A. LED Drivers

1. LED light driver shall be of high efficiency.
2. LED light driver shall allow continued operation of all other LEDs in the event of an LED failure.

B. Light Fixture Schedule

1. SA: Ceiling mounted, 120-volt, high efficiency LED, nominal 8" x 4', totally enclosed gasketed fixture suitable for wet locations. Fixture shall be provided with an electronic driver. Fixture shall produce a minimum of 4,000 initial lumens and have a color temperature of less than or equal to 4,100K. Housing shall be one-piece high impact plastic to provide durability and corrosion resistance. The lens shall be one-piece deep clear polycarbonate, resistant to damage. Fixture shall have plastic latches to apply positive, uniform pressure on the gaskets to seal against dust and moisture. Provide gasketed conduit hubs. Fixture shall be Holophane #EMS L48 4000LM IMAFL WD MVOLT GZ10 40K 80CRI-WLFEND2 or Lithonia #FEM-L48-6000LM-IMACD-MD-MVOLT-40K-80CRI-WLFEND2.
2. WA: Wall mounted, 120 volt, high efficiency LED fixture. The fixture housing shall be constructed of die-cast copper-free aluminum with powder coated finish. Fixture shall have a glass lens and photoelectric control, and shall be furnished with the terminal block option. Fixture shall be Holophane #TWR1 LED ALO SWW2 UVOLT PE DDBTXD.

PART 3 EXECUTION

3.1 INSTALLATION

A. Installation

1. Contractor shall furnish supports for light fixtures. Light 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 overhead structural members, independently from the ceiling system.
2. The fixture manufacturer's catalog numbers describing the various types of fixtures shall be used as a guide only and do not include all the required accessories or hardware that may be required for a complete installation. The Contractor shall be responsible for furnishing, at no additional cost to the Owner, all the required accessories and hardware for a complete installation.
3. All inoperable lamps shall be replaced with new lamps during the course of construction, up to and including the date of final acceptance by the Owner and Engineer.

END OF SECTION

SECTION 16530
BATTERY EMERGENCY LIGHTING UNITS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Work Included:
 - 1. Furnish, install and connect a complete system of conduits, conductors, unit type battery emergency lighting units and all other materials and equipment necessary for the installation of an emergency lighting system.
 - 2. Provide manufacturer specified for each fixture type. Substitutes will not be accepted without approval prior to the bid.

1.2 QUALITY ASSURANCE

- A. Regulations, Standards and Publications:
 - 1. FM Factory Mutual Engineering Corp.
 - 2. NEC National Electrical Code of National Fire Protection Association
 - 3. UL Underwriters' Laboratories
- B. Qualification:
 - 1. The complete system shall be of a type, which has been in satisfactory service for at least one year under automatic emergency lighting conditions.
 - 2. When more than one name of manufacturer of fixture is listed in these specifications, the first manufacturer and number determine the style and quality.

1.3 SUBMITTALS

- A. Shop Drawings:
 - 1. Submit manufacturer's latest publication of the following:
 - a. Battery Unit
 - b. Fixed Heads
 - c. Combination Battery Unit/Exit Fixtures

PART 2 PRODUCTS

2.1 MATERIALS

- A. Combination Battery Unit/Exit Fixtures:
 - 1. EA: Combination exit fixture/battery emergency light fixtures shall be back mounted, single-faced with red high intensity LED lamps and sealed nickel cadmium battery. The fixture housing shall be white polycarbonate. The exit fixtures shall operate on 120 VAC power. Fixture shall be Holophane #: ECC B R, or equal.

PART 3 EXECUTION

3.1 INSTALLATION

A. Battery Unit:

1. Battery units shall be firmly fastened to walls. Mounting height to be determined in field.

B. Wiring:

1. Wiring on low voltage side of unit shall be no smaller than #10.
2. Connect battery emergency lighting units and exit fixtures to lighting circuit for area being protected ahead of all local control switches.

END OF SECTION

SECTION 16700 INSTRUMENTATION

PART 1 GENERAL

1.1 DESCRIPTION

- A. Work Included
 - 1. Furnish and install all instrumentation and provide services as specified herein or as indicated on the Drawings.

1.2 QUALITY ASSURANCE

- A. Regulations and Standards
 - 1. UL Underwriters' Laboratories
 - 2. NEC National Electrical Code
 - 3. NEMA National Electrical Manufacturers Association
 - 4. ANSI American National Standards Institute
 - 5. IEEE Institute of Electrical and Electronic Engineers
 - 6. ISA Instrument Society of America
 - 7.
- B. All instrumentation equipment supplied shall be of the most current and proven design. Specifications and drawings call attention to certain features but do not purport to cover all details entering into the design of the instrumentation equipment.
- C. All necessary fuses and cables required for instrumentation equipment shall be provided with the equipment.

1.3 SUBMITTALS

- A. Shop Drawings
 - 1. Submit shop drawings on all instrumentation in accordance with the requirements of Section 01330. Shop drawings shall be complete in all respects and shall indicate all dimensions, installation methods, size, weight, capacity, ratings, integral controls and types of materials, elevations, and sections. Submittals shall include a complete bill of material, catalog information, descriptive literature of all components and wiring diagrams.

PART 2 PRODUCTS

2.1 MAGNETIC FLOW METERS

- A. Flow meter shall meet the requirements of AWWA C751-2019 and components in contact with the potable water shall meet the requirements of NST/ANSI/CAN 61-2023 and the Safe Drinking Water Act (SDWA).

- B. Magnetic flow meters shall be of the low frequency and short form characterized coil design. The characterized field principle of electro-magnetic induction shall produce a positive DC pulsed signal directly and linearly proportional to the flow rate.
- C. The meter body shall be carbon steel. The flow meter shall have a flanged body to fit between ANSI Class 150 pipe flanges. The flow meter shall have a polyurethane liner and Type 316 stainless steel electrodes. The electrodes shall be flush mounted type. Liners and electrodes shall be suitable for potable water. Provide all required mounting hardware, stainless steel grounding rings and grounding straps for the installation of the magnetic flow meter.
- D. The coils, which generate the field, shall be inside the pipe wall and shall be encapsulated in epoxy resin and encased behind the meter lining material. The ratio of flow velocity to reference voltage signals generated shall be compatible with the readout instrument without the necessity of circuit modifications. The meter shall have an average power consumption of 60 watts. Accuracy of the meter shall be $\pm 0.5\%$ of rate.
- E. The meter housing shall be splash-proof and weather resistant design. The meter shall be capable of accidental submergence in up to 30 feet of water for up to 48 hours without damage to the electronics.
- F. The meter shall be hydraulically calibrated at the manufacturer's calibration facility against a master meter, which is traceable to the National Bureau of Standards. Calibration curves shall be submitted for each flow meter for 3 points within the specified flow range.
- G. Complete zero stability shall be inherent characteristic of the meter system. This shall eliminate the requirement for valving downstream of the meter for creating a full pipe zero flow condition for calibration purposes. Meter systems requiring field zero adjustment will not be acceptable.
- H. The flow meter shall have a remote mounted microprocessor based, NEMA 4X signal converter. The signal converter shall have an LCD display to indicate the flow rate. The signal converter shall convert the meter's DC pulsed signal to a linear 4-20mA dc signal which is proportional to the flow rate. The converter shall operate on a 120V AC, 60 Hz power source and shall have RFI protection. Provide a signal cable to connect the signal converter to the flow meter. Length of cable shall be as required for the installation (See Electrical Drawings).
- I. The Magnetic Flow Meters shall be Endress & Hauser Promag W 400, Toshiba GF642, or equal.

SCHEDULE OF MAGNETIC FLOW METERS

SIZE	FLOW RANGE	LOCATION	SERVICE
1"	2.5 to 80 gpm	Well House	Potable water flow
6"	90 to 2,650 gpm	Well House	Potable water high flow

2.2 PRESSURE TRANSMITTERS:

- A. The components in contact with the potable water shall meet the requirements of NST/ANSI/CAN 61-2023 and the Safe Drinking Water Act (SDWA).
- B. The pressure transmitters shall be a single chamber capacitance type electronic transmitter, which shall produce a linear current output signal proportional to the gage pressure.
- C. The process connection shall be 1/4" NPT female and shall be 316L stainless steel. The transmitter shall have a ceramic process isolating diaphragm.
- D. The transmitter shall have a continuous 100 to 1 span adjustment. Reference accuracy shall be $\pm 0.05\%$ of span.
- E. Zero and span adjustment shall be electronic by means of zero and span buttons.
- F. Process temperature limits shall be -13 to +257°F. The temperature limits for the electronics shall be -4 to +158°F. Humidity limits shall be 0-100% relative humidity.
- G. The transmitter shall be a true 2-wire device with 24-volt DC power being derived from the control panel power supply. The electronic unit shall be of modular plug-in design utilizing integrated circuitry. The transmitter output shall be a linear 4-20mA dc signal with superimposed HART protocol.
- H. The range of the pressure transmitter shall be as indicated on the schedule below.
- I. The transmitter electronics housing shall be constructed of die cast aluminum with a polyurethane coating. The transmitter housing shall meet NEMA 4X requirements. The electrical connection shall be a 1/2" NPT conduit thread.
- J. Each transmitter shall be furnished with a mounting bracket and stainless steel bolts suitable for wall mounting the transmitter.
- K. Provide a calibration data sheet for each pressure transmitter.
- L. The pressure transmitters shall be Endress & Hauser Cerabar S PMC71, or equal.

SCHEDULE

PRESSURE RANGE	LOCATION	SERVICE
0-150 psi	Well House	Potable water pressure

2.3 SUBMERSIBLE LEVEL TRANSDUCERS:

- A. The submersible level transducers shall be an industrial submersible pressure transducer submerged in well water to accurately sense the hydrostatic level. The transducer shall be furnished with an integral signal cable with a molded cable seal.
- B. The transducer shall have a weatherproof housing constructed of 316 stainless steel. The transducer shall have a 1.65" sensing area and an integral diaphragm protector.
- C. The transducer shall operate in a temperature range of -4° to 176° F.
- D. The transducer cable shall be a polyethylene jacketed shielded cable. Length of cable shall be as required for transducer installation. Provide a stainless-steel cable hanger to support the cable.
- E. The pressure transducer shall be a 2-wire device with dc power being provided from the 24vdc power supply in the control panel. The transducer shall output a 4-20mA dc signal proportional to the wet well level.
- F. The accuracy shall be $\pm 0.05\%$ full span from 23° to 122° F with a resolution of $\pm 0.005\%$ full span.
- G. The submersible level transducers shall be In-Situ Level Troll 400, or equal.

SCHEDULE

ELEVATION	PRESSURE RANGE	LOCATION	SERVICE
Approximately 230 ft bls.	0 - 100 psia	Well House	Well level

2.4 CHLORINE RESIDUAL ANALYZERS:

- A. Chlorine residual analyzers shall use colorimetric DPD chemistry to continuously monitor the sampled water for free or total residual chlorine. The analyzer shall use a DPD indicator and a buffer solution.
- B. The analyzer shall be capable of measuring free or total residual chlorine by changing the indicator and buffer solutions.

- C. The analyzer shall take a measurement every 2.5 minutes and the results shall be displayed on a three-digit LCD readout in the range of 0-5 mg/l.
- D. The analyzer shall be designed for 30 days of unattended operation and shall use only 473 mL of each reagent per month.
- E. The analyzer shall operate with an LED light source with a peak wavelength of 520 nm.
- F. The analyzer shall measure a sample blank before each sample measurement to provide automatic zero reference to compensate for sample color and turbidity, and changes in light intensity due to voltage fluctuations or light source aging.
- G. The analyzer shall provide a minimum detection limit of 0.035 mg/L; precision of $\pm 5\%$ or 0.005 mg/L as Chlorine, whichever is greater; and an accuracy of $\pm 5\%$ or 0.035 mg/L as Chlorine, whichever is greater.
- H. The analyzer shall be furnished with a sample inlet fitting and a drain fitting.
- I. The analyzer shall be microprocessor controlled and shall be housed in an ABS plastic enclosure designed for wall mounting. The enclosure shall have two clear polycarbonate windows for viewing the measurement readout and the reagent levels.
- J. The analyzer shall operate on 120 volts, 1 phase power and shall be furnished with a power cord.
- K. The analyzer shall output a 4-20mA dc signal proportional to the chlorine residual.
- L. The analyzer shall have two user-selectable relay output alarms which are selectable for sample concentration alarm, analyzer system warning, or analyzer system shutdown alarm.
- M. The chlorine residual analyzers shall be Hach Model CL17 Free Chlorine Residual Analyzers.

SCHEDULE

RANGE	LOCATION	SERVICE
0 – 4.0 mg/L	Well House	Potable water

2.5 PH METERS:

- A. The pH meter shall consist of a pH sensor, a pH transmitter and interconnecting cable. The pH meter shall continuously monitor the pH of the water.

- B. The pH sensor shall have a ring-shaped PTFE diaphragm and fixed electrolyte. The pH sensor shall have a glass electrode and shall utilize Memosens technology. The pH sensor shall have a built-in temperature sensor.
- C. The pH transmitter shall be microprocessor-based and shall be housed in a NEMA 4X polycarbonate enclosure suitable for wall mounting. The transmitter shall have a two-line display to simultaneously display the pH and the temperature.
- D. The transmitter shall have a pH range of -2 to 16.
- E. The transmitter shall have a resolution of 0.01 pH, and an accuracy of $\pm 0.5\%$ of range.
- F. The transmitter shall operate on 120 volts, 1 phase power.
- G. The transmitter shall output a 4-20mA dc signal proportional to the measured pH.
- H. The pH meter shall be Hach.

SCHEDULE

RANGE	LOCATION	SERVICE
3.0 – 10.0	Well House	Potable water

2.6 NAMEPLATES

- A. Provide a laminated phenolic nameplate for each instrument. The nameplates shall be black with white engraved letters, and they shall be mounted on the front of each instrument or instrument enclosure, or where applicable attached to the instrument with a plastic wire tie. An instrument nameplate schedule shall be submitted to the Engineer for approval prior to performing any engraving.

PART 3 EXECUTION

3.1 INSTALLATION ASSISTANCE AND INSPECTION

- A. Provide the services of manufacturer's service representatives to assist in installation for all instrumentation specified herein.
- B. Each manufacturer's representative shall inspect the installation of each of their instruments and shall issue an installation certificate to the Owner and the Engineer for each instrument certifying that the instrument has been installed in accordance with the manufacturer's recommendations.

3.2 CALIBRATION

- A. Provide the services of manufacturer's service representatives to calibrate all instrumentation provided. All calibration shall be performed in the presence of the Engineer. The calibration of each instrument shall be performed after the instrument installation certificate has been issued.
- B. Each manufacturer's representative shall issue a calibration certificate to the Engineer for each instrument certifying that the instrument has been calibrated and is ready to be placed into service. The calibration certificates shall indicate the calibrated range or setpoint for each instrument.

3.3 TRAINING

- A. Provide four (4) hours of training on the instrumentation provided.
- B. All training shall be performed by a representative from the manufacturer and shall be specific to the instruments provided. Training shall include theory of operation, maintenance requirements, calibration methods and function of instrument in the Process Control System.

END OF SECTION

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SECTION 16710
WELL HOUSE BUILDING PLC
INPUT/OUTPUT LIST

PART 1 GENERAL

1.1 DESCRIPTION

- A. Work Included:
 - 1. The Input/Output (I/O) list for the Well House Building PLC is included in this section.
- B. I/O Type Abbreviations:
 - 1. DI - Digital Input
 - 2. AI - Analog Input

PART 2 PRODUCTS
NOT USED

PART 3 EXECUTION
NOT USED

PART 4 SCHEDULES

4.1 I/O LIST

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Device I/O TAG	P&ID Tagname	HMI/PLC Tagname	Description	Signal	Field 1 (Energized if a DI or DO)	Field 2 (De-Energized if a DI or DO)	P&ID	LOOP	PLC	I/O	Base	Slot	Point	Enclosure
PWP-1	HOR-XXX		Well Pump No. 1 (PWP-1) - HOR Switch	DI	Remote	Off/Hand								Well House CP
PWP-1	MC-XXX		Well Pump No. 1 (PWP-1) - Control Motor	DO	Start	Stop								Well House CP
PWP-1	MN-XXX		Well Pump No. 1 (PWP-1) - Run Status	DI	Running	Off								Well House CP
PWP-1	MF-OL-XXX		Well Pump No. 1 (PWP-1) - Starter Overload	DI	Normal	Fail								Well House CP
HFWP	HOR-XXX		High Flow Well Pump (HFWP) - HOR Switch	DI	Remote	Off/Hand								Well House CP
HFWP	VC-XXX		High Flow Well Pump (HFWP) - Control VFD	DO	Start	Stop								Well House CP
HFWP	VSC-XXX		High Flow Well Pump (HFWP) - Control Speed	AO	0 % (4 mA)	100 % (20 mA)								Well House CP
HFWP	VSI-XXX		High Flow Well Pump (HFWP) - Speed Indication	AI	0 % (4 mA)	100 % (20 mA)								Well House CP

Device I/O TAG	P&ID Tagname	HMI/PLC Tagname	Description	Signal	Field 1 (Energized if a DI or DO)	Field 2 (De-Energized if a DI or DO)	P&ID	LOOP	PLC	I/O	Base	Slot	Point	Enclosure
HFWP	MN-XXX		High Flow Well Pump (HFWP) - Run Status	DI	Running	Off								Well House CP
HFWP	VF-XXX		High Flow Well Pump (HFWP) - VFD Failure	DI	Normal	Fail								Well House CP
AIT-XXX	AIT-XXX		Potable Water (AIT-XXX) - Chlorine Residual	AI	0 mg/l (4 mA)	20 mg/l (20 mA)								Well House CP
AIT-XXX	AIT-XXX		Potable Water (AIT-XXX) - pH	AI	0 pH (4 mA)	14 pH (20 mA)								Well House CP
FIT-XXX	FIT-XXX		Potable Water (FIT-XXX) - Low Flow Rate	AI	0 GPM (4 mA)	XXX GPM (20 mA)								Well House CP
FIT-XXX	FIT-XXX		Potable Water (FIT-XXX) - High Flow Rate	AI	0 GPM (4 mA)	XXX GPM (20 mA)								Well House CP
CFP-XXX	CFP-XXX		Potable Water Chlorine (CFP-XXX) - Dosing Rate	AO	0 % (4 mA)	100 % (20 mA)								Well House CP
CFP-XXX	CFP-XXX		Hypochlorite Feed Pump (CFP-XXX) - Control Motor	DO	Start	Stop								

Device I/O TAG	P&ID Tagname	HMI/PLC Tagname	Description	Signal	Field 1 (Energized if a DI or DO)	Field 2 (De-Energized if a DI or DO)	P&ID	LOOP	PLC	I/O	Base	Slot	Point	Enclosure
PIT-XXX	PIT-XXX		Potable Water (PIT-XXX) - Pressure	AI	0 PSI (4 mA)	XXX PSI (20mA)								Well House CP
LIT-XXX	LIT-XXX		Well (LIT-XXX) - Level	AI	XXX BLS (4 mA)	XXX BLS 20 mA)								Well House CP
MCC-W	JF-XXX		MCC (MCC-W) - Power Status	DI	Normal	Fail								Well House CP
MCC-W	JL-XXX		MCC (MCC-W) - Power Usage	AI	0 KW (4 mA)	XXX KW (20 mA)								Well House CP
MCC-W	JK-XXX		MCC (MCC-W) - Surge Protector	DI	Normal	Fail								Well House CP
WH-PCP	JF-XXX		Pump Control Panel (WH-PCP) - Power Status	DI	Normal	Fail								Well House CP
WH-PCP	JK-XXX		Pump Control Panel (WH-PCP) - Surge Protector	DI	Normal	Fail								Well House CP
WH-PCP	JF-DC-XXX1		Pump Control Panel (WH-PCP) - Power Supply 1	DI	Normal	Fail								Well House CP
WH-PCP	JF-DC-XXX2		Pump Control Panel (WH-PCP) - Power Supply 2	DI	Normal	Fail								Well House CP

Device I/O TAG	P&ID Tagname	HMI/PLC Tagname	Description	Signal	Field 1 (Energized if a DI or DO)	Field 2 (De-Energized if a DI or DO)	P&ID	LOOP	PLC	I/O	Base	Slot	Point	Enclosure
WH-PCP	JF-UPS-XXX		Pump Control Panel (WH-PCP) - UPS Status	DI	Normal	Fail								Well House CP
WH-PCP	JBL-UPS-XXX		Pump Control Panel (WH-PCP) - Batteries	DI	Normal	Replace								Well House CP
WH-PCP	JB-UPS-XXX		Pump Control Panel (WH-PCP) - UPS	DI	On Utility	On UPS								Well House CP

END OF SECTION

SECTION 16900
DPCS CONTROL PANEL AND TESTING

PART 1 GENERAL

1.1 DESCRIPTION

- A. Section Includes: Requirements for installing and testing Commission furnished Distributed Process Control System (DPCS) Input/Output (I/O) Panels, and/or modifications to existing Distributed Process Control I/O System Panels as indicated. DPCS panels that do not include a programmable logic controller (PLC) are referred as Remote Input/Output (RIO) panels.
- B. Provides requirements for materials and installing of Contractor furnished DPCS system equipment and communication cables.

1.2 QUALITY ASSURANCE

- A. Work: Follow approved trade practices, manufacturers' recommendations, and applicable federal, local, and state codes.
 - 1. Instruments and control hardware associated with panels: Properly installed, wired, and tested at the shop and be suitable for operation.
 - 2. Contract Documents are intended to show and define panel design, fabrication, and installation.
- B. Equipment.
 - 1. Install following manufacturers' recommendations using installation manuals for guidance and for details not shown on Drawings.
 - 2. Provide for protection, insurance, and proper storage.
 - 3. Signals received from the field at DPCS monitoring control panel shall be made fully integrated and of the same type throughout circuit.
 - 4. Conduit connections/penetrations to cabinet: Located at side of cabinet as close to the bottom as possible; or bottom of cabinet as close to the fixed sides as possible.
 - a. Connections shall not interfere with installation of the backplane or operation of the door.
 - b. Connections to the top or back of cabinet: Not permitted without prior approval from the Commission.
 - c. Continuously protect and cover equipment from metal shards, dust, debris, and moisture.
 - d. Submit penetration detail or mark indelibly on panel the penetration locations for field acceptance.
- C. Elementary circuit diagrams shown on panel drawings illustrate some electrical schematics for major equipment associated with panels. These schematics are to be considered typical for equipment furnished.
 - 1. Provide technical support and integration services necessary to;

- a. Interface to panels.
 - b. Prepare wiring schematics for equipment.
 - c. Provide interconnections.
 - d. Make panels completely and permanently operational.
2. Furnish changes resulting from deviations from typical schematics, at no increase in scope or cost.
3. Upon request, Engineer will provide shop drawings of equipment supplied by Commission, for use in design of panels and any necessary equipment interface.

1.3 SUBMITTALS

- A. Submit the following in accordance with Section 01330.
 1. Record drawings for panels and enclosures, which have been wired.
 2. As-shipped panel drawings, for as-built purposes.
 3. Coordinate with point-to-point wiring documentation showing at a minimum:
 - a. Wiring between I/O panel interface terminal strip, including terminal and wire numbers for all wiring to the field device.
 - b. Communication cable wiring and interconnections.
 - c. Power connections to PLC/Remote I/O enclosures and other devices.
 - d. Final as-built drawings.
 4. Evidence of qualifications and experience (minimum of five years) for Fiber-Optic Specialty Contractor in areas of installation, termination, and testing of fiber-optic cable systems.
 5. Manufacturer's installation guideline documents for fiber optic cable and all fiber optic accessories.
 - a. Fiber optic cable must be installed within 3 years of its manufactured date.
- B. Submit the following in accordance with Section 01450.
 1. Test results for review and approval prior to commissioning the cable.
 - a. Certified calibrated Optical Time Domain Reflectometer (OTDR) for Fiber-optic test results for each stand of fiber.
 - (1) OTDR calibration certification must be within one year of the actual field test.
 - (2) Use a 500' minimum launch and receiver fiber optic cables.
 - (3) Format (connector pair to connector pair) so that each strand of fiber can be identified when reviewing results.
 - (4) Report loss in dB/km between connectors and dB loss across each connector and show OTDR graphs.
 - (5) Provide OTDR result files per each submission.
 - b. OTDR manufacturer's guidelines for performing OTDR testing and sample test results prior to testing.

2. Developed system test check sheet for Engineers approval.
 - a. Include check box to be initialed by Contractor and Engineer for each I/O point tested as outlined herein.

PART 2 PRODUCTS

2.1 GENERAL

- A. Provide Ancillary equipment, such as termination strips, interface hardware, wiring, cabling, intrinsically safe barriers, and accessories, that are necessary to provide a completely operational interface between the process control system panels to MCC, instrumentation, and all other field control panels.
 1. Do not mount this Ancillary equipment in the Commissioned furnished DPCS panels.
- B. Provide components as shown and/or as specified.
- C. Furnish necessary accessories such as instrument loop power supplies, mounting hardware, terminal blocks, control circuit breakers, and other items which may be required to complete the system.
- D. Analog signals received from field at panels: 4-20 mA DC signals.
 1. Furnish signal conversion necessary for compatibility with panel mounted instruments and interface to digital process control system.
- E. Provide control components such as relays, timers and other equipment necessary to provide the interfacing and/or interlocking required between motor starter and associated protective circuits, or other type of control circuit function applicable to a particular final control element, pre-mounted and wired in applicable panel. All Emergency Stop and other alarm Inputs shall be wired Failed-Safe (normally closed), where the de-energized circuit represents an alarm.
- F. DPCS Wiring Identification.
 1. Identify and label I/O field wiring originating from process control enclosure to field device and/or equipment throughout.
 2. Alphanumeric wire identification: Derived from base/slot/point position where wire is connected.
 3. Base/slot/point positions are identified at terminal within DPCS enclosure and/or on as-shipped panel drawings provided.

2.2 MATERIALS

- A. Electrical Wiring
 1. Solid wire used for AC circuits is not acceptable for use in DPCS enclosures and may not be used in power, instrumentation, or I/O circuits connected to DPCS enclosures
 2. Power wiring: CU stranded THHN, 600 volts.
 - a. 120 VAC circuits:

- (1) Line - BLACK
 - (2) Neutral - WHITE
 - (3) Ground - GREEN
 - (4) Minimum 12 AWG
- b. 24VDC circuits:
 - (1) Line - BLUE
 - (2) DC Common - BLUE WITH WHITE STRIPE
 - (3) Minimum 14 AWG
- 3. Discrete Input Wiring (120 VAC unless otherwise specified): CU stranded THHN, 300 V.
 - a. Signal - RED
 - b. Minimum 14 AWG
- 4. Discrete Output Wiring: CU stranded THHN, 300 V.
 - a. 120 VAC- RED, Minimum 14 AWG
 - b. 24 VDC- BLUE, Minimum 14 AWG
- 5. Analog Wiring: No. 18 AWG, twisted, shielded single pair, instrumentation cable designed for noise rejection for process control, computer, or data log applications and following NEMA WC 55. Belden 88760 or equal.
 - a. Outer Jacket: 45-mil nominal thickness.
 - b. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer overlapped for 100 percent coverage.
 - c. Dimension: 0.31-inch nominal OD.
 - d. Conductors:
 - (1) Bare soft annealed copper, Class B, 7-strand concentric, following ASTM B8.
 - (2) 7-strand tinned copper drain wire.
 - (3) Insulation: 15-mil nominal PVC.
 - (4) Jacket: 4-mil nominal nylon.
 - (5) Pair conductors: Color-code Red (+), Black (-).
- 6. CAT5E or CAT6 Cable: No. 24 AWG, Unshielded Twisted Pair (UTP) plenum rated and supports 100 Mbps fast Ethernet or faster.
- 7. Additional guidelines
 - a. Home runs from device's terminal blocks to DPCS panel's terminal blocks with no intermediate connections or splices unless specifically shown on plans.
 - b. Intended and designed for use with 24 VDC or less: Considered Low Voltage.
 - c. To prevent electrical interference and provide isolation from higher voltages, all Low Voltage wire: Installed in separated and dedicated rigid conduit or cable trays that provide segregation.

B. Fiber Optic Cable and Accessories.

- 1. Fiber lengths between fiber optic distribution (FOD) panels that run from building to building: Minimum of 12 conductors.
 - a. Approved manufacturers:

- (1) Draka, DXPCC Heavy Duty Chemical Resistant Cable
 - (2) Belden Tray Optic Heavy-Duty All Dielectric Cable, CPE Jacket
 2. Fiber lengths between interior FOD panels and installed in raceways: ezDistribution indoor/outdoor and tight buffer, minimum of 8 conductors; multimode = 6H; and fiber grade = M2
 - a. Approved manufacturer:
 - (1) Draka
 3. Fiber: 62.5/125 microns.
 4. Fiber optic cable connectors: Provide ST type pre-polished or fusion-spliced fan breakout kits. Mating losses not to exceed 0.75 dB per connection.
 5. Fiber optic patch cables: Duplex type with ST connectors.
 - a. No more than 2 meters of slack at either end or 3 meters total.
 - b. Only use soft Velcro tie wraps for securing patch cables.
 6. Fiber Optic Distribution Boxes (FOD):
 - a. Approved manufacturers
 - (1) Siecor.
 - (2) Corning.
 - (3) Or equal.
 7. Patch panel connectors mounted within FOD: ST type.
 8. Raceways for fiber optic cable: Heavy wall rigid galvanized steel.
 9. All other raceways, fittings, boxes and terminal cabinets: Follow Specification 16050.
- C. Wire Identification Labels: White polyolefin heat shrink type.
- D. Printed Labels: Produced using Brady Pro Plus marker printer or equal.
1. Signal Conditioners:
 - a. Analog current loop isolators, opto coupler, passive isolator and signal converter.
 - b. Approved manufacturers:
 - (1) Moore Industries.
 - (2) Weidmuller

PART 3 EXECUTION

3.1 GENERAL

- A. DPCS Wiring Identification:
1. Identify I/O field wiring originating from DPCS enclosure to field device and or equipment throughout as described hereafter.
 2. Derive alphanumeric wire identification from rack/slot/point position where wire is connected.
 3. Identify rack/slot/point positions at field terminal blocks within DPCS enclosure, field device and/or on as-shipped panel drawings provided.

- B. Analog Cables:
 - 1. Provide heat shrinkable sleeves over outer jacket of cable and conductors at cable termination points.
 - 2. Ground shield of cable at DPCS monitoring control panel only.

3.2 FIELD TESTING

- A. Fiber Optic Testing:
 - 1. OTDR on-reel test: Required after fiber cable is delivered to site and prior to installation of cable at WSSC facility. Results must be within 10% factory test from manufacturer.
 - a. Submit performance test data in report for approval.
 - 2. Perform OTDR test on each fiber conductor after fiber runs are installed. Submit performance test data and OTDR graphs and files in report for approval.
 - a. Performance test data:
 - (1) Connector mating losses not to exceed 0.75 dB per connector.
 - (2) Attenuation losses not to exceed 3.5 dB per kilometer.
 - b. Remove from site any Fiber Optic Cable that does not test satisfactorily.
 - c. Fiber Optic test must be inclusive of testing cumulative (dB) losses through patch panel connection, patch fiber, and dB/km loss for each fiber cable between connector pairs.
 - 3. Satisfactorily test each fiber optic cable member prior to connection at any point along network.
 - a. Terminate all fiber members within fiber-optic patch panels. Use FOD manufacturers' guidelines to install and secure fiber cable within box.
 - b. Identify both active and spare pairs at each termination point along network.
- B. Open Loop Testing
 - 1. General: The open loop test encompasses testing signaling from field devices, such as MCC drives, pumps, valves, instrumentation, and other controls/controllers connected to process control system PLC or RIO panels. It provides the ability to test a device's wiring prior to the RIO panel being made completely functional with the DPCS. Testing can be scheduled only after all devices within a given panel are completely wired, permanently terminated, and energized from permanent sources.
 - a. Conduct test after field conductors have been terminated and identified within process control system PLC or RIO panel and at field terminations.
 - b. Conduct test in presence of Engineer. Accomplish test prior to preliminary testing for equipment as outlined in Section 01450.

- c. Verify that equipment wiring, instrumentation, limit switches, drives, MCC, and other controls/controllers have been properly connected and calibrated.
- d. Develop system test document, including an I/O point list, and have approved by Engineer.
- e. Use approved system test document to record testing results for each loop.
- f. Connect field equipment to permanent power source and energize during test. Signals should not jumpered unless there is a safety or process reason.
- g. Deficiencies: Retest and correct prior to Close Loop testing

C. Conducting Open Loop Test:

- 1. For analog inputs, at field terminals using sourcing meter or using field device, induce a 4 to 20 mA DC signal.
 - a. Test signal at 0 percent, 50 percent, and 100 percent.
 - b. Observe and record the change of state at I/O module within DPCS PLC or RIO panel.
- 2. For digital inputs, operate field device or any equipment connected thereto or jumper applicable terminals at field device.
 - a. Observe and record the change of state at I/O module within DPCS PLC or RIO panel.
- 3. For analog outputs:
 - a. If control network has been successfully tested, PLC will induce signal.
 - (1) Test output at 0 percent, 50 percent, and 100 percent at terminals within the RIO enclosure to field device.
 - b. Otherwise, disconnect one associated loop wire or fuse from terminal within DPCS RIO panel and generate signal.
 - (1) Test output at 0 percent, 50 percent, and 100 percent.
 - c. Observe and record the change of state at I/O at field device.
- 4. For digital outputs:
 - a. If control network has been successfully tested, PLC will induce output signal.
 - b. Otherwise, jumper the signal at terminal within DPCS RIO panel.
 - c. Observe and record change of state at I/O at field device.

D. Prerequisite Requirements to Closed Loop Test:

- 1. Process control network must be successfully tested and made operational prior to closed loop testing.
- 2. Successfully calibrate field instrumentation, limit switches, MCC devices, VFDs, and ancillary field devices.
- 3. Submit calibration certification.
- 4. Verify field equipment is fully functional, powered, and made available to be controlled by PLC.
- 5. Notify Engineer 10 days before commencement of pre-final testing of equipment as outlined in section 01450.

6. For a given device or system, after Open Loop testing is complete, provide Engineer 5 days' notice before commencing Closed Loop Testing.
- E. Conducting Closed Loop Test:
1. Accomplish test with coordination between the Contractor operating equipment and Commission verification at DPCS monitoring control panel, servers, and or operator station(s).
 2. For analog inputs, induce by field device a 4 to 20 mA DC signal. Test signal at 0 percent, 50 percent, and 100 percent and observe at DPCS monitoring control panel, servers, and or operator station(s).
 3. For digital inputs, operate field device/contact to observe change of state at DPCS monitoring control panel, servers, and/or operator station(s).
 4. For analog outputs, induce a signal with a varying output. Test signal at 0 percent, 50 percent, and 100 percent from DPCS monitoring control panel, servers and or operator station(s) to field device and observe at equipment or field device.
 5. Digital outputs are a change of state initiated by the DPCS monitoring control panel, servers and or operator station(s).
 - a. Observe operation of equipment and/or device at both field and DPCS monitoring control panel, servers, and/or operator station(s).
- F. Final Testing:
1. For the purposes of control strategy proofing, 10 days prior to final testing as outlined in section 01450, Contractor will provide access and ability to operate equipment through the DPCS. This proofing may last up to 10 days.

END OF SECTION

SECTION 16910 CONTROL DESCRIPTION

I. SYSTEM DESCRIPTION

The existing potable water well is being replaced with a new Well House. Additionally, some of the water lines and connections to the treatment plant buildings are also being replaced.

The Distributed Process Control System (DPCS) HMI will be configured and programmed by the Owner. PLC and OIT programming will be by the Contractor. PLC programming will adhere to the following:

- All code is to be written in ladder logic. Any other code types (Sequential Function, Function Block, Structured Text, etc.) will not be accepted unless approved by Process Control Group.
- If using AB ControlLogix PLC, all Tags must be scoped at the Global/Controller level.
- Use the Process Control Group supplied abbreviation list for tag naming and I/O identification.
- Any code written that deliberately tries to overly complicate the program flow and readability will not be accepted.
- All PLC controllable field devices (i.e., if the device has at a minimum an HOA switch, open/start command, and feedback status) will have its own device in ladder. Common device logic that passes and receives I/O statuses is Not acceptable.
- It should be assumed that any PLC supplied will be integrated into the plant control system and customer permissives should be accommodated in logic.
- No software Remote / Local mode on OIT. There should be a mechanical HOA switch on front of control panel wired to PLC as input status.

A. WELL PUMPS

One Small constant speed well pumps will supply potable water to the treatment plant via two (2) hydropneumatics tanks and one of (2) water softeners. Hypochlorite will be introduced for disinfection prior to exiting the well house and entering the potable water distribution network. During periods of high flow, the Large variable speed well pump will be operational, the smaller well pump will cease operation, as well as the water softener.s, along with the hypochlorite system..

B. CHEMICAL FEED

The chlorine residual analyzer along with the (2) potable water flow transmitters will be used to regulate the speed of the sodium hypochlorite feed pumps to maintain a predetermined chlorine residual. There is a low flow meter and transmitter as well as a high flow meter and transmitter. Hypochlorite feed pump No. 1 will be paced from the small well pump flow and Hypochlorite feed pump No. 2 will be paced from the large well pump flow meter.

II. EQUIPMENT AND DESIGNATIONS

A. Well Pumps	Two (1 small flow and 1 large flow)
B. Residual Chlorine Analyzer	One
C. pH Analyzer	One
D. Magnetic Flow Meters	Two (1 low flow and 1 high flow)
E. Level Transmitter	One (well level)
F. Sodium Hypochlorite Feed Pump	Two (1 low flow and 1 high flow)

III. RELATED EQUIPMENT OPERATION

A. None

IV. POWER AND CONTROL CONFIGURATION

The Well House Control Panel will house the PLC that contains the control program.

Control and Monitoring will be available as follows:

CONTROL/INDICATION LOCATION	@ Equipment /Process	@ MCC	I/O to or from Well House CP
SMALL WELL PUMP			
Local-Off-Remote (LOR) Select		X	
Remote Status			DI
Start-Stop			DO
Run Status		X	DI
Starter Overload		X	DI
LARGE WELL PUMP			
Local-Off-Remote (LOR) Select		X	DI
Start-Stop		X	DO
Speed Control		X	AO
Speed Indication		X	AI
Run Status		X	DI
VFD Failure		X	DI
INSTRUMENTS AND ANALYZERS			
Well Level Transmitter			AI
Potable Water High & Low Flow Transmitters	X		AI's
Potable Water Pressure Transmitter	X		AI
pH Indicating Analyzer	X		AI

CONTROL/INDICATION LOCATION	@ Equipment /Process	@ MCC	I/O to or from Well House CP
Chlorine Residual Analyzer	X		AI
SODIUM HYPOCHLORITE FEED PUMP			
Local-Off-Remote (LOR) Select	X		
Speed Control			AO
POWER MONITORING			
Power Failure		X	AI
Power Indication		X	AI
Surge Protection Failure		X	DI
Control Panel			
Power Failure			
Surge Protection Failure			AI
Power Supply 1 Failure			DI
Power Supply 2 Failure			DI
UPS Failure			DI
UPS Battery Replacement			DI
On UPS			DI

A. POWER DISTRIBUTION

The small well pump will be powered from MCC-WH and the large well pump will be powered from a VFD also located in the Well House.

Small Well Pump Equipment Summary

The small well pump will be Full Voltage Non-Reversing (FVNR) starter. The motor starter will have provisions for locking out the motor in the de-energized state with the following controls and indications.

1. Control power transformer.
2. I/O blocks.
3. LOCAL-OFF-REMOTE (LOR) three position selector switch.
4. RUN and STOPPED indicating lights.
5. STARTER OVERLOAD indicating light and reset pushbutton.

Large Well Pump Equipment Summary

The large well pump will be on a Variable Speed Drive (VFD). The VFD will have provisions for locking out the motor in the de-energized state with the following controls and indications.

1. Control power transformer.
2. I/O blocks.
3. LOCAL-OFF-REMOTE (LOR) three position selector switch.
4. RUN and STOPPED indicating lights.
5. LCD/LED VFD status, control, and diagnostics display.

6. % speed control.
7. % speed indication.

Low Flow DPCS Input/Output Summary:

The following information at a minimum will be transmitted to the DPCS system from the motor starters:

1. LOR selector switch status.
2. Run status.
3. Starter Overload.

The DPCS system will transmit to the starters the following:

1. Start-Stop command.

High Flow DPCS Input/Output Summary:

The following information at a minimum will be transmitted to the DPCS system from the VFD:

2. LOR selector switch in AUTO.
3. Run status.
4. VFD failure.
5. % speed indication

The DPCS system will transmit to the VFD/bypass starters the following:

1. Operate at % speed.
2. Start-Stop command.

V. DESCRIPTION OF OPERATION

A. WELL PUMPS

Control Modes:

Each well pump can be operated locally at the Motor Control Center (MCC), Variable Frequency Drive (VFD), or through the Distributed Process Control System (DPCS). A LOCAL-OFF-REMOTE selector switch will be provided on the MCC motor starter bucket and on the VFD.

Each of the well pumps will have the following control modes:

Local/Manual Mode:

In Local mode, an operator will select the Local position from the LOCAL-OFF-REMOTE selector switch to run a well pump. The largewell pump will also allow an operator to adjust the speed of the pump from the front of the VFD. In the Off position, a well pump will not run. Local operations should only be used for testing and maintenance purposes.

DPCS Auto Low Flow Mode:

A well pump can only be operated in Auto Mode when the LOCAL-OFF-REMOTE switch is in the REMOTE position.

In software DPCS Auto, the small pump will operate when the potable water pressure drops below an operator-adjustable low pressure (initially set at 50 psi) and will shut off when the pressure increases to an operator-adjustable high pressure (initially set at 80 psi).

DPCS High Flow Mode:

High flow mode will be initiated when the potable water pressure drops to low-low pressure (initially set at 30 psi). The low flow pump will shutdown and the high flow pump will start with the speed adjusted to maintain a constant pressure (initially set at 80 psi). The pump will continue to run until the potable water flow drops to an operator adjustable flow (initially set at 100 gpm). The mode will then automatically switch back to low flow mode operation.

DPCS Manual Mode:

Not Used

Interlocks and Alarms:

Regardless of operating mode, a well pump will be shut down for any of the following abnormalities:

1. Motor overload
2. VFD failure.
3. High-high potable water pressure (initially set at 100 psi).

The DPCS will provide Alarms and Indications regardless of the operating mode:

1. Motor overload.
2. VFD failure.
3. Instrument or analyzer failure as indicated by an analog signal less than 4 mA
4. Potable water pressure high-high or low-low.
5. High flow pump operating.

B. SODIUM HYPOCHLORITE FEED PUMP

Control Modes:

The Sodium hypochlorite feed pumps can be operated locally at the pumps or through the DPCS. Operation of the pump locally will be through a graphical display on the pump.

Local/Manual Mode:

In Local mode, an operator can select Local operation through the graphical display and adjust the speed of the pumps.

DPCS Auto Mode:

In software DPCS Auto, pump No. 1 will be flow paced from the low flow transmitter with feedback trim from the residual chlorine analyzer. In software DPCS Auto, pump No. 2 will be flow paced from the high flow transmitter with feedback trim from the residual chlorine analyzer.

DPCS Manual Mode:

Not Used

Interlocks and Alarms:

Regardless of operating mode, the pump will be shut down for any of the following abnormalities:

1. None

The DPCS will provide Alarms and Indications regardless of the operating mode:

1. Low or high chlorine residual

END OF SECTION

SECTION 16920 CONTROL PANELS

PART 1 GENERAL

1.1 DESCRIPTION

- A. Section Includes: Design standards and manufacturing requirements for Distributed Process Control System (DPCS) panels and enclosures furnished to WSSC by others. It applies to Programmable Logic Controller (PLC) panels and Remote Input/Output (RIO) panels used to control plant equipment and processes. Follow Section 16900 for installation, startup and testing of DPCS panels.

1.2 REFERENCES

- A. Underwriters Laboratory UL508A – Safety Standards for Industrial Control Panels
- B. National Electric Code Section 409 – Industrial Control Panels
- C. NEMA 250-2008 – Enclosures for Electrical Equipment

1.3 QUALITY ASSURANCE

- A. The Owner will provide sample power distribution, I/O module and network diagrams, and sample RLL code for adherence. DPCS and PLC equipment and software: Approved by the Owner.
- B. List of approved and current manufacturers and models will be provided. The current approved DPCS and PLC manufacturers are Allen Bradley ControlLogix. The PLC will be programmed use RLL primarily, using Structured Text when needed and the only viable option. The PLC program will be fully annotated. The current approved Operator Interface Panel is Wonderware AIS (12” or greater). Wonderware InTouch is the approved HMI software.
- C. DPCS panels.
 - 1. Utilize standard catalogued PLC equipment approved by WSSC and suitable for use in industrial water/wastewater processing environment.
 - 2. Include components shown on contract drawings and accessories and hardware not shown but necessary to meet manufacturer recommendations and/or WSSC specifications.
 - 3. Equipment: Installed following manufacturer’s recommendations. Follow manufacturer’s installation manuals for guidance and details not shown on contract drawings.

1.4 SUBMITTALS

- A. Submit for review following Section 01330. Drawings: AutoCAD format and may be electronically transmitted.
 - 1. Power distribution wiring diagram.
 - 2. PLC wiring diagrams including all I/O points.
 - 3. PLC RLL code.
 - 4. Communication and remote I/O interface module wiring diagrams.
 - 5. Operator interface terminal (OIT) wiring diagram if applicable.
 - 6. Back panel and subpanel layouts showing location of panel-mounted equipment.
 - 7. Enclosure elevation drawing showing location of externally mounted equipment.
 - 8. Enclosure assembly diagram if applicable.
 - 9. Complete bill of materials.

PART 2 MATERIALS

2.1 ENCLOSURES

- A. NEMA Rating: Follow standards for NEMA type indicated on drawings or as specified herein.
 - 1. NEMA Type 12 dust-tight:
 - a. Provided for indoor controlled environment locations as shown on drawings. Provide continuous gasket around door opening.
 - b. Phosphate coating for rust proofing and white enamel panel interior finish.
 - 1) Exterior finish: Hoffman custom paint color #RAL7021 (T014) or ANSI-61 gray powdercoat.
 - 2) Enclosures requiring legs: Paint color to match enclosure.
 - 2. NEMA Type 4 watertight and dust-tight: Provided for indoor or outdoor locations as shown on Drawings.
 - 3. NEMA Type 4X corrosion resistant: Provided for indoor and outdoor locations as shown on Drawings.
 - a. Door clamps and hinge pins: Stainless steel.
 - 4. NEMA-rated enclosures for PLC and Remote I/O panels: Hoffman Brand or equal.
- B. General.
 - 1. Designed for connection to 120VAC branch circuits. Equipment that requires higher voltage sources, e.g. VFDs and uV reactor controls: Supplied in separate enclosures.
 - 2. Enclosures that contain interlocked control circuits or circuit supplied from external power source which cannot be de-energized by panel disconnect: Furnish with following warning label;
CAUTION: THIS EQUIPMENT MAY HAVE MORE THAN ONE POWER SOURCE OR IS INTERLOCKED WITH OTHER EQUIPMENT.
 - 3. Mounted outdoors or in unheated areas: Provide internal condensation and freezing protection with thermostat control.

4. Contain incandescent or LED light package equipped with manually operated switch. At least one GFCI-type duplex utility outlet: Provided on control panel.
5. Fully enclosed units with front and/or rear access doors, designed to fit in space available, as specified in contract drawings.
6. Enclosures which contain PLC processor and communication modules: Equipped with door-mounted factory window kits to enable viewing of status LEDs.
7. Vapor-phase protective corrosion inhibitors.
 - a. Inhibitor: Activated upon shipment to site.
 - b. Panels:
 - 1) Do not store with inhibitors inactive.
 - 2) Cover to reduce ventilation and prolong inhibitor life, if necessary.
 - c. Approved Manufacturers:
 - 1) Hoffman A-HC15E.
 - 2) 10E.
 - 3) Or Equal.
8. Front door-mounted nameplate that identifies panel inside, e.g., PLC-D, CHEM RIO-4.
 - a. Nameplates.
 - 1) As shown on contract drawings or listed in specifications.
 - 2) Laminated plastic having black letters on white background and attached using stainless steel screws.
9. Print pocket.
 - a. Mounted inside door.
 - b. Include one copy of relevant as-built drawings prior to shipment.
10. Factory back panels for mounting control panel components and equipment.
 - a. Side panels may be used to increase amount of available panel space.
 - b. 24 inch deep or greater that contain back panel: Supplied with studs for future installation of full length side panels on both sides of enclosure.
11. Sufficient structural reinforcements to limit vibration and prevent distortion or damage to panel and components during shipment, installation and operation.

C. Free-Standing Steel Enclosures

1. Single door: 12-gauge sheet steel.
2. Multiple door: 10-gauge steel.
3. Back panels and side panels: Minimum 12-gauge steel.
4. Full size back panels: Equipped with stiffeners and heavy duty supports as needed to ensure rigidity.
5. Exterior welds: Ground and sanded to smooth finish free of burrs.
6. Surface: Free of ridges, nuts, bolt heads, and similar protrusions.
7. Removable lifting lugs on top of enclosure designed to facilitate rigging and lifting of enclosure during installation.
 - a. Plugs: Provided to fill the lifting ring holes after installation is complete.
8. Full-length door with handle-operated three point latch for front or rear access. Certain installations may require lockable door handles.
9. Floor stands or foot kits, when required, as shown on panel drawings.

10. Provide steel stiffeners as necessary to prevent deflection of back panels and doors due to heavy panel-mounted or door-mounted components.
 - a. Stiffener: Minimum 0.25 inches deep by 1 inch wide tack welded to back of the panel or door.

D. Wall-Mounted Steel Enclosures

1. 14-gauge steel.
2. Back panels and side panels: Minimum 12-gauge steel.
3. Doors: Equipped with rubber gaskets and continuous hinges.
4. PLC enclosures: Equipped with 2-point latching door handles.
 - a. In wet or corrosive environments screw clamps may be required around perimeter of door to ensure tight seal.
 - b. Certain installations may require lockable door handles.

2.2 PANEL WIRING AND TERMINATIONS

- A. Designed, manufactured and tested following latest standards listed herein.
- B. Back panel and side panel wire bundles.
 1. Run inside Panduit-style wire duct to facilitate tracing of circuits.
 2. Exposed wire bundles connecting door-mounted devices and side panels to back panel are allowed.
 3. Fastened down at suitable intervals, not to exceed 12 inches in length.
- C. Segregate AC control power and I/O wiring, and DC control power and I/O wiring within panel as much as possible.
 1. Group wires and cables according to function. Run in separate wire ducts and/or bundles.
 2. Keep analog signals (4-20 mA and 0-10V) as far away from AC control power and I/O wiring as possible.
- D. Use flexible stranded copper wiring.
 1. No solid conductor wire is permitted.
- E. 120VAC and 24VDC wiring in panel: Type MTW, rated for operation at 600V at conductor temperatures not to exceed 90 deg. C.
- F. Analog I/O and Instrumentation cable: No. 18 AWG, twisted, shielded single pair, instrumentation cable with minimum of six twists per foot and including continuous foil shield with drain wire. PVC-coated and rated for operation at 300V at conductor temperatures not to exceed 90 deg. C.
 1. Individual Pair Shield: 1.35 mil, double-faced aluminum/synthetic polymer overlapped for 100% coverage.
 2. Outer Jacket: 45-mil nominal thickness.
 3. Dimension: 0.31 inch nominal OD.
 4. Conductors:

- a. Bare soft annealed copper, Class B, 7-strand concentric, following ASTM B8.
 - b. 20 AWG, 7-strand tinned copper drain wire.
 - c. Insulation: 15-mil nominal PVC.
 - d. Jacket: 4-mil nominal nylon.
 - e. Pair conductors: Color-code Red (+), Black (-).
- G. Minimum wire conductor sizing: Follow UL 508A standards for industrial control panels:
 AC line side power: No smaller than 14 AWG.
 AC line and control circuits: No smaller than 16 AWG.
 DC line, load and control circuits: No smaller than 16 AWG.
 Analog signal wiring: No smaller than 20 AWG.
- H. Panel wiring: Color coded as follows:

BLACK	AC line, load and control circuits operating at line voltage.
WHITE	AC neutral
RED	AC control circuits at line voltage which are controlled by a relay contact or other control element
BLUE	DC, line load and control circuits
BLUE WITH WHITE STRIPE	DC common or 0VDC
YELLOW	Interlocked control circuits or any circuit supplied from external power source which cannot be de-energized by control panel disconnect.
GREEN	Equipment grounding conductors with or without yellow stripe.

- I. Analog and instrumentation conductors: Color coded as follows:
- 1. RED: Positive (+)
 - 2. BLACK: Negative (-)
- J. Wire:
- 1. Run in continuous lengths from screw terminal to screw terminal.
 - 2. Provide wire service loops to simplify removal of panel components.
 - 3. Do not splice wiring.
 - 4. Identified at both ends with white machine printed, sleeve-type labels.

- a. Hand lettered wire labels are not allowed.
- K. Wire numbering: Consistent with nomenclature used in sample drawings.
 - 1. All PLC I/O module wiring: Numbered according to I/O point base/slot/point assignments.
- L. 120 VAC Discrete Inputs: The DPCS panel will provide 120VAC to field equipment for signaling purposes only.
 - 2. Wires: Red.
 - 3. Field equipment: Equipped with 120VAC rated dry contacts and shall operate the dry contacts. All Emergency Stop and other alarm Inputs shall be wired Failed-Safe (normally closed), where the de-energized circuit represents an alarm.
 - 4. For each dry contact, a pair of wires shall be installed and landed from the DPCS panel to the dry contact.
 - a. One wire shall be hot (+) the other shall be used to return power back to the DPCS when the dry contact is closed.
 - b. Both wires shall be continuous home-runs from field equipment panel to DPCS panel with NO intermediate terminations or splices.
 - c. A sample drawing will be provided and followed.
- M. 120 VAC or 24VDC Relay Outputs: The DPCS panel will be Supplied with 120VAC or 24 VDC control power from the field equipment for control purposes only.
 - 1. Wires: Yellow to indicate foreign voltage.
 - 2. DPCS Discrete Output card will provide a dry contact to switch power on and off. Each dry contact will only have one function and serve only one piece of field equipment (for example, a single dry contact cannot be used to turn on a pump and used to illuminate a panel light).
 - 3. For each dry contact, a pair of wires shall be installed and landed from the DPCS panel to the field equipment.
 - a. One wire shall be hot (+) the other shall be used to return power back to the field equipment when the dry contact is closed.
 - b. De-energizing field equipment shall consequently de-energize the 120VAC or 24VDC control power.
 - c. Both wires: Continuous home-runs from field equipment panel to DPCS panel with NO intermediate terminations or splices.
 - d. A sample drawing will be provided and followed.
 - 4. In general, the current for Allen Bradley 1756 output modules shall not exceed 2 Amps and never exceed the manufacturer's limitations. The A-B relay output module (1756-OW16I) used on DPCS panels does not have on board fusing, therefore one of the 2 terminals provided for field connections, typically the line side, shall be equipped with a 2A rated fast blow fuse.
 - 5. In general, the current for CTI output modules shall not exceed 5 Amps and never exceed the manufacturer's limitations. The CTI relay output module (#2534) used on DPCS panels is equipped with on board fusing; therefore standard thru terminals may be used for field connections.

2.3 TERMINAL BLOCKS

- A. Factory assembled on standard 35mm din rail mounted on standoffs to provide easy access to terminal screws.
 - 1. Prefabricated terminal strips are not allowed.
- B. Screw type with pressure plate (compressor type) requiring no lugs on connecting wires.
 - 1. Rated for wire size 12 AWG or smaller.
 - 2. Rated for 600 volt service.
 - 3. Cage clamp style terminals are not allowed.
- C. Furnished with engraved plastic markers displaying wire numbers or alphanumeric designation shown on drawings and/or on the I/O point list.
 - 1. If connected to PLC I/O modules: Numbered according to I/O point base/slot/point assignments.
- D. Reserve one side of each terminal block assembly for incoming field wiring.
 - 1. Common connections and jumpers required for internal wiring on field side of terminal is not allowed.
 - 2. No more than two wires terminated at any single screw terminal.
- E. Through terminals and fuse terminals ganged together to create common voltage buses: Utilize internal screw jumpers.
 - 1. Wire jumpers and comb jumpers are not allowed.
- F. I/O module points, including unused spares: Connected to terminal blocks.
 - 1. Terminal block assemblies for power distribution: Include minimum 25 percent spare fuse terminals, connected to AC or DC bus via internal jumpers.
- G. Fused terminal blocks.
 - 1. Follow typical wiring diagrams for power distribution and I/O modules.
 - 2. Required for overcurrent protection of analog input modules and discrete output modules not equipped with internal fuses or protected by interposing relays.
 - 3. Provided with blown-fuse indicator and fast-acting, 5 x 20mm fuses, unless approved otherwise.
 - 4. Cross section not greater than 8mm.
- H. Terminal block assemblies for analog input and output channels.
 - 1. Include ground terminals that connect directly to panel ground through din rail.
 - 2. Ground terminals: Green and yellow in color.
- I. Feed through terminal blocks: High density with cross section not greater than 2.5mm.
- J. Approved Manufacturer.
 - 1. Weidmuller brand

2. Or equal.

<u>Terminal Type</u>	<u>Wiedmuller Cat. No.</u>
Analog input (+), fused	WSI6
Analog input (-)	WDU2.5
Analog input shield	WPE2.5
Analog output (+)	WDU2.5
Analog output (-)	WDU2.5
Analog output shield	WPE2.5
Discrete input	WDK2.5*
Discrete output	WDU2.5
Digital output, fused	WSI6
All others	WDU2.5 or WSI6

*Note: Discrete input terminal block assemblies require 2-tier terminals. The top tier is used for the individual inputs. The terminals on the bottom tier are ganged together using internal screw jumpers to form a voltage bus for wetting of field contacts.

2.4 PANEL MOUNTED DEVICES

A. Analog signals.

1. Sent to and received from the field: 4-20mA
2. Analog I/O modules: Configured for 4-20mA signals.
3. Include signal converters necessary to make DPCS panel compatible with field equipment on panel.

B. Panel and enclosure.

1. Equipped with ground lugs for connection to external ground.
2. Screw terminal-type ground bus bolted to back panel: Provided for grounding electrical equipment and instrumentation.

C. Instruments, pilot devices or operator panel mounted on outside of enclosure:

1. Suitable for flush mounting.
2. Match the NEMA rating of enclosure.
3. Located between 30" and 62" from floor.

- D. Panel mounted devices:
 - 1. Mounted on din rail whenever possible
 - a. Din rail segments: Extended to include unused panel space.
 - 2. Designed to facilitate removal and maintenance of equipment after installation.
 - 3. Identified by markers placed adjacent to, but not on, given device.
 - 4. Markers:
 - a. Display device tagnames and/or descriptive names.
 - 1) Engraved plastic nameplates or labels printed with indelible ink. Hand lettered markers are not allowed.

2.5 PILOT DEVICES

- A. Selector switches, pushbuttons, and indicating lights: Heavy duty, oil-tight, 30mm, NEMA 13-rated.
- B. Selector switches and pushbuttons.
 - 1. Supplied with operator mechanisms, appropriate number of contact blocks, and any necessary legend plates bearing pertinent information.
 - 2. Contact block terminals: Labeled for identification purposes and contain no less than one single-pole, double-throw contact.
 - 3. Contact blocks: Heavy duty type rated for 10A breaking current at 120V.
- C. Stop and emergency stop pushbuttons: Red in color unless approved otherwise.
 - 1. Other pushbuttons: Black unless approved otherwise.
- D. Pushbuttons.
 - 1. Operation: Momentary.
 - 2. Switch operation for local-remote, auto-manual, and computer-manual selection: Maintained in all positions.
 - 3. Provided with flush head bezels.
- E. Spring return selector switches: Required where indicated on Contract drawings.
- F. The following color code shall be used for the lenses of all indicating lights:

<u>FUNCTION</u>	<u>COLOR</u>	<u>FUNCTION</u>	<u>COLOR</u>
ON	Red	HIGH	White
OFF	Green	AUTOMATIC	White
CLOSED	Green	MANUAL	Blue
OPEN	Red	LOCAL	Blue
LOW	White	REMOTE	White
FAIL	White	POWER ON	White
TRIPPED	White		

- G. Indicating lights: Push-to-test LED-type, rated for 120V operation.

- H. Selector switches, pushbuttons, and indicating lights: Allen-Bradley Series 800, Siemens Class 52, or equal.

2.6 INTERPOSING RELAYS

- A. Used in conjunction with discrete inputs when field equipment being monitored is not compatible with 120VAC.
- B. Discrete outputs: Energize interposing relays interlocked with field control circuits, unless approved otherwise.
 - 1. Relays.
 - a. Coils rated to match field equipment.
 - b. Contacts rated for no less than 5A.
 - c. Only one Form C contact per relay.
 - d. LEDs to indicate when coil is energized.
 - e. Manual override switches for testing.
 - f. Turck/Releco type C12-A21X or equal.
- C. Provide surge suppressors on DC operated relay coils to reduce high transient voltage generated when circuit to operating coil is opened.
- D. May be required when using unfused PLC relay output modules.

2.7 POWER DISTRIBUTION

- A. DPCS panels: Furnished with two 120VAC, 20A-rated circuits.
 - 1. Line filtered circuit for powering the PLC, relay outputs, field contacts for digital inputs, 24VDC power supply, instrumentation, etc.
 - 2. Panels that contain the PLC processor and communication modules: Furnished with 120V receptacle on line filtered circuit for powering transceiver.
 - 3. Auxiliary circuit for powering enclosure lights and utility receptacle.
- B. Provide master disconnect switch and auxiliary branch circuit protectors (miniature circuit breakers).
 - 1. Circuit breakers: Used on AC inputs to power supplies and auxiliary circuits.
 - 2. Provide fused terminal blocks for 24VDC-powered devices and for connecting power to bottom tier of digital input terminal block assemblies.
- C. Input terminals, branch circuit protectors, and fuse terminals: Mounted on din rail and grouped according to function.
 - 1. Fuse terminals for digital input terminal block assemblies: Mounted next to digital input terminals.
- D. Auxiliary Branch Circuit Protectors: Siemens Series SY with trip characteristic C, or equal.

E. DPCS Panel Power Supply

1. Provide DPCS panel with 24VDC power supply rated for either 5A or 10A.
2. Power supplied: Meet or exceed the following specifications;

Input Power:	85 to 132 VACS, 47 to 63 Hz
Minimum Efficiency:	90%
Overload Rating:	150% I (out) rated up to 5 s/min
Protection:	Internally fused, preset current limit
Operating Temp. Range:	0 to 60 deg. C
Mounting:	Din rail mount
Output Voltage:	22.8 to 28V, adjustable
Output Voltage Regulation:	Typical 0.3% V (out)
Ripple and Noise:	<50 mV, pp
Temperature Coefficient:	0.02 percent per degree centigrade
Manufacturer:	Siemens 6EP1333-2AA01 (5A) Siemens 6EP1334-2AA01 (10A) Siemens 6EP1961-3BA20 (Redundancy)

3. DPCS panels that contain PLC processor:
 - a. Equipped with redundant power supplies and redundancy module that can switch to backup unit in case of failure.
 - 1) Redundancy module status contact: Wired into PLC digital input.

F. Power Line Transient Protection.

1. Provide panels containing solid state electronic equipment with line voltage surge suppressor provided with;
 - a. Surge arrester.
 - b. RFI filter.
 - c. Voltage clamp.
 - d. Terminals for incoming and load wires that shall trip power feed circuit breakers.
 - e. Automatic device reset.
 - f. Din rail mountable.
2. Approved Manufacturers;
 - a. Islatrol brand IE-120.

G. Uninterruptable Power Supply: Ferrups style with MBB bypass transfer switch, quick disconnect cables with twistlock connectors, and caster kit.

H. Exhaust Fan Motor Starter

1. The exhaust fan motor starter shall be across-the-line magnetic type rated in accordance with NEMA standards, sizes and horsepower ratings. The motor starter shall have a 120 volt coil. The motor starter shall be located in the Control Room Exhaust Fan Control Panel. The motor starter shall be furnished with an overload relay. Provide a heater element in each phase of the relay sized for the motor nameplate full load amps.

2. The exhaust fan motor starter shall be Allen-Bradley Bulletin 509 or Square D Class 8536.

PART 3 EXECUTION

3.1 FACTORY TESTING.

- A. Equipment: Inspected and tested prior to being shipped to field.
- B. Each piece of hardware: Energized and tested to verify components function following manufacturer specifications.
- C. Factory testing: Include integrated system test to demonstrate proper functioning of CPU, local I/O modules, remote I/O network and remote I/O modules. Conduct test using minimally configured system.
- D. Personal computer and software necessary to create PLC hardware configuration for testing: Provided by factory
 1. WSSC will provide CPU rack for testing remote I/O panels upon request.
- E. Test Each I/O point following procedures outlined below. For purposes of factory testing;
 1. “Field terminals” shall mean the terminal blocks on the DPCS panels meant to receive field wiring
 2. “Console” shall mean the personal computer used to configure PLC and verify I/O test.

Digital Inputs: Jump each digital input field terminal to 120VAC or 24VDC, according to module type. Observe change of state at console.

Digital Outputs: For relay output modules with field connections to both line and load, force each output on at the console and measure the change of state at field terminals with continuity tester. For relay output modules connected to interposing relays on DPCS panel, verify proper output voltage and operation of interposing relays.

Analog Inputs: Introduce 4 to 20 mA DC signal at field terminal and observe changing value at console. Test response at 4 mA, 12 mA and 20 mA.

Analog Outputs: Force each output at console with values corresponding to 4 mA, 12 mA and 20 mA, and measure results at field terminals.

- F. Provide 5 working days notice prior to starting factory testing. WSSC will typically witness testing, but may waive this requirement on case-by-case basis.

- G. Patent defects in equipment: Repaired or replaced, as required, at no cost to the Commission, until substantial completion.
 - 1. If Latent defects are found notify the Commission immediately.
- H. Any factory modifications to DPCS panels shall be approved, tested, and documented prior to final acceptance.

3.2 POST TESTING

- A. Submit following documentation within 14 days of finishing factory panel testing.
 - 1. As-built versions of shop drawings listed herein.
 - 2. Fully annotated PLC logic backed up on CD-ROM.
 - 3. OIT configuration, tags and screens backed up CD-ROM.
 - 4. Complete I/O list following Process Control Group format.
- B. Submit final as-shipped drawings prior to shipment for approval and provide one copy within enclosure(s) to be shipped.
- C. Provide for protection, insurance and proper storage of equipment until received and inspected by the owner.
- D. Deliver spare parts for DPCS panels, as specified in contract drawings and documentation, prior to panel installation.

END OF SECTION

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SECTION 16947
FIBER-OPTIC COMMUNICATION CABLE

PART 1 GENERAL

1.1 DESCRIPTION

- A. Section includes materials, installation, and testing of multimode fiber optic cable. Multimode shall be used everywhere.
- B. Drawings indicate desired location and arrangement of pull boxes, cable runs, and other items.
 - 1. Exact locations: Determined in field, based on physical size and arrangement of equipment, finished elevations and obstructions.
 - 2. Adhere as closely as possible to locations shown on drawings.
- C. Related work specified elsewhere:
 - 1. Basic Electrical Materials and Methods – Section 16050
 - 2. Digital Process Control System Installation – Section 16900

1.2 QUALITY ASSURANCE

- A. Fiber Optic Specialty Contractor Qualifications:
 - 1. Minimum of five years' experience with installation of fiber-optic systems similar to this project.
 - 2. Test equipment must be factory certified within one year of approved testing results.

1.3 SUBMITTALS

- A. Submit following Section 01300.
 - 1. Catalog data on fiber-optic cable, high-density polyethylene (HPDE) duct, pull boxes, connectors, conduit sealant, closures, enclosures, identification tape, and mounting hardware.
 - a. All material must be installed and accepted within three years of date of manufacture.
 - 2. Detailed bill of materials.
 - 3. Testing.
 - a. Catalog data on testing equipment.
 - b. Written test procedure outlining steps and methods used to test cable before and after installation.
 - c. Sample copy of test form to be used in test procedure.
 - d. Sample optical time domain reflector (OTDR) test results and graph.
 - 4. Cable and duct installation procedure.
 - a. Outline construction methods used.
 - b. Identify steps to ensure cable is not damaged during installation.

5. Factory test results for each cable reel, stating signal loss for each fiber in cable.
 6. Field test results for each cable reel, stating signal loss for each fiber in cable before and after installation, as specified herein.
 7. Record drawings indicating locations and station numbers of all pull boxes.
- B. Submit following Section 01450 and as specified herein.
1. Written evidence of minimum five years' experience with installation termination and testing of fiber-optic cable systems similar to this project.
 2. List of completed installations similar to this project. Include name and address of Company, name of project, and date of completion.
 3. Name and qualifications of supervisory personnel directly responsible for installation of fiber-optic system.

1.4 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Deliver, handle, and store equipment following Section 16900 and manufacturer's recommendations.

PART 2 PRODUCTS

2.1 MULTI-MODE FIBER-OPTIC CABLE

- A. Provide multi-mode fiber-optic cable suitable for use with both 850 and 1,300 nm transmission equipment.
- B. Fiber.
1. 62.5-micron core with 125-micro cladding material.
 2. Maximum individual fiber loss: 3.5 dB/km at 850 nm and 1.5 dB/km at 1,300 nm.
 3. Color-coded.
 4. 12 fiber-pair per fiber-optic cable, unless otherwise specified.
 5. Operating Temperature range: -40°C to 80° C
 6. Crush resistance: 250-lb./inch minimum
 7. Tensile load rating: 600 pounds minimum per fiber optic cable.
- C. Continuous outer jackets of cable: Free from holes, splits, blisters, or inclusions. Same requirement for inner jackets within cable structure and fiber coatings.
- D. Provide loose-tube type cable construction.
- E. Provide fiber optic cable from one distributor.
1. Approved manufacturers
 - a. Draka as follows:
 - (1) Armored burial cable DLSZHD for direct burial applications.

2.2 FIBER-OPTIC ACCESSORIES

- A. For connectors, provide ST type pre-polished or fusion-spliced fan breakout kits. Mating losses not to exceed 0.75 dB per connection.
 - 1. Fiber optic patch cables: Duplex type with ST connectors.
 - a. No more than 2 meters of slack at either end or 3 meters total.
 - b. Only use soft Velcro tie wraps for securing patch cables.
- B. Install connectors after fiber-optic cables are pulled and run to desired location.
- C. Fiber optic patch panels.
 - 1. Approved manufacturers:
 - a. Siecor
 - b. Corning
 - c. Or equal
- D. Provide all other raceways, fittings, boxes, and terminal cabinets following specification 16050.

2.3 FIBER OPTIC DISTRIBUTION BOX (FOD)

- A. Provide minimum of one FOD box to enclose indoor/outdoor fiber optic cable connections for each area as shown on drawings, or wherever FOD box is needed.
- B. If location is not shown on drawings, locate near to RIO enclosure.
- C. Fiber optic cable connections and restraining in FOD enclosures must meet fiber optic cable and FOD manufacturer's recommendations.
- D. Provide ST connectors and connect fiber optic strands to FOD rack.
- E. FOD box: Constructed of Low Zero halogen material, easy to punch, drill, file or saw.
- F. Provide brackets for wall mounting, hardware grounding kit, twelve 6-fiber panels for 72 fibers total capacity and NEMA 4X.
- G. Approved Manufacturer:
 - 1. Corning, Model EDC-12P-NH.

2.4 CABLE PACKING

- A. Permanently mark cable to identify manufacturer, date manufactured, length of cable, product identification code, and UL messages when appropriate.
- B. Marking: Print at regular intervals no more than 1 meter apart.
- C. Package cable and duct on reel with inner hub diameter greater than recommended minimum-ending diameter of cable.

- D. Anchor holes on reels: Admit 63.5-mm (2.5-inch) diameter spindle without binding.
- E. Package: Sturdy enough to endure reasonable handling in process of shipping and storage.
- F. Attach the following information to reel (as a tag), or clearly and permanently stencil, or label on each reel:
 - 1. Customer order number.
 - 2. Customer job number.
 - 3. Customer reel number.
 - 4. Termination.
 - 5. Ship date.
 - 6. Manufacturer's name.
 - 7. Factory reel number.
 - 8. Manufacturer's cable code (type and fiber count).
 - 9. Length of cable.
 - 10. Weight of cable and reel.
 - 11. Defect tag.
- G. Seal ends of cable and duct to prevent the escape of filling compound and entry of moisture during shipping, handling, storage, and installation.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Install fiber optic cable:
 - 1. After field reel test report approval.
 - 2. Following engineering data, instructions and recommendations of equipment manufacturers and contract drawings.
 - 3. Performed by workers skilled in fiber optic installations.
 - 4. Do not exceed manufacturer's minimum installation and operating cable-bending radii, pull strength and vertical rise.
 - 5. Do not kink cable and duct as it comes off spool.
 - 6. Do not allow vehicular or pedestrian traffic to run over duct or cable.
 - 7. Use dynamometers or breakaway pulling swings to ensure pulling line tension does not exceed installation tension values specified by the manufacturer.
 - 8. Record and submit maximum pulling tension for each pull, after installation is complete.
 - 9. Provide cable runs and required loops in one continuous length. Do not splice.
 - 10. All penetrations through the bottom of cabinets. If impractical, consult WSSC to discuss penetrations through the side of cabinet.

- B. Test each fiber optic cable member before connection at any point along the network.
 - 1. Identify both active and spare pairs at each termination point along the network.
 - 2. Terminate all fiber members within fiber-optic patch panels.
- C. Conduit Installation
 - 1. Multi-mode fiber: Run though new and existing duct banks and conduit following fiber-optic cable and FOD manufacturers' recommendations and as shown on drawings.
 - a. Check each for foreign material and collapsed sections prior to pulling fiber-optic cable.
 - 2. Run fiber-optic cable though conduit at above ground locations.
 - a. Pull mandrel through conduit to check inside diameter and verify conduit is free from obstructions.
 - b. If mandrel will not pass-through conduit, replace or repair conduit at obstruction point.

3.2 FIELD TEST

- A. Inspect fiber optic cable for physical damage.
- B. Install connectors on each fiber to perform field tests.
- C. Perform fiber optic test with an optical time domain reflectometer (OTDR) for each strand of fiber to verify attenuation, length, continuity, and proper installation.
 - 1. Perform OTDR test by approved independent company.
 - 2. Test using:
 - a. Multimode OTDR at 850 nm and 1300 nm wavelength for multimode fiber.
 - b. Use a 500' minimum launch and receive fiber optic cables.
 - 3. Submit results of measurements for approval.
- D. Test fibers for breaks, abnormalities, and overall attenuation characteristics to ensure that installed cable adheres to required optical parameter.
 - 1. Provide written certification of dB loss at each test location.
- E. Perform attenuation tests:
 - 1. After delivery to site, before cable is removed from the reel.
 - 2. After installation of cable.
 - a. Final test each end of cable after all terminations have been made and installation is complete.
- F. Cable reels that fail continuity or that have higher than specified attenuation shall be subject to rejection and replaced at no additional cost.

3.3 TEST RESULTS

- A. Furnish written Certification.
 - 1. Tests conducted for each fiber, extending to end of each fiber-optic cable run.
 - 2. Provide for each test location:
 - a. Clearly label test type, location, date, wavelength, index of refraction, fiber number, fiber color and fiber identification, as shown on Drawings.
 - b. Format report and trace graphs so that each strand can be identified. Report loss in dB/km between connectors and dB loss across each connector.
 - c. Overall distance and distances to every termination on individual fibers from trace graphs.
 - d. Overall distance and distances to every termination on individual fibers from length markers on cable jacket.
- B. Performance test data:
 - 1. Connection mating losses not to exceed 0.75 dB per connection.
 - 2. Attenuation losses not to exceed 3.5 dB per kilometer.
 - 3. Remove from job site Fiber Optic Cable that does not test satisfactorily.

3.4 FIELD QUALITY CONTROL AND TESTING.

- A. Prerequisites:
 - 1. Inspect for physical damage.
- B. Preliminary Test
 - 1. Install connectors on each fiber to perform field tests.
 - 2. Perform test and submit results.
- C. Prefinal Test
 - 1. Verify all punch list items have been corrected.
 - 2. Verify all equipment functions as complete units, as specified.
- D. Final Test
 - 1. Verify all pre-final punch list items have been corrected.

END OF SECTION

SECTION 16950 TESTING

PART 1 GENERAL

1.1 DESCRIPTION

- A. Section Includes: Requirements for performing, recording, and completing electrical and mechanical equipment field testing program.
- B. Testing Requirements for Division 2 Sections: As specified therein.
- C. Procedures Contained in Section 01450: Applicable as specified.

1.2 QUALITY ASSURANCE

- A. Testing Procedures: Follow Section 01450 and engage independent testing company to perform tests and submit data as specified herein.
 - 1. Preliminary Test:
 - a. Demonstrate that equipment and connections, when energized, perform functions required by Contract Documents, approved Contractor's Submittals, and approved Operation and Maintenance Manuals for each item of equipment or system.
 - b. Have quality of workmanship and installation examined for deficiencies and listed on punch list for repair prior to Prefinal Test.
 - c. Obtain approval and inspection of work by other agencies or organizations before installation or operation, when required by local codes or laws.
 - (1) Submit to Engineer: 1 signed original and 3 copies of approvals.
 - d. Following Construction Schedule and with Engineer's approval, schedule Preliminary Tests minimum of 10 days before Prefinal Tests are scheduled.
 - e. Ensure performance and recording of Contractor's tests and independent testing company tests before Preliminary Tests to avoid delays of scheduled testing procedures.
 - 2. Prefinal Testing: Enables unanimous, satisfactory acceptance for online use by Inspector by demonstrating that:
 - a. Equipment has been installed following Contract Documents and approved Contractor's Drawings.
 - b. Project phases have been completed.
 - c. Integrated equipment and systems operate as complete units.
 - d. Punch list items developed in Preliminary Tests have been corrected.
 - 3. Final Test: Precedes scheduling of Certificate of Final Acceptance and verifies that:
 - a. Outstanding items of punch lists have been corrected.

- b. Project work is ready to be placed in service and turned over to the Commission.
- B. Inspections and Tests: Follow latest edition of applicable test procedures of these standards associations:
 - 1. ANSI.
 - 2. IEEE.
 - 3. ICEA.
 - 4. NEC.
 - 5. NEMA.
 - 6. NETA.
 - 7. AWWA.
- C. Coordinate tests with data, instructions, and recommendations in Short Circuit Calculations and Coordination Studies specified herein and approved before testing.

1.3 SUBMITTALS

- A. Data, Certificates, and Record Drawings: Submit following Sections 01330 and 01450.
- B. Schedule of Dates and Times for Testing: Include description of equipment and systems to be tested and testing sequence.
- C. Short Circuit Calculations and Coordination Study, Low Voltage:
 - 1. Submit complete study in booklet form at shop drawing phase for electrical equipment.
 - 2. Include Low Voltage Distribution System specified in Section 16050 and 16143 and shown on One Line Diagram in Contract Drawings.
 - 3. Contents:
 - a. Overcurrent and ground fault coordination charts, indicating relations of time current curves between selectively coordinated protective devices.
 - b. New 480 Volt feeder breaker in existing Control Building and associated 480 Volt service feeder to MCC-WH.
 - c. 480 Volt Motor Control Center MCC-WH and associated 480 Volt feeders and loads.
 - d. Dry type transformers and associated primary and secondary feeders.
 - e. 208Y/120V Panelboards.
 - 4. Make revisions required by Engineer and resubmit for final approval.
- D. Record Forms
 - 1. Submit test data record forms for each system and item of equipment tested in preapproved form and format.
 - 2. Neatly print or type test form to permit photocopying without loss of clarity to include.
 - a. Project identification.

- b. Test stage identification: Preliminary or Prefinal.
- c. Sequence number of test: First Test, Second Test, and Final Test.
- d. Beginning and ending test dates.
- e. Identification of testing facility: Contractor, independent testing company, or Manufacturer.
- f. Signature of person conducting tests or chief of test team on test data record forms or title sheet of multiple page test report, typewritten or neatly printed name to permit photocopy without loss of clarity.

1.4 TEST EQUIPMENT

- A. Test Instruments, Meters, and Auxiliary Equipment: Tested and calibrated within 6 months of use on this contract and provided by Contractor and independent testing companies and by manufacturers' field service personnel where required.

1.5 DEFINITIONS

- A. Prerequisites: Items of work or submittals required before requirements of this Section.

PART 2
NOT USED

PART 3 EXECUTION
NOT USED

END OF SECTION

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