



ADDENDUM NO. 1

DATE: August 14, 2026
FROM: City of Grand Junction Purchasing Division
TO: All Offerors
RE: Ridges Primary Pump Station MCC Replacement Project IFB-5971-26-DD

Offerors responding to the above referenced solicitation are hereby instructed that the requirements have been clarified, modified, superseded and supplemented as to this date as hereinafter described.

Please make note of the following clarifications:

Incorporate Division 26 Specifications per the attached

The original solicitation for the project noted above is clarified as noted. All other conditions of the subject remain the same.

Respectfully,

A handwritten signature in blue ink that reads "Dolly Daniels".

Dolly Daniels, Senior Buyer
City of Grand Junction, Colorado

SECTION 26 05 00

COMMON WORK RESULTS FOR ELECTRICAL

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. General: This section specifies several categories of provisions for electrical work, including:
1. Certain adaptive expansions of requirements specified in General Conditions.
 2. General performance requirements within the whole electrical system.
 3. General work to be performed as electrical work, because of its close association.
- B. Drawings: Examine all drawings relating to the project. Include all work, materials, and equipment mentioned or shown as being provided under this division. Refer to all Drawings and details in coordinating and completing the work. Study all Drawings to determine any conflicts with ordinances and statutes. Report any discrepancies, conflicts, or omissions; accomplish work required for conformance and/or completion.
- C. Specifications: Examine all specification divisions relating to the project. Include all work, materials, and equipment mentioned as being provided under this division. Study all specifications to determine any conflicts with ordinances and statutes. Report any discrepancies, conflicts, or omissions; accomplish work required for conformance and/or completion.
- D. General Outline: The facilities and systems of the electrical work can be described (but not by way of limitation) as follows:
1. Coordination and installation of new electrical equipment and distribution.
 2. New electrical service and power distribution system, including the electrical connecting of equipment not specified to be connected as work of another Division.
 3. Motor starters/controllers and control/protection work as indicated.
 4. Lighting systems.
 5. Controls and instrumentation systems as indicated.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
- D. Section 26 05 33.23 – SURFACE RACEWAYS FOR ELECTRICAL SYSTEMS
- E. Section 26 05 33.16 – BOXES FOR ELECTRICAL SYSTEMS
- F. Section 26 27 26 – WIRING DEVICES

1.03 REFERENCES

- A. ANSI Standards - American National Standards Institute
- B. ASTM Standards - American Society of Testing Materials
- C. IEEE Standards - Institute of Electrical and Electronic Engineers
- D. ICEA Standards - Insulated Cable Engineers Association
- E. NECA Standards - National Electrical Contractors Association
- F. NEMA Standards - National Electrical Manufacturers Association
- G. NFPA 70 - National Electrical Code (NEC)
- H. OSHA Standards - Occupational Safety and Health Act
- I. UL Standards - Underwriters' Laboratories

1.04 ACTION SUBMITTALS

- A. General: Electrical compliance submittals shall be prepared and submitted in accordance with the Conditions of Contract, General Conditions, and this specification section. The types of submittals required for electrical work are defined herein. Refer to each Division 26 specification section for detailed requirements for submittal content. Administrative submittals are specified elsewhere in the Contract Documents.
- B. Content: Electrical compliance submittals shall include the following information.
 - 1. Each specification section shall be submitted separately for approval. All equipment included in the submittal shall be listed. Combined section submittals are not acceptable.
 - 2. Shop Drawings: Project shop drawings and other data prepared specifically for fulfillment of the project requirements. Shop drawings include fabrication, physical size, dimensioned layout, wiring diagrams, coordination and similar drawings and diagrams, and include performance data associated therewith, including weights, capacities, speeds, outputs, consumptions, efficiencies, voltages, amperages, cycles, phases, noise levels, operating ranges, and similar information. Installation manuals shall be furnished in the shop drawing submittals.
 - 3. Manufacturer's Data: Manufacturer's most current standard printed product information, including (as applicable) promotional brochures, product specifications, installation instructions and diagrams, statements of compliance with standards, performance charts or curves, and similar information concerning the standard portions of the manufacturer's products.
 - 4. Certifications: Written statements, either standard printed forms or specifically prepared text, executed specifically for the project application by an authorized officer of the contracting firm, manufacturer, or other firm as designated, certifying (to the best of his knowledge) to compliance with the requirements as specified.
 - 5. Specification Conformance: Each electrical submittal shall include a copy of the applicable specification section, with addendum updates included, and all referenced and applicable sections, with addendum updates included, with each paragraph check-marked to indicate specification compliance or marked to indicate requested deviations from specification requirements. Check marks (in the margin adjacent to the beginning of

the paragraph) shall denote full compliance with a paragraph as a whole. If deviations from the specifications are indicated and therefore requested by the CONTRACTOR, each deviation shall be underlined and denoted by a number in the margin to the right of the identified paragraph. The remaining portions of the paragraph not underlined will signify compliance on the part of the CONTRACTOR with the specifications. The submittal shall be accompanied by a detailed, written justification for each deviation. Failure to include a copy of the marked-up specification sections, with justification(s) for any requested deviations to the specification requirements, with the submittal shall be sufficient cause for rejection of the entire submittal with no further consideration.

- C. Submittal Presentation: Submittal data shall be assembled in electronic format. Each file shall contain a cover sheet, indexed by item and cross-referenced to the appropriate specification paragraph. Catalog cuts shall be edited to show only the items, model numbers, and information that applies to the equipment being furnished. All component and subassembly data sheets shall also be provided.
- D. Partial, incomplete or illegible submittals will be returned to the CONTRACTOR without review for re-submittal.

1.05 INFORMATION SUBMITTALS

A. Instruction Manuals:

1. General: Submittals shall be in accordance with Conditions of Contract and the General Conditions, Specification Sections and the requirements of this specification section. Instruction Manuals shall be submitted complete prior to commencing any training; partial or incomplete data shall not be accepted.
2. Electronic Copy: One (1) electronic copy of all Instruction Manuals shall be provided in portable document format (.PDF).
3. Content: Instruction Manuals shall include the following information.
 - a. Contact Information: Instruction Manuals shall include the names, addresses, and telephone numbers of the manufacturer, the nearest representative of the manufacturer, and the nearest supplier of the manufacturer's equipment and parts.
 - b. Manufacturer's Product Warranties: Manufacturer's standard printed commitment in reference to a specific product and normal application, stating that certain acts of restitution will be performed for the Purchaser or Owner by the manufacturer, when and if the product fails within certain operational conditions and time limits. Any extended warranties or service agreements provided within this contract shall also be included.
 - c. User Manuals: The written instructions by the manufacturer, fabricator, or installer of equipment or systems, detailing the procedures to be followed by the Owner in configuration, operation, control, and shutdown of each operating item of the equipment and each electrical system.
 - d. Maintenance Manuals: The compiled information provided for the Owner maintenance and troubleshooting of each system of operating equipment, including lubrication, emergency control, parts replacement, spare parts inventory recommendation, listing of tools and accessories needed for maintenance, and similar instructions.
 - e. Guarantees: The CONTRACTOR's specific signed commitment (sometimes requiring also that other countersign) to the Owner that certain acts of restitution

will be performed when and if certain portions of electrical work fail within certain operational conditions and time limits.

- f. Certifications: Written statements, either standard printed forms or specifically prepared text, executed specifically for the project application by an authorized officer of the contracting firm, manufacturer, or other firm as designated, certifying (to the best of his knowledge) the equipment installation, configuration, and startup is in compliance with the manufacturer's recommendations and the project requirements.
- g. Test Reports: The results of all specified factory and field tests shall be included with the Instruction Manuals.
- h. Startup Reports: Equipment manufacturer's field startup reports shall be included with the Instruction Manuals.
- i. Configuration Data: A written record documenting the setup and configuration of each system that is software, hardware, or firmware configurable in the field shall be included in the Instruction Manual. All configuration parameters, jumpers, switch settings, etc., shall be recorded.
- j. As-Built Control Wiring Diagrams and Assembly Drawings: As-built control diagrams and assembly drawings shall be provided in appropriately sized binders. Drawings shall not be folded or otherwise reduced in size for assembly in the instruction manual binder. As-built drawings shall be organized by facility or location. Electronic copies shall be included with the operation and maintenance manual files.

B. Drawings

- 1. Where the CONTRACTOR is required to provide information on drawings as part of the specified work, such drawings shall be prepared on 11 inch by 17 inch paper complete with borders and title blocks clearly identifying project name, equipment and the scope of the drawing. Drawings shall be prepared on a computer-aided drafting (CAD) system. All CAD drawing files shall be converted to .DWG file format and submitted on CD-ROM media. All CAD drawing files shall be updated to reflect final as-constructed conditions.

1.06 QUALITY ASSURANCE

- A. General: Refer to General Conditions for general administrative/procedural requirements related to compliance with codes and standards. Materials and workmanship shall comply with all applicable codes, specifications, local ordinances, industry standards, and utility company regulations. In case of difference between codes, state laws, local ordinances, industry standards, utility company regulations, and the contract documents, the most stringent shall govern.

B. Definitions:

- 1. Elementary or Schematic Diagram: A schematic (elementary) diagram shows, by means of graphic symbols, the electrical connections, and functions of a specific circuit arrangement. The schematic diagram facilitates tracing the circuit and its functions without regard to the actual physical size, shape, or location of the component devices or parts.
- 2. One-line Diagram: A one-line diagram shows by means of single lines and graphical symbols the course of an electrical circuit or system of circuits and the components, devices or parts used therein. Physical relationships are usually disregarded.

3. Block Diagram: A block diagram is a diagram of a system, instrument, computer, or program in which selected portions are represented by annotated boxes and interconnecting lines.
 4. Wiring or Connection Diagram: A wiring or connection diagram includes all the devices in a system and shows their physical relationship to each other including terminals and interconnecting wiring in an assembly.
 5. Interconnection Diagram:
 - a. Interconnection diagrams shall show all external connections between terminals of equipment and outside points, such as motors and auxiliary devices. References shall be shown to all connection diagrams that interface to the interconnection diagrams.
 - b. Interconnection diagrams shall be of the continuous line type. Bundled wires shall be shown as a single line with the direction of entry/exit of the individual wires clearly shown. Wireless diagrams and wire lists are not acceptable. Wire identification shall be shown as actually installed.
 - c. The wire identification for each end of the same wire shall be identical. All devices and equipment shall be identified. Terminal blocks shall be shown as actually installed and identified in the equipment complete with individual terminal identification.
 6. Arrangement, Layout, or Outline Drawings: An arrangement, layout, or outline drawing is one that shows the physical space and mounting requirements of a piece of equipment. It may also indicate ventilation requirements and space provided for connections or the location to which connections are to be made.
- C. Identification of Listed Products: Electrical equipment and materials shall be listed for the purpose for which they are to be used, by an independent testing laboratory. Three such organizations are Underwriters Laboratories (UL), Canadian Standards Association (CSA), Electrical Testing Laboratories (ETL), and National Electrical Manufacturers Association (NEMA).
1. When a product is not available with a testing laboratory listing for the purpose for which it is to serve, the product may be required by the inspection authority to undergo a special inspection at the manufacturer's place of assembly. All costs and expenses incurred for such inspections shall be included in the original contract price.
- D. Symbols: Except as otherwise indicated, refer to the symbol's legend on the Drawings for definitions of symbols used on the Drawings to show electrical work.
- E. Coordination Meetings: The CONTRACTOR shall include as Work of this section of the specifications the requirement for the following coordination meetings to be held at the project site. The primary function of the meetings shall be to ensure compliance with the requirements of the construction documents and facilitate timely performance of the contract. The CONTRACTOR shall have in attendance at each meeting a representative of the Electrical Subcontractor who is responsible for the execution of the Work of this contract. The preliminary schedule and agenda for each of the meetings shall be as described below. The specific dates for each of the meetings shall be scheduled by the CONTRACTOR and approved by the Construction Manager. The Construction Manager shall be provided with two (2) weeks minimum advanced written notice of proposed scheduled meeting dates.
- 1.07 PROJECT/SITE CONDITIONS
- A. Environmental Conditions: The following environmental conditions are typical for the project site. All electrical equipment and materials shall be sized and derated for the specified conditions:

1. Elevation: 4,583 feet above mean sea level
 2. Outdoor Temperature:
 - a. Winter: -10 to 40 °F
 - b. Summer: 40 to 105 °F
 3. Indoor Air Temperature: 40 to 104 °F
- B. Area Classifications: For the purpose of delineating the basic electrical construction materials and installation requirements for this project, areas of the project have been classified on the Drawings as defined below. Electrical work within these areas shall conform to the requirements described below as well as the referenced code requirements.
1. Dry Non-Process Areas (NEMA 12): Areas requiring general purpose, NEMA 12, construction are indoor areas typically environmentally controlled non-process areas such as electrical rooms. NEMA 1 enclosures are acceptable where NEMA 12 and NEMA 1 gasketed are not available.
 2. Wet Process Areas (NEMA 4X): Areas requiring corrosion resistant, NEMA 4X, construction are all wet process areas. Wet process areas typically contain wastewater, chemicals, or sludge pumping or piping systems and are subject to spills and washdown. Wet process areas shall also include those areas containing chemicals.
 3. Outdoor Areas (NEMA 4X): Areas requiring corrosion resistant, NEMA 4X, construction are all outdoor areas. Outdoor areas are any areas located outside of a structure or not fully enclosed with four walls and a roof.
 4. Chemical Areas (NEMA 4X): Areas requiring corrosion resistant, NEMA 4X, non-metallic construction are all chemical storage or usage locations cited on plan Drawings. Such areas are chemically aggressive to all metallic construction.
 5. Hazardous Areas (NEMA 7): Area requiring explosion proof, NEMA 7, construction are all hazardous areas. Hazardous areas typically contain exposed wastewater, chemicals, and/or sludge pumping or piping systems and are subject to spills, wash down, and combustible gas presence. Hazardous areas are prone to corrosion.
- C. Construction Materials: Construction materials required for each area classification are listed in Table 260500-A appended to the end of this specification section. Refer to the individual specification section for each component for material composition and installation practices.

1.08 HANDLING AND STORAGE

- A. Delivery: Deliver electrical materials and equipment properly packaged. Utilize factory fabricated containers or wrappings for materials and equipment which protect materials and equipment from damage. Inspect materials and equipment to ensure that no damage has occurred during shipment.
- B. Storage: Store electrical materials and equipment indoors in original packaging in areas specifically designated for equipment storage. Protect equipment and materials from construction traffic and debris.
- C. Handling: Handle electrical materials and equipment carefully to prevent physical damage to materials and equipment. Remove packaging, including the opening of crates and containers, avoiding the use of excessive hammering, and jarring which could damage the materials and equipment contained therein. Do not install damaged materials or equipment; remove from site and replace damaged materials and equipment with new.

PART 2 PRODUCTS

2.01 EQUIPMENT AND MATERIALS

- A. Equipment and materials shall be new and free from defects. All material and equipment of the same or a similar type shall be of the same manufacturer throughout the work. Standard production materials shall be used wherever possible.

2.02 ELECTRICAL EQUIPMENT IDENTIFICATION

- A. General: Nameplates shall be made from laminated phenolic plastic. The nominal size of the nameplates shall be 3/4 inch high by 2 inches long. Nameplates shall have white backgrounds with 3/16-inch black letters. Nameplate engraving shall minimally identify the equipment or equipment served by the labeled device and shall be in complete English terminology as indicated on the Drawings. Nameplates shall be attached to enclosures utilizing UL-recognized mounting kits designed to maintain the overall UL Type rating of the enclosure. Mounting kit fasteners shall be stainless steel Type AHK10324X as manufactured by Hoffman, rivets, or epoxy-based adhesive.
- B. Legends: Descriptions given on the single line diagrams, control one-line diagrams, and panel schedules shall be used as the basis for nameplate engraving. In addition to the English description, each nameplate shall also indicate the equipment or device tag number. Additional engraving legend requirements shall be as defined below. If abbreviations are required because of space limitations, abbreviations shall be submitted to the ENGINEER for approval.
- C. Equipment: Nameplates shall be provided for the following equipment. Additional engraving requirements shall be as indicated in parenthesis for each equipment type.
 - 1. Panelboards, electrical cabinets, and enclosures
 - 2. Electrical switchgear and switchboards
 - 3. Motor-control centers
 - 4. Control panels
 - 5. Control stations (indicating equipment controlled)
 - 6. Power transfer equipment
 - 7. Transformers (indicating power source and equipment served)
 - 8. Disconnect, transfer, and bypass switches (indicating power source and equipment controlled)
 - 9. Light switches and manual motor starters (indicating power source and equipment controlled)
 - 10. Local motor starters (indicating power source and equipment controlled)

2.03 CUTTING AND PATCHING

- A. Comply with the requirements of the General Conditions for the cutting and patching of other work to accommodate the installation of electrical work. Except as individually authorized by the Construction Manager, cutting and patching of electrical work to accommodate the installation of other work is not permitted.

2.04 HOUSEKEEPING

- A. General: Electrical equipment shall be protected from dust, water and damage during the construction period. Electrical equipment including, but not limited to, motor control centers, motor controllers, panelboards, switchgear, and buses shall be wiped free of dust and dirt on the outside and kept dry.
- B. Upon completion of the work, remove all litter, waste material, unused materials, and CONTRACTOR's tools and equipment from the job site.
- C. Remove all construction debris, packing materials, shipping labels, etc., from the interior and exterior of the equipment. Thoroughly clean and remove construction markings from interior surfaces.
- D. Clean exterior surfaces of equipment of all construction debris and markings and leave the equipment in an unblemished condition.
- E. Clean all equipment filters in accordance with the manufacturer's instructions.
- F. Touch-up scratched or marred surfaces to match original finish.

2.05 TESTING

- A. The tests specified in Section 26 08 00 – Commissioning of Electrical Systems of these specifications shall be performed prior to energizing the electrical circuits.

2.06 CLOSEOUT

- A. General: Refer to the General Conditions sections for general closeout requirements.
- B. Lubrication: Clean and lubricate operational equipment.
- C. Training: Instruct OWNER personnel thoroughly in the operation, sequencing, maintenance, and safety/emergency provisions of the electrical systems.

2.07 MAINTENANCE MATERIALS

- A. Extra stock of spare parts, materials, replacement units, accessories, adjustment devices, and similar items as designated, for the OWNER initial use in maintaining the electrical equipment and systems in continued operation. Maintenance materials shall be furnished where specified in each equipment specification.

2.08 RECORD DOCUMENTS

- A. Record documents refer to those documents maintained and annotated by the CONTRACTOR during construction, and include record drawings in accordance with the General Conditions sections, and the following additional schedules, lists, and drawings:
 - 1. Interconnection Diagrams (Part 1 of this Section).
 - 2. Original Submittal Drawings (Part 1 of this Section).

PART 3 EXECUTION

3.01 INSPECTION

- A. Examine areas and conditions under which equipment is to be installed and notify CONTRACTOR in writing of conditions detrimental to proper completion of the work. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to the Installer.

3.02 GENERAL

- A. Coordinate equipment installation work with electrical raceway and wire/cable work, as necessary for proper interface.
- B. Tighten connectors and terminals, including screws and bolts, in accordance with equipment manufacturer's published torque tightening values for equipment connectors. Where manufacturer's torque 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.
- C. Cables larger than No. 6 AWG which hang from their vertical connections shall be supported from the structure within 2 feet of the connection.

3.03 INSTALLATION OF FREESTANDING EQUIPMENT

- A. Install equipment at the locations indicated, complying with manufacturer's written instructions, applicable requirements of NEC and NECA standards, and in accordance with recognized industry practices to ensure that products fulfill requirements.
- B. The floor or slab upon which the freestanding equipment is installed shall be smooth and level (within 1/8 inch per three feet in any direction).

3.04 INSTALLATION OF WALL-MOUNTED EQUIPMENT

- A. Install equipment at the locations indicated, complying with manufacturer's written instructions, applicable requirements of NEC and NECA standards, and in accordance with recognized industry practices to ensure that products fulfill requirements.
- B. Equipment enclosure shall be mounted on u-channel supports anchored to associated wall.
- C. Conduits shall be terminated on the sides and bottom of enclosures. Conduits shall not be installed in the top of the enclosure without approval of the Construction Manager.

3.05 GROUNDING

- A. Provide equipment grounding connections to equipment as indicated. Tighten connections to comply with tightening torques specified in UL Standard 486A to assure permanent and effective grounding.

3.06 FIELD QUALITY CONTROL

- A. Field inspection and testing of equipment shall be completed prior to energizing the equipment.
- B. Prior to energization of electrical circuitry, check all accessible connections to manufacturer's tightening torque specifications.

3.07 ADJUSTING AND CLEANING

- A. Adjust operating mechanisms for free mechanical movement.
- B. Touch-up scratched or marred surfaces to match original finish.

3.08 RUBBER MATS

- A. A three-foot-wide rubber mat shall be furnished and installed on the floor and in front of each piece of electrical equipment located indoors. The mat shall be long enough to cover the full length of each enclosure. The mat shall be 1/4 inch thick with beveled edges, canvas back, solid type with corrugations running the entire length of the mat. The mat shall be guaranteed extra quality, free from cracks, blow holes or other defects detrimental to their mechanical or electrical strength. The mat shall meet OSHA requirements and the requirements of ANSI/ASTM D 178 J6-7 for Type 2, Class 2 insulating matting.

3.09 CORROSION PROTECTION

- A. Wherever dissimilar metals, except conduit and conduit fittings, come into contact, the CONTRACTOR shall isolate these metals as required with neoprene washers, nine (9) mil polyethylene tape, or gaskets.
- B. Anti-oxidant compounds shall be used whenever there is a termination involving aluminum. Ideal Noalox or ENGINEER approved equivalent is acceptable.
- C. Bare aluminum is not permitted to be in direct contact with concrete or soil. Manufacturer approved protective coatings must be provided between aluminum and these materials.

TABLE 26 05 00-A

Component	Area Classification				
	Dry Non-Process Area (NEMA 12)	Wet Process Area (NEMA 4X)	Outdoors (NEMA 4X)	Chemical Areas (NEMA 4X)	Hazardous Areas (NEMA 7)
Rigid Conduit (exposed)	GRS	PGRS	GRS	PVC Schedule 80	PRAC
Rigid Conduit (concealed) ⁴	GRS	PGRS	PGRS	PVC Schedule 40	PRAC
Flexible Conduit ⁵	LFMC	LFMC	LFMC	LFMC	LFMC
Support Systems	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel/PVC	Stainless Steel
Fastening Hardware and Hanger Rods ^{2,3}	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel
Control Stations & Enclosures ^{2,3}	Steel	Stainless Steel	Stainless Steel	Fiberglass/PVC	Stainless Steel or Cast Aluminum (Explosion Proof)
Receptacles ^{2,6}	GFCI	WP, GFCI	WP, GFCI	WP, GFCI, NM	WP, GFCI, Explosion Proof

Switches ²	General	WP	WP	WP, NM	Stainless Steel or Cast Aluminum (Explosion Proof)
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Table A Notes:

1. Enclosures, device boxes, control stations, and raceway systems shall be mounted with 1/4-inch (minimum) air space between the electrical system and supporting structure.
2. Conduit terminations to control stations, enclosures, and device boxes in NEMA 4X, 7, and 12 areas shall be made through threaded hubs. Chemical Areas shall use Plastic Non-Metallic enclosures.
3. Control station and enclosure NEMA sealing ratings shall meet or exceed the rating designated by the area classification.
4. Conduit encased in concrete duct bank or beneath slab on grade shall be rigid nonmetallic conduit, raceway type PVC Schedule 40. Conduit concealed in concrete walls shall be raceway type PRAC.
5. Flexible conduit shall be utilized for final connections to equipment. Length shall be no greater than 24" and shall be fully supported per NEC.
6. All GFCI protection shall be provided by GFCI circuit breakers. GFCI receptacles are not permitted unless specifically called out by a note on the Drawings. All receptacles shall not be Tamper Resistant unless specifically called out on the Drawings.

Legend:

GRS – Galvanized Steel Conduit
 RAC – Rigid Aluminum Conduit
 PGRS – PVC Coated Galvanized Steel Conduit
 PRAC – PVC Coated Rigid Aluminum Conduit
 FMC – Flexible Metallic Conduit
 LFMC – Liquid tight Flexible Metallic Conduit
 WP – Weatherproof
 GFCI – Ground Fault Circuit Interrupter
 NM – Non-Metallic

Refer to surface raceways for electrical systems (see referenced sections) for additional requirements and details on conduit types and requirements.

END OF SECTION

SECTION 26 05 19

LOW VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The CONTRACTOR shall furnish, install, connect, test, and place in satisfactory operating condition all low voltage wire and cable indicated on the Drawings and as specified herein and/or required for proper operation. The work of connecting cables to equipment and devices shall be considered a part of this Section. All appurtenances required for the installation of cable and wire systems shall be furnished and installed by the CONTRACTOR.
- B. The scope of this Section does not include internal wiring factory installed by electrical equipment manufacturers.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00– COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 33.23 – SURFACE RACEWAYS FOR ELECTRICAL SYSTEMS
- E. Section 26 05 33.16 – BOXES FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

- A. ICEA Standards - Insulated Cable Engineers Association
- B. ASTM Standards - American Society of Testing Materials
- C. UL 1277 - Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members
- D. UL 44 - Standard for Thermoset-Insulated Wire and Cable
- E. ISO 9000 - International Organization for Standardization

1.04 SUBMITTALS

- A. In accordance with the procedures and requirements set forth in the General Conditions, the CONTRACTOR shall obtain from the wire and cable manufacturer and submit the following:
 - 1. Shop Drawings
 - 2. Reports of Field Tests
 - 3. Wiring Identification Methods
- B. Each submittal shall be identified by the applicable specification section.

1.05 SHOP DRAWINGS

- A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed material's compliance with the Contract Documents.
- B. Partial, incomplete, or illegible Submittals will be returned to the CONTRACTOR without review for resubmittal.
- C. Shop drawings shall include but not be limited to:
 - 1. Product data sheets.
 - 2. Cable pulling calculations (if required).
 - 3. Wiring identification methods and materials.
 - 4. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

1.06 IDENTIFICATION

- A. Each cable shall be identified as specified in Part 3, Execution, of this Specification.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. The wire and cable to be furnished and installed for this project shall be the product of manufacturers who have been in the business of manufacturing wire and cable for a minimum of ten (10) years. Wire and cable shall be designed, constructed and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as specified herein and indicated on the Drawings. Only one (1) manufacturer for each wire and cable type shall be permitted.
- B. The wire and cable manufacturer shall be ISO 9000 registered.
- C. The use of repackaged, respooled, or recycled wire is strictly prohibited. All wire shall be virgin and fresh stock, free from splices.

2.02 POWER WIRE AND CABLE

- A. Power cable and wire shall consist of stranded copper conductor with insulation type XHHW-2, rated 90°C and 600V.

- B. Conductors shall be stranded copper per ASTM-B8 and B-3, and Class B or C stranding contingent on the size unless otherwise specified. Minimum size wire shall be No. 12 AWG.
- C. Multi-conductor power cable assemblies shall be UL 1277 Listed, provided with a bonding conductor, and furnished with an overall PVC jacket.
- D. Power wire and cable shall be manufactured by the Okonite Company, the Southwire Company, General Cable, or approved equal.

2.03 CONTROL CABLE

- A. Control cable and wire shall consist of stranded copper conductor with insulation type XHHW-2, rated 90°C and 600V.
- B. Conductors shall be stranded copper per ASTM B-8 and B-3, and Class B or C stranding contingent on the size unless otherwise specified. Minimum wire size shall be No. 14 AWG.
- C. Multi-conductor control cable assemblies shall be UL 1277 Listed, provided with a bonding conductor, and furnished with an overall PVC jacket.
- D. Control cable shall be manufactured by the Okonite Company, the Southwire Company, General Cable, or approved equal.

2.04 LIGHTING AND RECEPTACLE WIRE

- A. The lighting and receptacle branch circuit wire shall consist of stranded copper conductor with insulation type THHN-THWN, rated 90°C dry, 75°C wet, and 600V.
- B. Conductors shall be solid copper per ASTM- B-3. Minimum size wire shall be No. 12 AWG.
- C. Lighting and receptacle wire shall be manufactured by the Okonite Company, the Southwire Company, General Cable, or approved equal.

2.05 INSTRUMENTATION CABLE

- A. The instrumentation cable for analog signals shall be single, shielded, twisted pairs or triads with 600-volt insulation and shall have a 75°C (minimum) insulation rating.
- B. Conductors shall be tin, or alloy coated (if available), soft, annealed copper, stranded per ASTM-B8, Class B stranding unless otherwise specified. Minimum size wire shall be No. 16 AWG.
- C. The instrumentation cable shall be Okoseal-N Type P-OS for single pair or triad applications and Okoseal-N Type SP-OS for multiple pair or triad applications as manufactured by the Okonite Company, Belden equivalent, Southwire Company equivalent, or approved equal.

2.06 COMMUNICATION CABLE

- A. Ethernet Shielded Twisted Pair (S/FTP) Cable. Ethernet cables and connectors shall be provided for a complete and working system, and/or as shown on the Drawings. Cable for Ethernet wiring shall be S/FTP Cat-6 cable.
 - 1. Category 6 S/FTP Cable shall meet the following requirements:
 - a. 23 AWG
 - b. 4 twisted pairs individually screened

- c. 100% coverage aluminum foil tape shield with overall braided screen
- d. Overall PVC jacket, 600 volt rated
- e. 1000BASE-T
- f. 30V rating with -10° to +75°C operating temperature
- g. Rated up to 250MHz
- 2. Plenum rated cable
 - a. Cable shall have FEP insulation jacketing and FEP insulation for conductors. Nonplenum rated cable shall have PVC insulation jacketing and polyethylene insulation for conductors. Cat-6 plenum rated cable shall be Belden 1872 or equal.

2.07 CONDUCTOR IDENTIFICATION

- A. Conductors shall be identified using a color-coding method. Color coding for individual power, control, lighting, and receptacle conductors shall be as follows:

- 1. 480/277V AC Power
 - a. Phase A - BROWN
 - b. Phase B - ORANGE
 - c. Phase C - YELLOW
 - d. Neutral - GREY
- 2. 120/208V or 120/240V AC Power
 - a. Phase A - BLACK
 - b. Phase B - RED
 - c. Phase C - BLUE
 - d. Neutral - WHITE
- 3. DC Power
 - a. Positive Lead - RED
 - b. Negative Lead - BLACK
- 4. DC Control
 - a. All wiring - BLUE
- 5. 120VAC Control
 - a. 120 VAC control wire shall be RED except for a wire entering a motor control center compartment or control panel which is an interlock. This interlock conductor shall be color coded YELLOW.
- 6. 24VAC Control
 - a. All wiring - ORANGE
- 7. Equipment Grounding Conductor
 - a. All wiring - GREEN

- B. Individual conductors No. 2 AWG and smaller shall have factory color coded insulation. It is acceptable for individual conductors larger than No.2 AWG to be provided with factory color

coded insulation as well, but it is not required. Individual conductors larger than No.2 AWG that are not provided with factory color coded insulation shall be identified using colored tape in accordance with the requirements listed in Part 3 herein. Insulation colors and tape colors shall be in accordance with the color-coding requirements listed above.

- C. Conductors that are a part of multi-conductor control cable assemblies shall have black insulation. The conductor number shall be printed on each conductor's insulation in accordance with ICEA S-58-679, Method 4. Each conductor within the cable assembly shall also be identified with a heat shrink tag with color coded background in accordance with the requirements listed in Part 3 herein. Background color shall be in accordance with the color-coding requirements listed above.
- D. Conductors that are a part of multi-conductor power cable assemblies shall have black insulation. The conductor number shall be printed on each conductor's insulation in accordance with ICEA S-58-679, Method 4. Each conductor No.2 AWG and smaller within the cable assembly shall also be identified with a heat shrink tag with color coded background. Each conductor larger than No.2 AWG within the cable assembly shall also be identified using colored tape. Heat shrink tags and colored tape shall be in accordance with the requirements listed in Part 3 herein. Tape color and heat shrink tag background color shall be in accordance with the color-coding requirements listed above.

2.08 CABLE PULLING LUBRICANTS

- A. Cable pulling lubricants shall be non-hardening type and approved for use on the type of cable installed. Lubricant shall be Yellow #77 Plus by Ideal, Cable Gel by Greenlee, Poly-Gel by Gardner Bender, or approved equal.

PART 3 EXECUTION

3.01 POWER, CONTROL, AND LIGHTING/RECEPTACLE WIRE AND CABLE INSTALLATION

- A. The wire and cable shall be installed as specified herein and indicated on the Drawings.
- B. The cables shall be terminated in accordance with the cable and/or termination product manufacturer's instructions for that particular type of cable.
- C. To minimize oxidation and corrosion, wire and cable shall be terminated using an oxide-inhibiting joint compound recommended for "copper-to-copper" connections. The compound shall be Penetrox E as manufactured by Burndy Electrical or approved equal.
- D. Splices shall not be allowed in the underground manhole and handhole systems. If splices are required, the CONTRACTOR shall obtain approval in writing from the ENGINEER prior to splicing. Splicing materials shall be barrel type butt splice connectors and heat shrink tubing as manufactured by 3M, Ideal, or approved equal. No splicing of instrumentation cable is allowed. The use of screw-on wire connectors (wire nuts) shall only be permitted for lighting and receptacle circuits.
- E. Wire and Cable Sizes
 - 1. The sizes of wire and cable shall be as indicated on the Drawings, or if not shown, as approved by the ENGINEER. If required due to field routing, the size of conductors and respective conduit shall be increased so that the voltage drop measured from source to load does not exceed 2-1/2%.

F. Additional Conductor Identification

1. In addition to the color-coding identification requirements specified in Part 2 herein, individual conductors shall be provided with heat shrinkable identification tags. Identification tags for individual conductors shall have a white background where the conductor insulation is colored. Identification tags for individual conductors shall have a colored background where the conductor insulation is black. Background color shall match that of the taping provided on the individual black conductors.
2. Multi-conductor cables shall be provided with heat shrinkable identification tags in accordance with Part 2 herein.
3. All wiring shall be identified at each point of termination. This includes but is not limited to identification at the source, load, and in any intermediate junction boxes where a termination is made. The CONTRACTOR shall meet with Owner and ENGINEER to come to an agreement regarding a wire identification system prior to installation of any wiring. Wire numbers shall not be duplicated.
4. Wire identification shall be by means of a heat shrinkable sleeve with appropriately colored background and black text. Wire sizes #14 AWG through #10 AWG shall have a minimum text size of 7 points. Wire sizes #8 AWG and larger shall have a minimum text size of 10 points. Sleeves shall be of appropriate length to fit the required text. The use of handwritten text for wire identification shall not be permitted.
5. Sleeves shall be suitable for the size of wire on which they are installed. Sleeves shall not be heat-shrunk onto control cables. Tags shall remain loose on cable to promote easier identification. For all other applications, sleeves shall be tightly affixed to the wire and shall not move. Sleeves shall be heat shrunk onto wiring with a heat gun approved for the application. Sleeves shall not be heated by any means which employs the use of an open flame. The CONTRACTOR shall take special care to ensure that the wiring insulation is not damaged during the heating process.
6. Sleeves shall be installed prior to the completion of the wiring terminations and shall be oriented so that they can be easily read.
7. Sleeves shall be polyolefin as manufactured by Brady, Seton, Panduit, or approved equal.
8. Wire identification in manholes, handholes, pull boxes, and other accessible components in the raceway system where the wiring is continuous (no terminations are made) shall be accomplished by means of a tag installed around the bundled group of individual conductors or around the outer conductor jacket of a multi-conductor cable. Identification shall utilize a FROM-TO system. Each group of conductors shall consist of all the individual conductors in a single conduit or duct. The tag shall have text that identifies the bundle in accordance with the 'FROM' and 'TO' column for that conduit number in the conduit and wire schedule. Minimum text size shall be 10 point. The tag shall be affixed to the wire bundle by the use of nylon wire ties and shall be made of polyethylene as manufactured by Brady, Seton, Panduit, or approved equal.
9. Where colored tape is used to identify cables, it shall be wrapped around the cable with a 25% overlap and shall cover at least 2 inches of the cable.

G. Wiring Supplies

1. Only electrical wiring supplies manufactured under high standards of production and meeting the approval of the ENGINEER shall be used.
2. Rubber insulating tape shall be in accordance with ASTM Des. D119. Friction tape shall be in accordance with ASTM Des. D69.

H. Training of Cable

1. The CONTRACTOR shall furnish all labor and material required to train cables around cable vaults within buildings and in manholes and handholes in the outdoor underground duct system. Sufficient length of cable shall be provided in each handhole, manhole, and vault so that the cable can be trained and racked in an approved manner. In training or racking, the radius of bend of any cable shall be not less than the manufacturer's recommendation. The training shall be done in such a manner as to minimize chaffing. Reference Surface Raceways for Electrical Systems (See Referenced Sections).
2. Instrumentation cable shall be racked separate from other AC and DC wiring to maintain the required separation as follows:
 - a. 18 inches for 480/277VAC wiring
 - b. 12 inches for 208/120VAC wiring
 - c. 6 inches for 24VDC wiring

I. Conductor Terminations

1. Where wires are terminated at equipment which requires lugs, connections shall be made by solderless mechanical lug, crimp type ferrule, or irreversible compression type lugs. Reference individual equipment specification sections as applicable for additional termination requirements.
2. Where enclosure sizes and sizes of terminals at limit switches, solenoid valves, float switches, pressure switches, temperature switches, and other devices make terminations impractical due to the size of the field wiring, the CONTRACTOR shall terminate field wiring in an adjacent junction per the requirements of Boxes for Electrical Systems (See Referenced Sections), complete with terminal strips. CONTRACTOR shall install the smaller wiring from the device to the junction box in a conduit, using the terminal strip as the means for joining the two different wire sizes. Splicing of wires in lieu of using terminal strips is not acceptable.
3. All spare conductors shall be terminated on terminal blocks mounted within equipment or junction boxes. Unless otherwise noted, coiling up of spare conductors within enclosure is not acceptable.

J. Pulling Temperature

1. Cable shall not be flexed or pulled when the temperature of the jacket is such that damage will occur due to low temperature embrittlement. When cable is pulled with an ambient temperature of 40°F or less within a three (3) day period prior to pulling, the cable reels shall be stored three (3) days prior to pulling in a protected storage area with an ambient temperature of 55°F or more. Cable pulling shall be completed during the workday for which the cable is removed from the protected storage. Any remaining cable reels shall be returned to storage at the completion of the workday.

3.02 INSTRUMENTATION CABLE INSTALLATION

- A. The CONTRACTOR shall install all cable or conductors used for instrumentation wiring (4 20 mA DC, etc.) in conduit as specified in Surface Raceways for Electrical Systems (See Referenced Sections). Only instrumentation cable as specified herein shall exclusively occupy these conduits. No other wiring for AC or discrete DC circuits shall be installed in these conduits.
- B. All shielding shall be continuous and shall be grounded at one point only.

- C. Where instrumentation cables are installed in panels, manholes, handholes, and other locations, the CONTRACTOR shall arrange wiring to provide maximum clearance between these cables and other conductors. Instrumentation cables shall not be installed in same bundle with conductors of other circuits.
- D. Special instrument cable shall be as specified or recommended by the manufacturer of the equipment or instruments requiring such wiring. Installation, storage, and terminations shall be per manufacturer's recommendations.

3.03 TESTING

- A. All testing shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 - 1. Shop Test
 - a. Cable and wiring shall be tested in accordance with the applicable ICEA Standards. Wire and cable shall be physically and electrically tested in accordance with the manufacturer's standards.
 - 2. Field Tests
 - a. After installation, all wires and cables shall be tested for continuity. Testing for continuity shall be "test light" or "buzzer" style.
 - b. After installation, some wires and cables shall be tested for insulation levels. Insulation resistance between conductors of the same circuit and between conductor and ground shall be tested. Testing for insulation levels shall be as follows:
- B. For #8 AWG and larger 600V power and control cable, apply 1,000 VDC from a Megohmmeter for one (1) minute for all 600V wires and cables installed in lighting, control, power, indication, alarm and motor feeder circuits. Resistance shall be no less than 100 Megaohms. Insulation testing is not required for power and control cables smaller than #8 AWG.
- C. 600V instrumentation signal cable shall be tested from conductor to conductor, conductor to shield, and conductor to ground using a Simpson No. 260 volt-ohmmeter or approved equal. The resistance value shall be 200 Megaohms or greater.
- D. Wires and cables shall be tested before being connected to motors, devices or terminal blocks.
- E. If tests reveal defects or deficiencies, the CONTRACTOR shall make the necessary repairs or shall replace the cable as directed by the ENGINEER, without additional cost to Owner.
- F. All tests shall be made by and at the expense of the CONTRACTOR who shall supply all testing equipment. Test reports shall be submitted to the ENGINEER.

(EXHIBIT A) TEST DATA - MEGOHMS TEST NO. ____							
Date:			Company:				
Time:			Location:				
Circuit:	Circuit Length:	Aerial:	Duct:	Buried:	No. of Conductors	Size:	AMG MCM Shld:
Insulation Material:			Insulation Thickness:		Voltage Rating:		Age:
Type: ____ Pothead ____ Terminal					Location: Indoors____ Outdoors____		
Number and Type of Joints:							
Recent Operating History:							
Manufacturer:							
State if Potheads or Terminals were grounded during test:							
List associated equipment included in test:							
Miscellaneous Information:							

(EXHIBIT A) TEST DATA - MEGOHMS TEST NO. ____							
Part Tested: Test Made: _____ Hours/Days: _____ After Shutdown: _____							
Grounding Time: Dry Bulb Temperature: _____ Wet Bulb Temperature: _____							
Test Voltage: _____				Equipment Temperature: _____ How Obtained: _____ Relative Humidity: _____ Absolute Humidity: _____ Dew Point: _____			
Megohmmeter: Serial Number: _____ Range: _____ Voltage: _____ Calibration Date: _____							
Test Connections	To Line To Earth To Ground	To Line To Earth To Ground	To Line To Earth To Ground	Test Connections	To Line To Earth To Ground	To Line To Earth To Ground	To Line To Earth To Ground
☐ Minute				5 Minutes			
☐ Minute				6 Minutes			
3/4 Minute				7 Minutes			
1 Minute				8 Minutes			
2 Minutes				9 Minutes			
3 Minutes				10 Minutes			
4 Minutes				10 1/2 Minutes			
				Ratio			
Remarks:							

END OF SECTION

SECTION 26 05 26

GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The CONTRACTOR shall furnish and install grounding systems complete in accordance with the minimum requirements established by Article 250 of the NEC. Article 250 of the NEC shall be considered a minimum requirement for compliance with this Specification.
- B. Grounding of all instrumentation and control systems shall be furnished and installed in accordance with the manufacturer/system requirements and IEEE 1100-92, Powering and Grounding of Sensitive Electronic Equipment. Conflicts shall be promptly brought to the attention of the ENGINEER.
- C. In addition to the NEC requirements, building structural steel columns and overhead crane structure supports shall be permanently and effectively grounded.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 33.23 – SURFACE RACEWAYS FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

- A. UL 467 - Grounding and Bonding Equipment
- B. IEEE 81 - Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
- C. IEEE 1100-92 - Powering and Grounding of Sensitive Electronic Equipment
- D. NETA ATS - Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Shop Drawings - Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.
 - 1. Partial, incomplete, or illegible submittals will be returned to the CONTRACTOR without review for resubmittal.
 - 2. Shop drawings shall include but not be limited to:

- a. Product data sheets.
- b. Drawings and written description of how the CONTRACTOR intends to furnish and install the grounding system.
- c. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

C. Manufacturer's Certification - Certify that products meet or exceed specified requirements.

D. Identified by applicable specification section.

1.05 INFORMATION SUBMITTALS

A. Submittals shall be in accordance with the General Conditions, and as specified herein.

B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:

- 1. Manufacturer's equipment warranty.
- 2. Copies of Submittals.
- 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety.
- 4. Contact information for local representative and supplier.

C. Results of certified field tests.

1.06 HANDLING AND STORAGE

A. Equipment shall be carefully transported, stored, handled, and set in place in a manner that will prevent damage, misalignment, and distortion to the components.

B. Follow manufacturer's recommendations regarding handling and storage at all times prior to installation of the equipment.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. The equipment covered by these specifications shall be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.

2.02 GROUND RODS, RING, AND GRID

- A. Ground rods shall be rolled to a commercially round shape from a welded copper clad steel manufactured by the molten welding process or by the electro formed process (molecularly bonded). They shall have an ultimate tensile strength of 75,000 pounds per square inch (psi) and an elastic limit of 49,000 psi. The rods shall be not less than 3/4 inch in diameter by 10 feet in length; and the proportion of copper shall be uniform throughout the length of the rod. The copper shall have a minimum wall thickness of 0.010 inch at any point on the rod. Ground rods shall be UL 467 listed. The ground rods shall be manufactured by Erico Products, Blackburn, or equal.
- B. Except where specifically indicated otherwise, all exposed non-current carrying metallic parts of electrical equipment, metallic raceway systems, grounding conductors in nonmetallic raceways and neutral conductors of wiring systems shall be grounded.
- C. The ground connection shall be made at the main service equipment and shall be extended to the grounding system surrounding the structure. The grounding shall also be connected to the point of entrance of the metallic water service. Connection to the water pipe shall be made by a suitable ground clamp or lug connection to a plugged tee. If flanged pipes are encountered, connection shall be made with the lug bolted to the street side of the flanged connection. Where a Cathodic Protection system is used on equipment, the grounding of this equipment shall meet the Cathodic Protection system Manufacturer's installation requirements. Refer to the Cathodic Protection system specifications for additional requirements.
- D. Where ground fault protection is employed, care shall be taken so that the connection of the ground and neutral does not interfere with the correct operation of the ground fault protection system.

2.03 FITTINGS

- A. Grounding connections to equipment shall be bolted. Cable end connections shall be made by hydraulic crimp or exothermically welded. Split bolt type connectors are not acceptable. Fittings shall be UL 467 listed.

2.04 EQUIPMENT GROUNDING CONDUCTORS

- A. An insulated equipment grounding conductor, which shall be separate from the electrical system neutral conductor, shall be furnished and installed for all circuits. Insulation shall be of the same type as the underground conductors in the raceway and shall be green in color. Equipment grounding conductors shall be furnished and installed in all conduits. Use of conduits as the NEC required equipment grounding conductor is not acceptable.

2.05 EQUIPMENT GROUNDS

- A. Equipment grounds shall be solid and continuous from a connection at earth to all distribution panelboards. Ground connections at panelboards, outlets, equipment, and apparatus shall be made in an approved and permanent manner.

2.06 EXOTHERMIC WELDS

- A. All exothermic welding shall be completed per welding kit manufacturer's instructions. Exothermic welds shall be CadWeld by Erico or ThermoWeld.

2.07 EXISTING GROUNDING SYSTEMS

- A. The CONTRACTOR shall connect the new ground ring to any existing grounding rings or conductors if found. Unless noted in the Drawings, the presence of an existing grounding ring does not relieve the CONTRACTOR from installing a new grounding ring as shown on the Drawings.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Metal surfaces where grounding connections are to be made shall be clean and dry. Steel surfaces shall be ground or filed to remove all scale, rust, grease, and dirt. Copper and galvanized steel shall be cleaned with emery cloth to remove oxide before making connections.
- B. Ground Grid and Ring
 - 1. A main ground grid or ring shall be provided for each structure and interconnecting structure grids consisting of driven ground rods as shown on the Drawings. The ground rods shall be interconnected by the use of copper cable exothermically welded to the rods. The grounding cables shall be installed after the excavations for the building have been completed and prior to the pouring of concrete for the footings, mats, etc. Copper "pigtails" shall be connected to the ground grid and shall enter the buildings and structure from the outside and shall be connected to steel structures, and equipment as described in this Section and as required to provide a complete grounding system. The copper pigtailed shall be exothermically welded to the ground grid and connected to building reinforcement steel by hydraulic crimp.
 - 2. Grounding conductors shall be continuous between points of connection; splices shall not be permitted.
 - 3. Where conductors are exposed and subject to damage from personnel, traffic, etc., conductors shall be installed in metal raceway. The raceway shall be bonded to the grounding system.
 - 4. Where subsurface conditions do not permit use of driven ground rods to obtain proper ground resistance, rods shall be installed in a trench or plate electrodes shall be provided, as applicable and necessary to obtain proper values of resistance.
 - 5. Buried exothermic welds and ground ring shall not be backfilled until inspected by ENGINEER.
- C. Raceways
 - 1. Conduit which enters equipment such as switchgear, motor control centers, transformers, panelboards, variable frequency drives, instrument and control panels, and similar equipment shall be bonded to the ground bus or ground lug, where provided, and as otherwise required by the NEC.

3.02 TESTING AND STARTUP

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 - 1. Witnessed Shop Tests
 - a. None required.

2. Field Tests

- a. Field testing shall be done in accordance with the requirements specified in the General Conditions, and NETA Acceptance Testing Specifications, latest edition.
- b. Fall of potential tests shall be performed on the ground grid per IEEE81 recommendations by a third party, independent testing firm. A fall of potential plot shall be submitted at the conclusion of testing for ENGINEER review.
Documentation indicating the location of the rod and grounding system as well as the resistance and soil conditions at the time the measurements were made shall be submitted. Testing shall show that the ground grid has 5 ohms resistance or less. Due to soil conditions and/or unforeseen field conditions, ground resistances greater than 5 ohms may be acceptable if specifically approved in writing by the ENGINEER. Ground resistance measurements shall be made in normally dry weather not less than 48 hours after rainfall and with the ground grid under test isolated from other grounds.
- c. Continuity tests for the grounding electrode conductor shall also be performed. Test will be accepted when a resistance of less than 1 ohm is shown for this conductor.

END OF SECTION

SECTION 26 05 33.16

BOXES FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The scope of work under this Section includes furnishing and installing all pull boxes, junction boxes, and outlet boxes.
- B. Requirements for other boxes and enclosures are not included in this Section. Reference to each specific Division 26 equipment Section for requirements related to that equipment's respective enclosure.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 26 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS
- E. Section 26 05 33.23 – SURFACE RACEWAYS FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

- A. UL 514A - Metallic Outlet Boxes
- B. UL 514C - Standard for Non-metallic Outlet Boxes, Flush Device Boxes, and Covers
- C. UL 50 - Enclosures for Electrical Equipment, Non-environmental Considerations
- D. UL 50E - Enclosures for Electrical Equipment, Environmental Considerations
- E. UL 1203 - Standard for Explosion-proof and Dust-ignition-proof Electrical Equipment for use in Hazardous (Classified) Locations
- F. NEMA 250 - Enclosures for Electrical Equipment

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Product Datasheets
- C. Layout Drawings for all boxes larger than standard receptacle boxes.
- D. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In

the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

1.05 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:
 - 1. Manufacturer's equipment warranty.
 - 2. Copies of Submittals.
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety.
 - 4. Contact information for local representative and supplier.

1.06 HANDLING AND STORAGE

- A. Follow manufacturer's recommendations regarding handling and storage at all times prior to placing the devices in service.

PART 2 PRODUCTS

2.01 PULL AND JUNCTION BOXES

- A. General
 - 1. All pull and junction boxes shall be UL listed and labeled.
 - 2. Pull and junction boxes shall not be provided with eccentric or concentric knockouts.
 - 3. Pull and junction boxes mounted embedded in concrete shall be UL listed for embedment.
 - 4. Where metallic boxes are used, they shall be of all welded construction. Tack welded boxes are not acceptable.
- B. Pull Boxes
 - 1. All pull boxes shall be provided with a matching gasketed cover. For covers with dimensions of 24 inches by 24 inches or less, the cover shall be held in place by machine screws. Other screw types are not acceptable. For covers with dimensions greater than 24 inches by 24 inches, the cover shall be hinged and held in place by screw-operated clamp mechanisms. Hinge pins shall be removable. Clamp mechanism material of construction shall match that of the associated box.
 - 2. Pull boxes shall not have any wire terminations inside, other than those for grounding/bonding. A ground bar shall be provided with the necessary number of screw type terminals. Twenty (20) percent of the total amount of terminals otherwise required for the pull box (minimum of two) shall be provided as spare terminations. Boxes

requiring any other wire terminations shall be furnished and installed in accordance with the requirements for junction boxes herein.

3. Pull boxes shall be 6 inches wide by 6 inches tall by 4 inches deep, minimum. For applications requiring larger boxes, the box shall be sized in accordance with the fill requirements and dimensional requirements of the NEC.
4. Barriers shall be provided in pull boxes to isolate conductors of different voltages, types, and functions. Barrier material of construction shall match that of the box. Isolation shall be provided between the following groups:
 - a. Power wiring
 - b. AC Control wiring
 - c. DC Control wiring
 - d. Instrumentation wiring
 - e. Network wiring

C. Junction Boxes

1. Junction boxes used for lighting and receptacle circuits only shall be provided with a matching gasketed cover held in place by machine screws. Other screw types are not acceptable.
2. Junction boxes for all uses other than lighting and receptacle circuits shall be provided with a hinged, gasketed cover. Hinge pins shall be removable. Cover shall be held in place by screw-operated clamp mechanisms. Clamp mechanism material of construction shall match that of the associated box.
3. Barriers shall be provided in junction boxes to isolate conductors and terminal blocks of different voltages, types, and functions. Barrier material of construction shall match that of the box. Isolation shall be provided between the following groups:
 - a. Power wiring
 - b. AC control wiring
 - c. DC control wiring
 - d. Instrumentation wiring
 - e. Network wiring
4. Junction boxes used for lighting and receptacle circuits only shall be allowed to have screw-on (wire nut) type connectors for wire terminations/junctions.
5. Junction boxes for all uses other than lighting and receptacle circuits shall be provided with terminal strips consisting of the necessary number of screw type terminals. Current carrying parts of the terminal blocks shall be of ample capacity to carry the full load current of the circuits connected, with a 10A minimum capacity. Terminal strips shall be rated for the voltage of the circuits connected. A separate ground bar shall be provided with the necessary number of screw type terminals. Twenty (20) percent of the total amount of terminals otherwise required for the junction box (minimum of two) shall be provided as spare terminations. When barriers are provided within the box, separate terminal strips shall be provided in each barrier area. Terminals shall be lettered and/or numbered to conform to the wiring labeling scheme in place on the project.
6. Junction boxes shall be 6 inches wide by 6 inches tall by 4 inches deep, minimum. For applications requiring larger boxes, the box shall be sized in accordance with the fill requirements and dimensional requirements of the NEC. Terminal blocks (including spare terminals) shall be considered when sizing the junction box.

D. Enclosure Types and Materials

1. In non-hazardous locations, pull and junction boxes shall be furnished with the following enclosure type and material of construction, dependent upon the designation of the area in which they are to be installed. Area designations are indicated on the Drawings.

AREA DESIGNATION	ENCLOSURE TYPE AND MATERIAL
Indoor Wet Process Area	NEMA 4X, Type 304 Stainless Steel
Indoor Dry Process Area	NEMA 12, Painted Steel
Indoor Dry Non-process Area	NEMA 12, Painted Steel
Indoor Type 1 Chemical Storage/Transfer Area	NEMA 4X, Fiberglass or PVC
Indoor Type 2 Chemical Storage/Transfer Area	NEMA 4X, Type 304 Stainless Steel
All Outdoor Areas	NEMA 3R, Painted Steel

2. In hazardous locations, pull and junction boxes shall be furnished with the following enclosure type and material of construction, dependent upon the classification of the area in which they are to be installed. Area classifications are indicated on the Drawings.

AREA CLASSIFICATION	ENCLOSURE TYPE AND MATERIAL
Class I, Division 1, Group D	NEMA 7, Die Cast Aluminum
Class I, Division 2, Group D	NEMA 4X, Type 304 Stainless Steel
Class II, Division 1, Group F	NEMA 9, Die Cast Aluminum
Class II, Division 2, Group F	NEMA 4X, Type 304 Stainless Steel

3. Non-metallic enclosures, NEMA 7 enclosures, and NEMA 9 enclosures shall be provided with threaded integral conduit hubs.

2.02 OUTLET BOXES

A. General

1. Outlet boxes shall be provided with a trim appropriate for the wiring device installed inside. Reference Wiring Devices (See Referenced Sections) for outlet box trim requirements. An appropriate outlet box trim is required to achieve the NEMA rating of the outlet boxes as specified herein.

B. Surface Mount Outlet Boxes

1. Outlet boxes shall be the deep type, no less than 2.5 inches deep.
2. Outlet boxes shall be provided in single or multi-gang configuration as required, sized in accordance with the requirements of the NEC.
3. In non-hazardous locations, outlet boxes shall be furnished with the following enclosure type and material of construction, dependent upon the designation of the area in which they are to be installed. Area designations are indicated on the Drawings.

AREA DESIGNATION	ENCLOSURE TYPE AND MATERIAL
Indoor Wet Process Area	NEMA 4X, Cast Aluminum
Indoor Dry Process Area	NEMA 1, Cast Iron
Indoor Dry Non-process Area	NEMA 1, Cast Iron
Indoor Type 1 Chemical Storage/Transfer Area	NEMA 4X, PVC

Indoor Type 2 Chemical Storage/Transfer Area	NEMA 4X, Cast Aluminum
All Outdoor Areas	NEMA 4X, Cast Aluminum

4. In hazardous locations, outlet boxes shall be furnished with the following enclosure type and material of construction, dependent upon the classification of the area in which they are to be installed. Area classifications are indicated on the Drawings.

AREA CLASSIFICATION	ENCLOSURE TYPE AND MATERIAL
Class I, Division 1, Group D	NEMA 7, Die Cast Aluminum
Class I, Division 2, Group D	NEMA 4X, Cast Aluminum
Class II, Division 1, Group F	NEMA 9, Die Cast Aluminum
Class II, Division 2, Group F	NEMA 4X, Cast Aluminum

5. Outlet boxes shall be provided with integral threaded conduit hubs mounted external to the box. Boxes with threaded conduit hubs mounted internal to the box or as a part of the box wall are not acceptable.

C. Flush Mount Outlet Boxes

- Outlet boxes shall be no less than 2-1/8 inches deep, and 4-11/16 inches square. Boxes shall be UL listed and labeled. Pre-punched single diameter conduit knockouts are acceptable; however, concentric and eccentric knockouts are not acceptable.
- Outlet boxes mounted flush in CMU walls shall be made of galvanized, tack welded steel, and suitable for installation in masonry walls. Sectional type boxes are not acceptable for this application.
- Outlet boxes mounted flush in gypsum walls shall be made of galvanized pressed steel. Tack welded boxes are not acceptable for this application. Sectional type boxes are not acceptable for this application.
- Outlet boxes mounted cast into concrete shall be concrete tight and shall be made of galvanized steel or PVC.

PART 3 EXECUTION

3.01 INSTALLATION

A. Pull and Junction Boxes

- Pull boxes and junction boxes shall be solidly attached to structural members prior to installation of conduit and set true and plumb. Boxes shall not be supported by their associated conduits.
- Wooden plugs are not permitted for securing boxes to concrete. Appropriately rated anchors specifically suited for use in concrete shall be used.
- Box penetrations for conduits shall be made with a punch tool, and penetrations shall be of the size required for the conduit entry and/or hub. Oversized penetrations in boxes are not acceptable.
- Watertight conduit hubs shall be provided for boxes where a NEMA 4X enclosure rating is specified. Reference Surface Raceways for Electrical Systems (See Referenced Sections) for conduit hub requirements.

5. Pull and junction boxes may be installed flush mounted in gypsum, concrete, or CMU walls where appropriate if covers are easily removed or opened.
6. Pull and junction boxes shall be provided in the enclosure type and material of construction required for the area in which it is installed. Reference the requirements in Part 2 herein, and the area designations indicated on the Drawings.

B. Outlet Boxes

1. Outlet boxes shall be solidly attached to structural members prior to installation of conduit and set true and plumb. Boxes shall not be supported by their associated conduits.
2. Wooden plugs are not permitted for securing boxes to concrete. Appropriately rated anchors specifically suited for use in concrete shall be used.
3. Flush mounted outlet boxes shall be arranged and located so that tile and grout lines fit closely around the boxes, and so placed that the cover or device plate shall fit flush to the finished wall surface.
4. Outlet boxes shall be flush mounted in finished areas and other areas where practical. Flush mounted outlet boxes shall not be installed in hazardous areas and type 1 or 2 chemical storage/transfer areas.
5. For the below-named items, mounting heights from finished floor, or finished grade to top is applicable, depending on the type of wiring device to be installed in the outlet box. Mounting heights for outlet boxes shall be as follows, unless otherwise specified herein, indicated on the Drawings, or required by the Americans with Disability Act (ADA):
 - a. Light switches and wall mounted occupancy sensors, 48 inches
 - b. Receptacles in indoor dry process/non-process areas, 16 inches
 - c. Receptacles in indoor wet process areas and all indoor chemical storage/transfer areas, 48 inches
 - d. Receptacles in outdoor locations, 24 inches
 - e. Ceiling mounted occupancy sensors, as indicated on the Drawings
6. Outlet boxes shall be provided in the material of construction required for the area in which it is installed. Reference the requirements in Part 2 herein, and the area designations indicated on the Drawings.

END OF SECTION

SECTION 26 05 33.23

SURFACE RACEWAYS FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. Under this Section, the CONTRACTOR shall furnish and install all conduits and conduit fittings to complete the installation of all electrically operated equipment as specified herein and as required.
- B. The Drawings indicate the general location of conduits both exposed and concealed; however, the CONTRACTOR shall install these conduits in such a manner to avoid all interferences.
- C. All CONTRACTOR personnel installing PVC coated rigid conduit shall be trained as specified herein.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions - SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL

1.03 REFERENCES

- A. NFPA 70 - National Electrical Code (NEC)
- B. UL 467 - Grounding and Bonding Equipment
- C. UL 514 - Standard for Safety Conduit, Tubing, and Cable Fittings

1.04 SUBMITTALS

- A. In accordance with the procedures and requirements set forth in the General Conditions, the CONTRACTOR shall obtain from the equipment manufacturer and submit shop drawings. Each submittal shall be identified by the applicable Specification section.

1.05 SHOP DRAWINGS

- A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.
- B. Partial, incomplete, or illegible submittals will be returned to the CONTRACTOR without review for resubmittal.
- C. Shop drawings shall include but not be limited to:
 - 1. Product data sheets.
 - 2. Conduit identification methods and materials.

3. Evidence of training (e.g. Certificates of Completion) for all CONTRACTOR personnel that will install PVC coated rigid conduit. Training shall be as specified herein.
4. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. The material covered by this Specification is intended to be standard material of proven performance as manufactured by reputable concerns. Material shall be fabricated, constructed and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as specified herein and shown on the Drawings.

2.02 CONDUITS

- A. Unless specified otherwise herein, or indicated on the Drawings, all conduits shall be rigid, hot-dipped galvanized steel. Minimum size conduit shall be 3/4 inch unless otherwise indicated on the Standard Details. Unless specified otherwise herein or indicated on the Drawings, all encased conduits shall be PVC Schedule 40, minimum size 1 inch. The CONTRACTOR, at his option, for ease of installation to accommodate saddle size, may increase the size of encased conduits to 2-inch. However, no combining of circuits/conductors will be permitted in these larger conduits.
- B. All components (fittings, couplers, connectors, etc.) of the conduit system shall be of the same or compatible material of construction. Coated conduit systems shall include factory coated fittings couplings, connectors, and other components compatible with and approved for coated conduit systems.
- C. Rigid Steel Conduit
 1. Steel conduits shall be rigid type, heavy wall, hot-dipped galvanized inside and outside and as manufactured by Allied Tube and Conduit Corporation, Wheatland Tube Company, Jones & Laughlin Steel Company, or ENGINEER approved equal.
 2. Each length of conduit shall be shipped with a coupling on one end and a color-coded thread protector at the other end.
- D. Rigid Aluminum Conduit
 1. Aluminum conduits shall be rigid type, heavy walled as manufactured by Allied Tube and Conduit Corporation, Wheatland Tube Company, Jones & Laughlin Steel Company, or approved equal.
 2. Rigid aluminum conduit shall be manufactured of 6063 alloy in temper designation T1. Fittings shall be of the same alloy.

3. Rigid aluminum conduit shall be listed by Underwriters' Laboratories to U.L. Standard 6A shall be manufactured to 26 27 26 – Wiring Devices.
 4. Each length of conduit shall be shipped with a coupling on one end and a color-coded thread protector at the other end.
- E. Flexible Metal Conduit
1. Flexible metal conduit (FMC) shall be galvanized steel, single strip. FMC shall be UL listed. FMC shall be used to connect all indoor vibrating equipment, installed in dry locations, above reflected ceilings to lighting fixtures, and other applications as accepted by the ENGINEER. FMC shall be Galflex Type RWS as manufactured by Southwire, Type BR as manufactured by Electri-Flex, or approved equal.
- F. Liquid Tight Flexible Metal Conduit
1. Liquid tight flexible conduit (LFMC) shall be galvanized steel, single strip, with a copper strip interwoven and suitable as a grounding means. LFMC shall be UL listed. LFMC shall have an extruded moisture and oil-proof PVC jacket. LFMC shall be Titan Type UL as manufactured by Southwire, Liqueflex Type "LA" as manufactured by Electri-Flex, Anaconda Type UA as manufactured by Anamet Electrical, Inc., or approved equal.
 2. PVC coated or stainless-steel watertight connectors shall be used with liquid tight flexible metal conduit on both ends. LFMC shall be used to connect all vibrating equipment installed outdoors, in wet or damp areas, and other applications as directed by the ENGINEER.
- G. Liquid Tight Flexible Non-Metallic Conduit
1. Liquid tight flexible non-metallic conduit (LFNC) shall be constructed of PVC. LFNC shall be UL listed. LFNC shall have an extruded moisture and oil-proof PVC jacket. LFNC shall be Ultratite Type NM as manufactured by Southwire, Type NM as manufactured by Electri-Flex, Anaconda Type NMUA by Anamet Electrical, Inc., or approved equal.
 2. Watertight connectors shall be used with liquid tight flexible non-metallic conduit on both ends. LFNC shall be used to connect all vibrating equipment installed in sodium hypochlorite storage and transfer areas as specified herein, and other applications as directed by the ENGINEER or as indicated on the drawings.
- H. Rigid Nonmetallic Conduit
1. Rigid nonmetallic conduit shall be Schedule 40 polyvinyl chloride (PVC), 90°C, UL rated and shall conform to NEMA TC 2. Fittings and conduit bodies shall conform to NEMA TC3.
 2. Rigid non-metallic conduit shall be manufactured by Carlon, Triangle Conduit and Cable, Cantex, Inc., or approved equal.
- I. PVC Coated Metallic Conduit
1. PVC coated rigid steel conduit shall be furnished and installed as specified herein and indicated on the Drawings. The product shall be rigid galvanized steel conduit covered with a bonded 40 mil (minimum) thickness PVC jacket and coated inside with urethane. The conduit shall comply with NEMA RN-1 and shall be "Plasti-Bond Red" as manufactured by Robroy Industries, "OCAL-Blue" as manufactured by Thomas & Betts, Perma-Cote Supreme by Perma-Cote Industries, Kor Kap equivalent, or approved equal.

J. Conduit Fittings

1. Fittings for all conduit types shall conform to UL 467 and UL 514 as applicable.
2. Fittings for electrical metallic tubing shall be rain-tight and concrete-tight and shall be plated steel hexagonal threaded compression type.
3. Set screw or indenter type connectors shall not be used. Fittings for conduit installed in wet locations and underground shall provide a watertight joint. Fittings for rigid conduit shall be threaded.
4. Fittings or bushings shall be installed in easily accessible locations.
5. Where exposed conduits pass across structural expansion joints, approved weatherproof telescopic type expansion fittings shall be used. Fittings shall be OZ/GEDNEY Type AX, Crouse-Hinds Type XJG, or approved equal, watertight, and permit movement up to 4 inches. Each fitting shall be equipped with approved bonding jumpers around or through each fitting.
6. Where embedded conduits pass through expansion joints, approved watertight, concrete-tight deflection/expansion fittings shall be used. Fittings shall compensate for movement of 3/4-inch from the normal in all directions. Fittings shall be OZ/GEDNEY Type DX, Crouse-Hinds Type XD, or approved equal.
7. Conduit fittings ("condulets") shall be used on exposed conduit work for changes in direction of conduit runs and breaking around beams. "Condulets" shall be cast ferrous alloy, galvanized or cadmium plated, as manufactured by Crouse Hinds, OZ/Gedney, Appleton Company, or approved equal. Coated fittings and boxes shall be used with coated conduit in all chemically aggressive areas or where called for on the Drawings. Covers shall be of a design suitable for the purpose intended. In damp areas, the outside condulets shall be made watertight. Install all condulets with the covers accessible. Use proper tools to assemble conduit system to prevent injury to the plastic covering. No damage to the covering shall be permitted.
8. Conduit fittings shall be cast type of nonferrous metal or malleable iron thoroughly coated inside and outside with metallic zinc or cadmium after all machining has been completed. Cast fittings shall be provided with heavy threaded hubs to fit the conduit required. Covers shall be of the same material as the fittings to which they are attached and shall be screwed on with rubber or neoprene gaskets between the covers and fittings. Cast fittings 1 1/2 inches and above shall be of the "mogul" type.
9. PVC coated fittings shall be used with PVC coated conduit. All conduit nipples, elbows, couplings, boxes, fittings, unions, expansion joints, connectors, bushing, and other components of the raceway system shall be factory coated to maintain the corrosion-resistant integrity of the conduit system. The coated conduit and its respective components shall all be provided by the same manufacturer. Coated conduit shall be used in all areas specified herein or indicated on the Drawings.
10. Conduit seals shall be Type EYS as manufactured by Crouse-Hinds, Appleton equivalent, OZ/Gedney equivalent, or approved equal.

PART 3 EXECUTION

3.01 GENERAL

- A. Conduit shall be installed concealed unless otherwise indicated or specified. Conduit may be run exposed on walls only where concealing is not practical, or at the direction of the ENGINEER. No additional cost may be incurred during construction for running conduit exposed.

- B. The load applied to fasteners shall not exceed 1/4 of the proof test load. Fasteners attached to concrete ceilings shall be vibration and shock resistant. Holes cut to a depth of more than 1 1/2 inches in reinforced concrete beams or to a depth of more than 3/4 inch in concrete joints shall not cut the main reinforcing bars. Holes not used shall be filled. Spring steel fasteners are not permitted. Conduits shall be fastened to all sheet metal boxes and cabinets with two (2) locknuts where required by the National Electrical Code to ensure adequate bonding for grounding. Where insulated bushings are used, or where bushings cannot be secured firmly to the box or enclosure, a bonding jumper shall be installed to maintain suitable grounding continuity. Locknuts shall be the type with sharp edges for digging into the wall of metal enclosures. Bushings shall be installed on the ends of all conduits and shall be of the insulating type where required by the National Electrical Code.
- C. Conduit installed in concrete floor slabs or walls shall be located so as not to affect the designed structural strength of the slabs. Conduit shall be installed within the middle one third of the concrete slab except where necessary to not disturb the reinforcement. The outside diameter of conduit shall not exceed one third of the slab thickness, and conduits shall be spaced no closer than three (3) diameters except at cabinet locations. Curved portions of bends shall not be visible above the finish slab. Where embedded conduits cross expansion joints, suitable expansion/deflection fittings and bonding jumpers shall be provided. Conduit larger than 1 inch trade size shall be parallel with or at right angles to the main reinforcement. When at right angles to the reinforcement, the conduit shall be close to one of the supports of the slab. Conduits shall not be stacked more than two (2) diameters high in floor slabs. Embedded conduits shall be placed in accordance with the latest edition of ACI-318.
- D. Where outlets are shown near identified equipment furnished by this or other contractors, it is the intent of the Specifications and Drawings that the outlet be located at the equipment to be served. The CONTRACTOR shall coordinate the location of these outlets to be near the final location of the equipment served whether placed correctly or incorrectly on the Drawings. Changes in outlet locations required to serve the equipment furnished by other contractors on the Project shall be brought to the attention of the ENGINEER.
- E. Conduit passing through the walls and floors of buildings below grade shall be installed with appropriate watertight fittings to prevent the entrance of ground water around the periphery of the conduits. For vertical conduit penetrations through openings in concrete floors, the fittings shall be Type FSK Floor Seals as manufactured by OZ/Gedney. For conduit penetrations through openings in concrete walls, the fittings shall be Type WSK Thruwall seals as manufactured by OZ Gedney. Conduits shall be sloped away from the buildings toward splice boxes, handholes and/or manholes to provide drainage away from the building wall.
- F. Electric Metallic Tubing (EMT) style conduit is not permitted without special approval by the ENGINEER.

3.02 CONDUIT

- A. Unless otherwise specified herein or indicated on the Drawings, the minimum size conduit shall be 3/4 inch for exposed work and 1 inch for conduit encased in concrete or mortar. Multiple circuits may not be combined in the same conduit without the explicit written permission to do so by the ENGINEER.
- B. Conduit home runs for lighting circuits are not necessarily indicated on the Drawings; however, the circuit numbers are shown. Conduit shall be furnished and installed for these lighting circuits and shall be installed as required to suit field conditions, subject to review and acceptance by the ENGINEER.
- C. Where exposed, maintain a minimum distance of 6 inches from parallel runs of flues or water pipes. Conduit runs shall be installed in such locations as to avoid steam or hot water pipes. A

minimum separation of 12 inches shall be maintained where conduit crosses or parallels hot water or steam pipes.

- D. For floor mounted equipment, conduit may be installed overhead and dropped down, where underfloor installation is not practical. Groups of conduits shall be uniformly spaced, where straight and at turns. Conduit shall be cut with a hacksaw, or an approved conduit cutting machine and reamed after threading to remove all burrs. Securely fasten conduit to outlets, junction and pull boxes to effect firm electrical contact. Join conduit with approved couplings. Conduits shall be freed from all obstructions. Where conduit drops down, conduit shall be secured using Unistrut.
- E. Empty conduit systems shall be furnished and installed as indicated on the Drawings and shall have pull ropes installed. The polyethylene pull ropes shall be ¼" diameter, minimum. Not less than 12 inches of slack shall be left at each end of the pull rope.
- F. Each piece of conduit installed shall be free from blisters or other defects. Each piece installed shall be cut square, taper reamed, and a coat of galvanizing and conducting compound shall be applied to the threads. Galvanizing compound shall be CRC Zinc-It or approved equal. Threads on conduits shall be painted with a conducting compound prior to making up in a fitting.
- G. Conduit threaded in the field shall be of standard sizes and lengths.
- H. All bends shall be made with standard factory conduit elbows or field bent elbows. Field bending of conduit shall be done using tools approved for the purpose. Heating of conduit to facilitate bending is prohibited. Field bends shall be not less than the same radius than a standard factory conduit elbow. Bends with kinks shall not be acceptable.
- I. The equivalent number of 90 bends in a single conduit run are limited to the following:
 - 1. Runs in excess of 300 feet: 0
 - 2. Runs of 300 feet to 201 feet: 1
 - 3. Runs of 200 feet to 101 feet: 2
 - 4. Runs of 100 feet and less: 3
- J. All conduits for fiber optic cable shall have a minimum bending radius of 16 inches. Final bending radius shall be determined by the fiber optic cable manufacturer.
- K. Unless otherwise specified herein, indicated on the Drawings, or required by the NEC, conduit shall be supported every 8 feet (minimum) and shall be installed parallel with or perpendicular to walls, structural members, or intersections of vertical planes and ceilings with right angle turns consisting of fittings or symmetrical bends. Conduits shall be supported within 1 foot of all changes in direction. Supports shall be approved pipe straps, wall brackets, hangers or ceiling trapeze.
- L. In no case shall conduit be supported or fastened to another pipe or installed to prevent the removal of other pipes for repairs. Fastenings shall be by expansion bolts on concrete; by machine screws, welded threaded studs, or spring-tension clamps on steel work. Powder actuated fasteners may only be used to make connections where the use of this equipment complies with safety regulations and for structures in Seismic Design Categories A or B, unless the fasteners are approved for seismic use. Wooden plugs inserted in masonry and the use of nails as fastening media are prohibited. Threaded C clamps may be used on rigid steel conduit only. Conduits or pipe straps shall not be welded to steel.

- M. Aluminum conduits shall not be in contact with concrete surfaces. Where aluminum conduits are routed along concrete surfaces, they shall be installed with one hole cast straps with clamp-backs to space the conduit ¼" away from concrete surface. Where aluminum conduit passes through concrete, CMU or brick walls, the penetration shall be made such that the aluminum conduit does not come into contact with concrete, CMU, brick or mortar. All penetrations shall meet or exceed the UL design standards. Aluminum conduit shall transition to PVC coated steel conduit where entering a concrete encasement, floor or duct bank.
- N. No more than three (3) 90-degree bends will be allowed in any one conduit run. Where more bends are necessary, a conduit or pull box shall be installed. All bends in ¾-inch conduit shall be made with a conduit bender, and all larger sizes shall have machine bends. Joints in threaded conduit shall be made up watertight with the appropriate pipe thread sealant or compound applied to male threads only; and all field joints shall be cut square, reamed smooth, and properly threaded to receive couplings. No running threads are permitted. All conduit ends at switch and outlet boxes shall be fitted with an approved locknut and bushing forming an approved tight bond with box when screwed up tightly in place.
- O. Conduits stubbed up through concrete floors for connections to freestanding equipment and for future equipment shall be provided with an adjustable top or coupling threaded inside for plugs, set flush with the finished floor. Screwdriver operated threaded flush plugs shall be installed in conduits from which no equipment connections are made.
- P. Connections from rigid conduit to motors and other vibrating equipment, limit switches, solenoid valves, level controls, and similar equipment, shall be made with short lengths of liquid tight flexible metal conduit. These conduits shall be installed in accordance with the NEC and shall be furnished and installed with appropriate connectors with devices which will provide an excellent electrical connection between the equipment and the rigid conduit for the flow of ground current. Flexible metal conduit and liquid-tight flexible metal conduit length shall be three (3) feet, maximum.
- Q. Flexible metal conduit or liquid-tight flexible metal conduit installed between rigid metal conduit and motor terminal box and/or any other apparatus shall have a green insulated grounding conductor running through the flexible conduit. This conductor shall be terminated to the nearest pull box, motor terminal box, or any other apparatus ground terminal. Flexible metal conduit and liquid-tight flexible metal conduit shall be grounded and bonded per NEC Articles 348 and 350, respectively.
- R. Conduits installed within or underneath floor slabs, underground direct-buried or concrete encased conduits, and all conduits installed in areas subject to liquid inadvertently entering the conduit system shall be sealed or plugged at both ends in accordance with NEC Article 300-5(g). This requirement applies to both conduits containing conductors and "spare" conduits. Where practicable, the interior of the conduit shall be sealed as well as around the conductors by using conduit sealing bushings: Type CSB as manufactured by O/Z Gedney or approved equal. Where the conduit fill does not allow the use of these bushings, the conduits shall be tightly caulked or plugged.
- S. Conduits passing through sleeves in interior walls and floors shall be tightly caulked.
- T. The use of two (2) locknuts, one on each side of the enclosure, and a grounding bushing shall be required at all conduit terminations where hub type fittings are not required, such as electrical rooms, control rooms, and office areas.
- U. Conduit installation shall be arranged to minimize cleaning. No horizontal runs of conduit will be permitted in brick or masonry walls.

- V. Conduits shall not penetrate the floors or walls inside liquid containment areas unless specifically accepted by the ENGINEER.
- W. All conduits that are buried or encased in concrete that transition from the ground to any stationary structure or equipment shall be equipped with a longitudinal expansion coupling capable of at least four inches of expansion. Conduits with encasement that is rigidly tied to the stationary structure in accordance with the Standard Details shall not be required to have expansion couplings.
- X. Raceways shall not be installed concealed in water-bearing walls and floors.
- Y. All instrumentation wire and cable for analog signals shall be installed in rigid steel conduit or PVC coated rigid steel conduit to suit the application. This applies to all conduit installations including exposed, concealed in concrete encasement, and all other applications.
- Z. Other conduit uses not specifically listed above shall be brought to the attention of ENGINEER for a decision.

3.03 FITTINGS

- A. Conduit connections shall be made with standard coupling and the ends of the conduit shall butt tightly into the couplings. Where standard coupling cannot be used, Erickson three-piece couplings shall be used. Where conduits are installed in concrete, concrete-tight three-piece couplings shall be used.
- B. Weatherproof, insulated throat "Meyers" hubs shall be used on all conduit entries to boxes and devices without integral hubs in process areas to maintain enclosure NEMA rating integrity. The CONTRACTOR shall furnish and install "Meyers" hubs on all conduit entries into non-cast enclosures such as metallic or non-metallic control panels, control component enclosures, wireways, pull boxes, junction boxes, control stations, and similar type equipment when this type of equipment is located in process areas requiring NEMA 12, 4, and 4X integrity. This specified requirement for "Meyers" hubs does not apply to any area of the plant facilities where NEMA 12, 4, or 4X integrity is not required.

3.04 RIGID METALLIC

- A. Conduit shall be protected immediately after installation by installing flat noncorrosive metallic discs and steel bushings, designed for this purpose, at each end. Discs shall not be removed until it is necessary to clean the conduit and install the conductors. Before the conductors are installed, insulated bushings shall be installed at each end of the conduit.
- B. Where "all-thread" nipples are used between fittings and electrical equipment, they shall be so installed that no threads are exposed.

3.05 PVC COATED RIGID METALLIC

- A. All PVC coated conduit shall be installed in accordance with manufacturer's instructions. The CONTRACTOR shall use tools that are specifically suited for coated conduit systems. The use of pipe wrenches and other such tools on PVC coated RGS conduit is prohibited. The ENGINEER and UTILITIES reserve the right to reject any installation of coated conduit that does not meet the requirements of the Section or the manufacturer's instructions. The ENGINEER and UTILITIES also reserve the right to reject any installation that exhibits damage due to the improper use of tools. All rejected installations shall be replaced by the CONTRACTOR at no additional cost to UTILITIES. The use of PVC coated conduit repair compounds to repair damage or improper installation is prohibited.

- B. All CONTRACTOR personnel that install PVC coated RGS conduit shall be trained by the PVC coated RGS conduit manufacturer. Training shall include proper conduit system assembly techniques, use of tools appropriate for coated conduit systems, and field bending/cutting/threading of coated conduit. The CONTRACTOR shall furnish evidence of such training as specified herein. Training shall have been completed within the past 24 months prior to the Notice to Proceed on this Contract for all coated conduit installation personnel. CONTRACTOR personnel not trained within this timeframe shall not be allowed to install coated conduit or shall be trained/re-trained as required prior to commencement of conduit installation.
- C. PVC coated rigid steel conduit shall be furnished and installed, where exposed, in the following areas:
1. Below grade vaults.
 2. Chemical rooms.
 3. Wet-Process Areas

3.06 RIGID NON-METALLIC PVC

- A. A non-metallic raceway containing instrumentation cable (if specifically allowed herein) where installed exposed shall be installed to provide the following clearances:
1. Raceway installed parallel to raceway conductors energized at 480 through 208 volts shall be 18 inches and 208/120 volts shall be 12 inches.
 2. Raceway installed at right angles to conductors energized at 480 volts or 120/208 volts shall be 6 inches.
 3. Where practical, exposed raceways containing instrumentation cable shall cross raceway containing conductors of other systems at right angles.
- B. Install polyvinyl chloride (PVC) coated steel conduits when entering or exiting concrete except under electrical equipment where the conduit is not subject to physical abuse. Also install PVC coated steel conduit when transitioning between grade and a structure or an equipment stand. Extend stub-ups at least 12 inches above and below grade or finish floor. Conduits extending through the concrete floor shall be installed using straight runs (for vertical penetrations) or factory elbows (for conduits installed within the slab) of PVC coated rigid steel conduit.
- C. All conduit extending through the floor behind panels or into control centers or similar equipment may be PVC Schedule 40 and shall extend a minimum of 6 inches above the floor elevations, where practicable, with no couplings at floor elevations.
- D. Unless specifically identified on the Drawings as "Direct Buried," all conduits in the earth, including conduits below slabs-on-grade, shall be concrete encased. Joints in conduit shall be staggered so as not to occur side by side. Rigid non-metallic (PVC) conduit shall be connected to PVC coated rigid steel conduit at the point where it leaves the ground, with the transition to metal conduit occurring inside the concrete encasement.
- E. Install non-metallic conduits in accordance with manufacturer's instructions where specified herein or indicated on the Drawings.
- F. Join non-metallic conduit using cement as recommended by the manufacturer. Clean and wipe non-metallic conduit dry before joining. Apply full even coat of cement to entire area inserted in fitting. Allow joint to cure for twenty (20) minutes (minimum).

- G. No PVC conduit shall be installed exposed unless specifically accepted in writing by the ENGINEER. Where PVC conduit is allowed to be installed exposed, the conduit shall be Schedule 80.
- H. PVC Schedule 40 conduit shall be furnished and installed in concrete slabs (for slab-on-grade construction) and in walls when the conduit is shown to be encased. Rigid steel conduit shall be installed in all elevated slabs when the conduits are shown to be encased.
- I. PVC Schedule 40 conduit shall be installed in reinforced concrete encasement. Conduit shall be "direct buried" only if specifically indicated on the Drawings.

3.07 LIQUID TIGHT FLEXIBLE METAL CONDUIT

- A. Installed length shall be less than 24 inches unless otherwise approved by the ENGINEER. Conduit shall be supported as required by the NEC and apply no strain to the connected devices.
- B. Liquid-tight flexible metal conduit shall be used for all motor connections and where vibrating or moving devices that are located in wet locations, hazardous locations, or outside.

3.08 LIQUID TIGHT FLEXIBLE NON-METALLIC CONDUIT

- A. Liquid-tight flexible non-metallic conduit (LFNC) shall be furnished and installed, where required, in chemical storage and transfer areas. This conduit may not be used in hazardous locations.
- B. Installed length shall be less than 24 inches unless otherwise approved by the ENGINEER. Conduit shall be supported as required by the NEC and apply no strain to the connected devices.

3.09 CONDUIT IDENTIFICATION

- A. Conduits shall be provided with type 316 stainless steel, laser etched conduit tags. Tags shall be permanently fastened with stainless steel straps. Conduit identification as indicated on the drawings.
- B. Where there is an existing labelling system, the identification system for the conduits furnished and installed under this Contract shall match the existing identification system used at the facility.

3.10 TESTING

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 - 1. Field Tests
 - a. Field testing shall be done in accordance with the requirements specified in the General Conditions, and Common Work Results for Electrical (See Referenced Sections).
 - b. All conduit installed below grade or concrete encased shall be tested to ensure continuity and the absence of obstructions by pulling through each conduit a swab followed by a mandrel 85% of the conduit inside diameter. After testing, all conduits shall be capped after installation of a suitable pulling tape.

END OF SECTION

SECTION 26 05 73

POWER SYSTEM STUDIES

PART 1 GENERAL

1.01 RELATED DOCUMENTS

- A. Drawings and General Provisions of Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to Work of this Section. Should there be any conflict between provisions or requirements elsewhere indicated and the provisions of this division, request written clarification by addendum prior to submission of bid or abide by the interpretation of the ENGINEER.

1.02 SUMMARY

- A. General: This section specifies that the CONTRACTOR conduct the following power system studies for the electrical power distribution system.
 - 1. Short Circuit Study: Provide a complete short circuit study, equipment interrupting or withstand evaluation, and a protective device coordination study for the electrical power distribution system serving the wastewater treatment facility. The studies shall include all portions of the electrical power distribution system from the utility primary service drop through and including the 120v busses excluding single phase circuits.
 - 2. Protective Device Coordination Study: A protective device coordination study shall be performed to determine proper selection of power fuse ratings, protective relay characteristics and settings, ratios and characteristics of associated voltage and current transformers, and circuit breaker trip characteristics and settings. Study shall include coordination with upstream utility devices.
 - 3. Flash Hazards Analysis: A flash hazard analysis shall be conducted to determine the arc-flash incident energy at all power distribution and control equipment and to establish the flash protection boundary for said equipment. The scope of the analysis shall also include the preparation and installation of warning labels for all power distribution equipment.

1.03 SUBMITTALS

- A. General: Submit the following in accordance with the requirements of Specification 16050.
 - 1. The reports specified in paragraph 260573-2.1. The report shall be approved by the Construction Manager prior to releasing any power distribution equipment for manufacture.
 - 2. Sample of the arc flash hazard warning label.
 - 3. A copy of this specification section, with addendum updates included, and all referenced and applicable sections, with addendum updates included, with each paragraph check-marked to indicate specification compliance or marked to indicate requested deviations from specification requirements. Check marks (in the margin adjacent to the beginning of the paragraph) shall denote full compliance with a paragraph as a whole. If deviations from the specifications are indicated and therefore requested by the CONTRACTOR, each deviation shall be underlined and denoted by a number in the margin to the right of the identified paragraph. The remaining portions of the paragraph not underlined will signify compliance on the part of the CONTRACTOR with the specifications. The submittal shall be accompanied by a detailed, written justification for each deviation.

Failure to include a copy of the marked-up specification sections, along with justification(s) for any requested deviations to the specification requirements, with the submittal shall be sufficient cause for rejection of the entire submittal with no further consideration.

1.04 QUALITY ASSURANCE

- A. Qualifications: The studies shall be performed, sealed and signed by a professional engineer registered in the State of Colorado. The individual responsible for performing the studies and preparing the reports shall be an employee of an independent testing firm and shall have a minimum of ten (10) years' experience in power system analysis.
- B. Codes and Standards:
 - 1. Electrical Code Compliance: Comply with applicable local code requirements of the authority having jurisdiction and the National Electrical Code, NFPA 70.
 - 2. Institute of Electrical and Electronic Engineers (IEEE) Compliance: Study and analysis procedures shall comply with the following standards:
 - a. IEEE 141 - Recommended Practice for Electric Power Distribution for Industrial Plants
 - b. IEEE 242 - Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
 - c. IEEE 399 - Recommended Practice for Industrial and Commercial Power Systems Analysis.
 - d. IEEE 1584 - Guide for Performing Arc Flash Hazard Calculations
 - 3. National Fire Protection Association (NFPA) Compliance: Study and analysis procedures shall comply with the following standards:
 - a. NFPA 70E - Electrical Safety in the Workplace

PART 2 PRODUCTS

2.01 REPORT

- A. General: The product shall be a certified report summarizing the short circuit, protective device coordination, and arc flash hazard studies and provide conclusions and recommendations which may affect the integrity of the electric power distribution system.
- B. Short Circuit Analysis: The short circuit analysis shall be performed with the aid of a digital computer program and shall be performed in accordance with IEEE Standards 141 and 242 and shall utilize the ANSI method of short circuit analysis in accordance with ANSI C37.010. Short circuit interrupting and momentary duties shall be determined for an assumed three phase bolted fault at each pad-mounted transformer primary terminal and secondary terminals, low voltage switchgear and switchboard, motor control centers and distribution panelboards. A ground fault current study shall be provided for the same system areas.
- C. Normal system operating method, alternate operation, standby power operation, and operations which could result in maximum fault conditions shall be thoroughly addressed in the study. The study shall assume all motors operating at rated voltage with the exception that motors identified as standby shall not be included as fault current sources. Power distribution equipment bus impedance shall be assumed zero. The study shall be based on actual equipment data.

1. Content: The short circuit study shall include the following information:
 - a. The equipment manufacturer's published information used to prepare the study.
 - b. Assumptions made during the study.
 - c. Identification of calculation methods employed in the study.
 - d. One-line diagram of the power distribution system. The following information shall be either indicated on the one-line diagram or tabulated within the report:
 - 1) Location and function of each protective device in the system.
 - 2) Type designation, current rating, range or adjustment, manufacturer's style and catalog number for all protective devices.
 - 3) Power, voltage ratings, impedance, and primary and secondary connections of all transformers.
 - 4) Type, manufacturer, and ratio of all instrument transformers energizing each relay.
 - 5) Nameplate ratings of all motors and generators with their subtransient reactances. Transient reactances of synchronous motors and generators and synchronous reactances of all generators.
 - 6) Sources of short circuit currents such as utility ties, generators, synchronous motors, and induction motors.
 - 7) All significant circuit elements such as transformers, cables, breakers, fuses, reactors, etc.
 - e. Tabulation of all data used as input to the report including cable impedances, source impedances, equipment ratings, etc.
 - f. Fault current calculations including a definition of terms and guide for interpretation of computer-generated results.
 - g. Tabulation of results at each bus including fault impedance, X/R ratios, asymmetry factors, motor and generator contributions, short circuit kVA and symmetrical and asymmetrical fault currents.
 - h. Evaluation of results including a tabulation of equipment short circuit interrupt and withstand ratings and available fault currents at each device.
 - i. Conclusions and recommendations.
2. Utility System Impedance: CONTRACTOR shall be responsible for obtaining system impedance information from utility company. Actual transformer impedances and fault currents shall be used in the study unless a more conservative approach is taken. Regardless of the approach proposed, the utility impedance data shall be provided in the study.

D. Protective Device Coordination Study: A protective device coordination study shall be conducted in accordance with the National Electrical Code and the recommendations of IEEE Standard 399 to select and to verify the selection of power fuse ratings, protective relay characteristics and settings, ratios and characteristics of associated voltage and current transformers, and circuit breaker trip characteristics and settings. The coordination study shall include all voltage classes of equipment from the utility's incoming line protective device down to and including the main device of each 208-volt AC panelboard.

1. Content: The protective device coordination study shall include time-current curve sets graphically indicating the coordination proposed for the system. Time-current curves shall be plotted on full-size, 5-cycle, log-log graph paper with a maximum of eight protective

devices per plot. Device time-current characteristics shall be based on the published time-current curves for the equipment manufacturer proposed for use on this project. The coordination study time-current plots shall, at a minimum, include the following:

- a. Time-current curve for each protective relay or fuse showing graphically that the settings will provide protection and selectivity within industry standards. Each curve shall be identified, and the tap and time dial settings shall be specified.
- b. Time-current curves for each device shall be positioned to provide for maximum selectivity to minimize system disturbances during fault clearing. Reasonable coordination intervals and separation of characteristic curves shall be maintained
- c. Time-current curves and points for cable and equipment damage and symmetrical and asymmetrical fault currents.
- d. Circuit interrupting device operating and interrupting times.
- e. Maximum fault values.
- f. Transformer full load currents, magnetizing inrush current, and ANSI withstand parameters.
- g. Motor starting curves.
- h. Pertinent generator characteristics.
- i. Sketch of bus and breaker arrangement.
- j. Tabulation of all device settings including tap, time dial, pickup, instantaneous, and time delay settings.
- k. Conclusions and recommendations pertinent to final system coordination and selectivity.
- l. Discrepancies, problem areas, or inadequacies shall be clearly identified.

E. Flash Hazard Analysis: A flash analysis shall be conducted in accordance with the recommendations of IEEE Standard 1584 and NFPA 70E. The flash analysis shall address all power distribution and control equipment with potential to produce an arc flash when energized. The flash hazard analysis shall include the following:

1. Calculation of the flash protection boundary.
2. Calculation of the arc-flash incident energy.
3. Preparation and installation of all required warning labels. Warning labels shall be in accordance with the latest ANSI Z535.4 standards and shall minimally identify the equipment by type and designation, the arc flash boundary, and the type of personal protective equipment required.
4. Identify the required personal protective equipment with arc rating to provide adequate protection for personnel working on or near energized equipment or conductors.

PART 3 EXECUTION

3.01 DATA COLLECTION

A. The CONTRACTOR shall be responsible for obtaining and verifying all data required in preparation of the studies.

3.02 FIELD SETTINGS

- A. The results of the approved short circuit and protective device coordination study shall establish the final field settings for all protective devices. The CONTRACTOR shall perform field adjustments of the protective devices as required to place the equipment in final operating condition. Necessary field settings of devices and adjustments and minor modifications to equipment to accomplish conformance with the approved short circuit and protective device coordination study shall be carried out by the CONTRACTOR at no additional cost to Owner.

END OF SECTION

SECTION 26 08 00

COMMISSIONING OF ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

- A. Drawings and General Provisions of Contract, including General and Supplementary Conditions, apply to Work of this Section. Should there be any conflict between provisions or requirements elsewhere indicated and the provisions of this division, request written clarification by addendum prior to submission of bid or abide by the interpretation of the Engineer.

1.02 SUMMARY

- A. This section specifies the acceptance testing of electrical materials, equipment and systems. Contractor shall provide all labor, tools, material, power and other services necessary to provide the specified tests.

1.03 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions - SUBMITTALS
- C. Section 260500 – COMMON WORK RESULTS FOR ELECTRICAL

1.04 REFERENCES

- A. General: This section contains references to the InterNational Electrical Testing Association (NETA), ATS: Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems. It is a part of this section as specified and modified. In case of conflict between the requirements of this section and those of said document, the requirements of this section shall prevail.
- B. Safety and Procedural Requirements:
 - 1. Safety and Precautions: This specification does not include specific safety procedures. It is recognized that tests and inspections set forth by this specification may be potentially hazardous. Consequently, individuals performing these tests must be capable of conducting these tests in a safe manner and with complete knowledge of the hazards involved. Each person involved in this project must be provided with and use appropriate personal protective equipment.
 - 2. Safety practices that shall be followed include, but are not limited to, the following:
 - a. Occupational Safety and Health Act.
 - b. Accident Prevention Manual for Industrial Operations, National Safety Council.
 - c. Applicable state and local safety operating procedures.
 - d. Owner's safety practices.

3. Perform all testing work in accordance with the applicable codes and standards of the following agencies except as provided otherwise herein:
 - a. InterNational Electrical Testing Association – NETA Acceptance Testing Specifications (ATS).
 - b. National Fire Protection Association.
 - c. National Electrical Code, ANSI/NFPA 70.
 - d. Recommended Practice for Electrical Equipment Maintenance, ANSI/NFPA 70B.
 - e. Electrical Safety Requirements for Employee Workplaces, NFPA 70E.

1.05 APPLICATION

- A. General: Requirements for testing in accordance with this section are specified in this and other sections of Division 26. Where testing in accordance with this section is required, the required tests, including correction of defects where found, and subsequent retesting, shall be completed prior to energization of material, equipment or systems.

1.06 SUBMITTALS

- A. General: Submit the following in accordance with the requirements of Common Work Results for Electrical (See Referenced Sections).
- B. Description of all test procedures.
- C. Examples of test report forms for all specified tests including deficiency report forms.
- D. Final test report.
- E. A copy of this specification section, with addendum updates included, and all referenced and applicable sections, with addendum updates included, with each paragraph check-marked to indicate specification compliance or marked to indicate requested deviations from specification requirements. Check marks (in the margin adjacent to the beginning of the paragraph) shall denote full compliance with a paragraph as a whole. If deviations from the specifications are indicated and, therefore requested by the Contractor, each deviation shall be underlined and denoted by a number in the margin to the right of the identified paragraph. The remaining portions of the paragraph not underlined will signify compliance on the part of the Contractor with the specifications. The submittal shall be accompanied by a detailed, written justification for each deviation. Failure to include a copy of the marked-up specification sections, along with justification(s) for any requested deviations to the specification requirements, with the submittal shall be sufficient cause for rejection of the entire submittal with no further consideration.
- F. Submittal Presentation: Submittal data shall be assembled in folders or three-ring binders. Each folder or binder shall contain a cover sheet, indexed by item and cross-referenced to the appropriate specification paragraph. Catalog cuts shall be edited to show only the items, model numbers, and information that applies to the equipment being furnished.

PART 2 - PRODUCTS

2.01 TEST EQUIPMENT AND MATERIALS

- A. General: Test instruments shall be calibrated to references traceable to the National Institute of Standards and Technology and shall have a current sticker showing date of calibration, deviation from standard, name of calibration laboratory and technician, and date recalibration is required.
- B. NETA Compliance: Test equipment shall be in complete compliance with the latest edition of the ATS, Paragraphs 5.2 and 5.3.

PART 3 - EXECUTION

3.01 GENERAL

- A. The test procedures to be conducted by the Installing Contractor are defined as those tests specified in paragraph 260800 - 3.4 B.
- B. Tests and inspection shall establish that:
 - 1. Electrical equipment is operational within industry and manufacturer's tolerances.
 - 2. Installation operates properly.
 - 3. Equipment is suitable for energization.
 - 4. Installation conforms to requirements of contract documents and NFPA 70, NFPA 70E, and ANSI C2.
- C. Perform inspection and testing in accordance with NETA ATS, industry standards, and manufacturer's recommendations.
- D. Set, test, and calibrate protective relays, circuit breakers, and other applicable devices as required to coordinate with next upstream and downstream devices.
- E. Verify nameplate data for conformance to contract documents.
- F. Realign equipment not properly aligned and correct un-levelness.
- G. Properly anchor electrical equipment that is found to be inadequately anchored.
- H. Tighten accessible bolted connections, including wiring connections, with calibrated torque wrench to manufacturer's recommendations or as otherwise specified.
- I. Clean contaminated surfaces with cleaning solvents a recommended by manufacturer.
- J. Provide proper lubrication of applicable moving parts.
- K. Inform Owner's Representative of working clearances not in accordance with NFPA 70.
- L. Investigate and repair or replace:
 - 1. Electrical items that fail tests.
 - 2. Active components not operating in accordance with manufacturer's instructions.

3. Damaged electrical equipment.

M. Electrical Enclosures:

1. Remove foreign material and moisture from enclosure interior.
2. Vacuum and wipe clean enclosure interior.
3. Remove corrosion found on metal surfaces.
4. Repair or replace, as determined by Owner's Representative, door and panel sections having dented surfaces.
5. Repair or replace, as determined by Owner's Representative, poor fitting doors and panel sections.
6. Repair or replace improperly operating latching, locking, or interlocking devices.
7. Replace missing or damaged hardware.

3.02 TEST DOCUMENTATION

- A. Inspection and Test Procedures Documentation: Test procedure documentation shall be submitted in accordance with paragraph -260800 - 1.6.
- B. Test Report Forms: The test report forms are appended to the end of this section.
- C. Deficiency Reports: Deficiency reports shall be prepared for each item under test and submitted to the Engineer at the end of each day of testing. Deficiency reports shall identify the equipment under test by tag number and location and shall describe all deficiencies observed through the course of inspection and testing.

3.03 EQUIPMENT TESTING

- A. General: The inspection and test procedures described by the latest edition of the ATS, Section 7 shall establish the minimum requirements for electrical equipment inspection and testing. Additional test procedures, beyond the scope of ATS, Section 7, are defined herein and shall be conducted as specified.
- B. Installing Contractor Tests: The following types of equipment and/or systems shall be inspected and tested by the installing contractor:
 1. Insulation Resistance Tests: Insulation resistance tests shall be performed on the following types of equipment or systems:
 - a. Low Voltage (600 volt maximum) Power and Control Conductors and Cables: Insulation resistance tests shall be performed on all circuits 120 volts and above except interior lighting and 120 volt receptacle circuits.
 - b. Motor Control Centers (600 volt maximum)
 - c. Panelboards (600 volt maximum)
 2. Power and control conductor and cable insulation tests shall be performed in accordance with the latest edition of the ATS, Paragraph 7.3.2. Tests may be conducted with motors and other

equipment connected, except that solid-state equipment shall be disconnected unless the equipment is normally tested by the manufacturer at voltages in excess of 1000 volts DC.

3. The ambient temperature at which insulation resistance is measured shall be recorded on the test form.
4. Test results shall be evaluated against the results for cables of same type and length. Test results of less than 50 mega-ohms shall be investigated.

C. Signal Cables: All analog signal cables shall be tested as specified herein.

1. The loop resistance of each signal pair or triad shall be measured. Any pair or triad exhibiting a loop resistance of less than or equal to 50 ohms shall be deemed satisfactory. For pairs with greater than 50 ohm loop resistance, the Contractor shall calculate the expected loop resistance considering loop length and intrinsic safety barriers if present. Loop resistance shall not exceed the calculated value by more than 5 percent.
2. Each shield drain conductor shall be tested for continuity. Shield drain conductor resistance shall not exceed the loop resistance of the pair or triad.
3. Each conductor (signal and shield drain) shall be tested for insulation resistance with all other conductors in the cable grounded.
4. Instruments used for continuity measurements shall have a resolution of 0.1 ohms and an accuracy of better than 0.1 percent of reading plus 0.3 ohms. A 500 volt megohmmeter shall be used for insulation resistance measurements.

D. Test Records: Insulation resistance measurements shall be recorded on test report forms in compliance with Specification 260800 paragraph 3.3-B.

E. Pre-functional Checkout: Functional testing shall be performed in accordance with the requirements of this specification. Prior to functional testing, all protective devices shall be adjusted and made operative. Prior to energization of equipment, all system component tests shall be completed and the Contractor shall perform a functional checkout of the control circuit. Checkout shall consist of energizing each control circuit and operating each control, alarm or malfunction device and each interlock in turn to verify that the specified action occurs. The Contractor shall submit a description of his proposed functional test procedures prior to the performance of functional checkout.

F. Witnessing:

1. The ENGINEER reserves the right to observe all Contractor testing. The Engineer shall be notified five (5) days prior to testing.

3.04 TEST RESULTS

- A. General: Minimum acceptable test values shall be as specified in this specification and ATS. Where acceptable test values are not specified, the equipment manufacturers recommended test values shall be used.

END OF SECTION

Form 260800-A
Wire and Cable Resistance Test Data Form

Wire or Cable Number: _____ Date of Test: _____

Temperature, Degrees F: _____

Location of Test	Insulation Resistance, megohms
1. _____	_____
2. _____	_____
3. _____	_____
4. _____	_____
5. _____	_____

CERTIFIED _____ Date _____
Contractor's Representative

WITNESSED _____ Date _____
Owner's Representative

Form 260800-B
Signal Cable Resistance Test Data Form

Loop Number: _____

List all wiring associated with the loop in the table below. Make applicable measurements as indicated after disconnecting wiring.

Wire No.	Panel Tie	Field TB	Continuity Resistance		Insulation Resistance			
			Cond/Cond	Cond/Shield	Shield/Cond	Shield/GND	Cond/GND	Shield/Shield
A			--	(A/SH)				
B			(A/B)	--				
C			(A/C)	--				
D			(A/D)	--				

Continuity Test: Connect ohmmeter leads between wires A and B and jumper opposite ends together. Record resistance in table. Repeat procedure between A and C, A and D, etc. Any deviation of plus/minus 2 ohms between any reading and the average of a particular run indicates a poor conductor, and corrective action shall be taken before continuing with the loop test.

Insulation Test: Connect one end of a 500 volt megohmmeter to the panel ground bus and the other end sequentially to each completely disconnected wire and shield. Test the insulation resistance and record each reading.

CERTIFIED _____ Date _____
Contractor's Representative

WITNESSED _____ Date _____
Owner's Representative

SECTION 26 09 16

ELECTRICAL CONTROLS AND RELAYS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The CONTRACTOR shall furnish, install, test, and place in satisfactory operation all electric controls and relays as specified herein and indicated on the Drawings.
- B. Electrical control and relay systems shall be assembled using NEMA rated components. Components designed and built to International Electrotechnical Commission (IEC) standards are not recognized. Equipment designed, manufactured, and labeled in compliance with IEC standards is not acceptable.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 26 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

NEMA 250	Enclosures for Electrical Equipment
UL 508A	Standard for Industrial Control Panels
UL-1203	Standard for Explosion-proof and Dust-ignition-proof Electrical Equipment for use in Hazardous (Classified) Locations.
ANSI/ISA	NonIncendive Electrical Equipment for use in Class I and II, Division II Hazardous (Classified) locations.
UL 489	Molded Case Circuit Breakers, Molded Case Switches, and Circuit Breaker Enclosures

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Product Datasheets.
- C. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

1.05 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:
 - 1. Manufacturer's equipment warranty.
 - 2. Copies of Submittals
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety
 - 4. Contact information for local representative and supplier

1.06 TOOLS AND SPARE PARTS

- A. All spare parts as recommended by the equipment manufacturer shall be furnished to Owner by the CONTRACTOR. In addition to the manufacturer recommended spare parts, the following spare parts shall be provided for the local control stations:
 - 1. One (1) contact block of each type furnished on the project
 - 2. One (1) indicating light lens of each color furnished on the project
 - 3. One (1) LED lamp of each color furnished on the project
 - 4. One (1) Control Relay of each type furnished on the project
 - 5. One (1) Timing Relay of each type furnished on the project
 - 6. One (1) Contact and Coil Kit for each type of motor starter furnished on the project
- B. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.
- C. Spare parts shall be delivered at the same time as the equipment to which they pertain. The CONTRACTOR shall properly store and safeguard such spare parts until completion of the work, at which time they shall be delivered to Owner.
- D. Spare parts lists, included with the shop drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.
- E. Parts shall be completely identified with a numerical system to facilitate parts control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same part number.

PART 2 PRODUCTS

2.01 CONTROL COMPONENTS

- A. Pilot Devices
 - 1. General
 - a. All pilot devices shall be provided with a legend plate. Legend plates shall have a black background and white lettering and indicate the function of the respective

pilot device. Emergency Stop pilot devices legend plates shall have red background with white lettering. The text shown on the Drawings or indicated in the specifications shall be used as the basis for legend plate engraving (i.e., HAND-OFF-AUTO, RUN, EMERGENCY STOP, etc.).

- b. All pilot devices shall be selected and properly installed to maintain the NEMA 250 rating of the enclosure in which they are installed. All pilot devices shall be UL 508 Listed.
- c. All pilot devices shall be 30.5mm in diameter, unless otherwise indicated. 22mm devices are not acceptable.
- d. Pilot devices for all electrical equipment under this Contract shall be of the same type and manufacturer unless otherwise specified herein or indicated on the Drawings.
- e. In Class I Division 2 hazardous locations, pilot devices shall be the hermetically sealed type, constructed in accordance with ANSI/ISA.

2. Pushbuttons

- a. Pushbuttons shall be non-illuminated, black in color, and have momentary style operation unless otherwise indicated on the Drawings.
- b. Pushbuttons shall have the quantity of normally closed and/or normally open contacts as indicated on the Drawings and as required. In addition to the required contacts, one (1) spare normally open and one (1) spare normally closed contact shall be installed at each pushbutton. Contacts shall be rated for 5A at 250VAC/DC (minimum), but no less than required for the application.
- c. Pushbuttons shall be provided with a full guard around the perimeter of the button. Where a lockout style pushbutton is specified or indicated on the Drawings, provide a padlock-able guard.

3. Selector Switches

- a. Selector switches shall be non-illuminated, black in color, and have the number of maintained positions as indicated on the Drawings and as required. Handles shall be the extended type that provide a greater surface area for operation.
- b. Selector switches shall have the quantity of normally closed and/or normally open contacts as indicated on the Drawings and as required. In addition to the required contacts, one (1) spare normally open and one (1) spare normally closed contact shall be installed at each selector switch. Contacts shall be rated for 5A at 250VAC/DC (minimum), but no less than required for the application.
- c. Where indicated in the Drawings or Specifications, provide spring return positions.
- d. Selector switches shall be provided with an indexing component that fits into the keyed portion of the cutout for the device and prevents the switch from spinning when operated.

4. Indicating Lights

- a. Indicating lights shall LED type, with the proper voltage rating to suit the application, and push-to-test feature.
- b. Indicating light lens colors shall be as required in equipment specifications and/or as indicated on the Drawings. If lens colors are not indicated, the following colors shall be used:

Red	"Run", "On", "Open"
Green	"Off", "Closed"

Amber	"Alarm", "Fail"
White	"Control Power On"
Blue	General Status

5. Emergency Stop and Tagline Switches

- a. Emergency stop switches shall be non-illuminated, red in color, with a minimum 35mm diameter mushroom head and supplied with a protective guard to prevent accidental activation. Once activated, switch shall maintain its position and require a manual pull or twist to release/reset.
- b. Tagline switches shall have a plunger that activates upon tension from the associated safety cable. Once activated, switch shall maintain its position and require a manual release/reset.
- c. Emergency stop and tagline switches shall have the quantity of normally closed and/or normally open contacts as indicated on the Drawings and as required. In addition to the required contacts, one (1) spare normally open and one (1) spare normally closed contact shall be installed at each switch. Contacts shall be rated for 5A at 250VAC/DC (minimum), but no less than required for the application.

B. Relays and Timers

1. General

- a. Relays and timers shall be furnished with an integral pilot light for positive indication of coil energization.
- b. Relays and timers shall have tubular pin style terminals with matching 11-pin DIN rail mount socket.
- c. Relays and timers for all electrical equipment under this Contract shall be of the same type and manufacturer unless otherwise specified herein or indicated on the Drawings.
- d. Relays and timers shall fit a standard 11-pin tubular pin socket.

2. Control and Pilot Relays

- a. Relays shall have coil voltage as required to suit the application and/or as indicated on the Drawings.
- b. Relays shall be provided with contacts rated for 10A (resistive), minimum, at 120/240 VAC and 28 VDC. Relays shall have 3-pole, double-throw (3PDT) contact arrangement.

3. Time Delay Relays

- a. Timers delay relays shall utilize electronic timing technology. Mechanical or thermal timing devices are not acceptable.
- b. Relays shall have coil voltage as required to suit the application and/or as indicated on the Drawings.
- c. Relays shall be provided with contacts rated for 10A (resistive), minimum, at 120/240 VAC and 28 VDC. Relays shall have double-pole double-throw (DPDT) contact arrangement.
- d. Time delay ranges shall be as indicated on the Drawings and/or as required to suit the application. Timing range shall be adjustable from the front of the relay. On delay and off delay timer configurations shall be provided as indicated on the Drawings and/or as required to suit the application.

4. Elapsed Time Meters

- a. Elapsed time meters shall be non-resettable type with no less than a 6-digit display. Coil voltage shall be as required to suit the application and/or as indicated on the Drawings.

C. Control Terminal Blocks

- 1. Control terminal blocks shall be assembled on non-current carrying galvanized steel DIN mounting rails securely bolted to the enclosure or subpanel. Terminals shall be tubular screw type with pressure plate that will accommodate wire size range of #22 - #8 AWG.
- 2. Control terminal blocks shall be single tier with a minimum rating of 600 volts and 20A. Separate terminal strips shall be provided for each type of control used (i.e., 120VAC vs. 24VDC). Quantity of terminals shall be provided as required to suit the application. In addition, there shall be enough terminals for the termination of all spare conductors.
- 3. Terminals shall be marked with a permanent, continuous marking strip, with each terminal numbered. One side of each terminal shall be reserved exclusively for incoming field conductors. Common connections and jumpers required for internal wiring shall not be made on the field side of the terminal.

2.02 MOTOR STARTERS

- A. Motor starters shall conform to NEMA Standard IC1 and shall be for across-the-line starting, unless otherwise indicated. IEC rated equipment is not acceptable and shall be used as a basis for rejection of the equipment. The size of the starter shall be as required for the particular load. Minimum starter size shall be NEMA Size 1.
- B. A suitable control disconnect device(s) to comply with the requirements of the NEC shall be provided.
- C. Magnetic starters and contactors shall be electromagnetic vertical or horizontal lift design with double break cadmium oxide silver contacts. Design shall meet or exceed the requirements of UL and NEMA Standards. Coils shall be hot molded construction to protect the coils from mechanical and environmental damage. Contacts and coils shall be replaceable without replacing the entire starter assembly.
- D. Each starter shall be able to accommodate a minimum of three (3) auxiliary contacts in addition to the hold-in contact.
- E. Each starter shall be supplied with a 3 pole, manual reset overload relay. The relays shall be solid state type, with at least one isolated normally open and one isolated normally closed auxiliary contact that operates when a trip condition has occurred. Relays shall be self-powered, have a visible trip indicator, have a trip test function, and have selectable Class 10 or 20 operation. Overload relays shall be set for Class 10 operation unless otherwise directed by the ENGINEER. Overload relay shall have phase loss protection built in to trip the unit and protect the motor against single phasing. The CONTRACTOR shall provide the overload relay model with the correct current range for each application. Overload relay shall have adjustable current range dial. Eutectic alloy or bi-metallic type overload relays are not acceptable.
- F. Each motor starter coil shall be equipped with a surge-suppression device for protection of the solid-state equipment (e.g., programmable logic controller) wired as part of the control circuit.
- G. The minimum control power transformer VA requirements are shown below. Control power transformers shall be sized as required for the connected loads, plus 25% spare capacity.

- Size 1 75 VA
- Size 2 75 VA
- Size 3 200 VA
- Size 4 300 VA
- Size 5 500 VA

- H. The CONTRACTOR is advised to review the Contract Documents for additional requirements for space heaters, power factor correction capacitors, and similar equipment which may not be specified in this Division or shown on the Drawings. Control power transformers shall be fused, or circuit breaker protected on both the primary and secondary sides as shown on the Drawings.

2.03 CIRCUIT BREAKERS

- A. Circuit breakers shall be molded case type with trip and frame ratings as indicated on the Drawings. Provide electronic trip unit where indicated on the Drawings, with adjustable functions as indicated on the Drawings. Provide adjustable instantaneous trip for all circuit breakers rated 100 amps or greater.
- B. The Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.
- C. Circuit breakers shall have an interrupting rating of 65,000 amperes symmetrical at 480 VAC, unless otherwise indicated on the Drawings.
- D. Circuit breakers in non-hazardous locations shall be UL 489 Listed. Circuit breakers in hazardous locations shall be UL 1203 Listed.
- E. Circuit breakers shall be quick-make, quick-break and with an interlocked cover which cannot be opened when the breaker is in the "ON" position and capable of being locked in the "OPEN" position. An interlock defeat to allow opening while energized shall be provided.
- F. Where indicated on the Drawings, circuit breakers shall be 100% rated.
- G. Circuit breakers shall be NEMA style construction, IEC style circuit breakers are not acceptable.
- H. Manufacturer shall be:
 - 1. Square D Company (Schneider Electric)
 - 2. Eaton
 - 3. Siemens Energy and Automation
 - 4. Or ENGINEER Approved Equal

2.04 LOCAL CONTROL STATIONS

- A. Local control stations shall be furnished and installed complete with pushbuttons, selector switches, indicating lights, and other devices as indicated on the Drawings.
- B. Specific devices installed in local control stations shall be provided in accordance with the requirements specified elsewhere in this Section.

- C. In non-hazardous locations, local control stations shall be furnished with the following enclosure type and material of construction, dependent upon the designation of the area in which they are to be installed. Area designations are indicated on the Drawings.

AREA DESIGNATION	ENCLOSURE TYPE AND MATERIAL
Indoor Wet Process Area	NEMA 4X, Type 304 Stainless Steel
Indoor Dry Process Area	NEMA 12, Die Cast Zinc
Indoor Dry Non-process Area	NEMA 12, Die Cast Zinc
Chemical Storage/Transfer Area	NEMA 4X, Fiberglass or Thermoplastic Polyester
All Outdoor Areas	NEMA 4X, Type 304 Stainless Steel

- D. In hazardous locations, local control stations shall be furnished with the following enclosure type and material of construction, dependent upon the classification of the area in which they are to be installed. Area classifications are indicated on the Drawings.

AREA CLASSIFICATION	ENCLOSURE TYPE AND MATERIAL
Class I, Division 1, Group D	NEMA 7, Die Cast Aluminum
Class I, Division 2, Group D	NEMA 4X, Type 304 Stainless Steel
Class II, Division 1, Group F	NEMA 9, Die Cast Aluminum
Class II, Division 2, Group F	NEMA 9, Die Cast Aluminum

- E. Non-metallic enclosures, NEMA 7 enclosures, and NEMA 9 enclosures shall be provided with threaded integral conduit hubs. Conduit hubs shall be external to the enclosure.
- F. Local control stations for use in non-hazardous locations shall be UL-508 Listed. Local control stations for use in Class I Division 1 and Class II Divisions 1/2 hazardous locations shall be UL-1203 Listed. Local control stations for use in Class I Division 2 hazardous locations shall be in accordance with ANSI/ISA.
- G. Provide a nameplate on each local control station in accordance with Basic Electrical (See Referenced Sections). The name and/or number of the equipment associated with each control station shall be engraved on the nameplate, followed by the words "LOCAL CONTROL STATION".
- H. Manufacturer shall be:
1. Eaton
 2. Square D (Schneider Electric)
 3. Allen-Bradley
 4. Or ENGINEER Approved Equal

PART 3 EXECUTION

3.01 INSTALLATION

- A. Local control stations shall be provided in the enclosure type and material of construction required for the area in which it is installed. Reference the requirements in Part 2 herein, and the area designations indicated on the Drawings.

- B. All control components shall be mounted in a manner that will permit servicing, adjustment, testing, and removal without disconnecting, moving, or removing any other component. Components mounted on the inside of panels shall be mounted on removable plates and not directly to the enclosure. Mounting shall be rigid and stable unless shock mounting is required otherwise by the manufacturer to protect equipment from vibration. Component's mounting shall be oriented in accordance with the component manufacturer's and industries' standard practices.
- C. Pilot devices shall be properly bonded to the equipment enclosure door where they are installed. If proper bonding cannot be achieved through the locknuts that affix the device in place, a green colored bonding screw shall be provided on the pilot device. The bonding screw shall be bonded to the equipment enclosure using an insulated green bonding conductor.
- D. Local control station covers shall be bonded to the local control station enclosure using an insulated green bonding conductor.
- E. Wiring to devices at each local control station shall be provided with enough slack to permit the local control station cover to be removed and pulled at least 6 inches away from the enclosure.
- F. Terminal strips, relays, timers, and similar devices shall not be installed on the rear of the panel/cabinet doors. Terminal strips, relays, timers, and similar devices shall not be installed on the side walls of panel/cabinet interiors without written permission from the ENGINEER.

END OF SECTION

SECTION 26 22 00

LOW VOLTAGE TRANSFORMERS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The CONTRACTOR shall furnish, install, and test transformers for power and lighting distribution systems as specified herein, as indicated on the Drawings, and as required to complete the electrical installations.
- B. All equipment specified in this Section shall be furnished by the transformer manufacturer who shall be responsible for the suitability and compatibility of all included equipment.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 26 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

UL 1561	Dry Type General Purpose and Power Transformers
	U.S. Department of Energy 2016 Efficiency
NFPA 70	National Electric Code
NEMA ST-20	Dry Type Transformers for General Applications
ANSI C57	Standard General Requirements for Dry Type Distribution and Power Transformers

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Product Datasheets.
- C. Layout Drawings - Show complete transformer layout, including materials, sizes, locations, and dimensions.
- D. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is

not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

1.05 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:
 - 1. Manufacturer's equipment warranty.
 - 2. Copies of Submittals
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety
 - 4. Contact information for local representative and supplier

1.06 TOOLS AND SPARE PARTS

- A. All spare parts as recommended by the equipment manufacturer shall be furnished to Owner by the CONTRACTOR.
- B. Spare parts lists, included with the Shop Drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.
- C. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same parts number.

1.07 HANDLING AND STORAGE

- A. Equipment shall be carefully transported, stored, handled, and set in place in a manner that will prevent damage, misalignment, and distortion to the equipment.
- B. Follow manufacturer's recommendations regarding handling and storage at all times prior to placing the equipment in service.

1.08 GUARANTEES AND WARRANTY

- A. The equipment manufacturer shall guarantee for a period of five (5) years starting at the time of Substantial Completion, that the equipment supplied is free from defects in materials or workmanship and will meet the specified performance requirements when operated in accordance with the manufacturer's recommendations. The manufacturer shall correct any breach in this warranty at their expense.

PART 2 PRODUCTS

2.01 DRY TYPE TRANSFORMERS

- A. Furnish and install single-phase and three-phase general purpose, dry-type transformers, as specified herein and indicated on the Drawings. The transformers shall be 60 Hz, self-cooled, quiet design insulated of the two-winding type.

- B. The transformers shall be UL 1561 Listed.
- C. The primary windings shall be rated 480 VAC for use on 3 phase systems and connected delta unless indicated otherwise on the Drawings. KVA ratings shall be as shown on the Drawings. Furnish transformers with two 2 1/2% primary taps above, and four 2 1/2% primary taps below rated voltage for transformers 15 KVA and above, and two 2 1/2% primary taps above, and two 2 1/2% primary taps below rated voltage for transformers less than 15 kVA. All taps shall be full capacity rated.
- D. The ratings of the secondary windings shall be as indicated on the Drawings.
- E. Transformers shall be designed for continuous operation at rated KVA, 24 hours a day, 365 days a year, with normal life expectancy as defined in IEEE 65 and ANSI C57.96. This performance shall be obtainable without exceeding 150 degrees Celsius average temperature rise by resistance or 180 degrees Celsius hot spot temperature rise in a 40 degrees Celsius maximum ambient and 30 degrees Celsius average ambient. The maximum coil hot spot temperature shall not exceed 220 degrees Celsius. All insulating materials shall be flame retardant and shall not support combustion as defined in ASTM Standard Test Method D 635. All insulating materials shall be in accordance with NEMA ST 20 Standard for a 220 degrees Celsius UL component recognized insulation system.
- F. Transformers shall meet the latest edition of the Department of Energy Efficiency standards and be Energy-Star compliant.
- G. Transformer coils shall be of the continuous wound copper construction and shall be impregnated with nonhygroscopic, thermosetting varnish.
- H. All cores are to be constructed of high grade, nonaging, grain-oriented silicon steel with high magnetic permeability and low hysteresis and eddy current losses. Magnetic flux densities are to be kept well below the saturation point. The core laminations shall be tightly clamped and compressed with structural steel angles. The completed core and coil shall then be bolted to the base by means of vibration absorbing mounts to minimize sound transmission. There shall be no metal-to-metal contact between the core and coil assembly and the enclosure.
- I. All transformers shall be equipped with a wiring compartment suitable for conduit entry and large enough to allow convenient wiring. The maximum temperature of the enclosure shall not exceed 90 degrees Celsius. Transformers shall be furnished with lugs of the size and quantity required and suitable for termination of the field wiring.
- J. The core of the transformer shall be visibly grounded to the enclosure by means of a flexible grounding conductor sized in accordance with applicable NEMA, IEEE, and ANSI standards.
- K. Transformers shall have core and coil assemblies mounted on rubber isolation pads to minimize the sound levels. Transformers shall not exceed the sound levels listed in NEMA ST-20.
- L. Transformers shall be furnished with the following enclosure type and material of construction, dependent upon the designation of the area in which they are to be installed. Area designations are indicated on the Drawings.

AREA DESIGNATION	ENCLOSURE TYPE AND MATERIAL
Indoor Wet Process Area	NEMA 3R, Painted Steel
Indoor Dry Process Area	NEMA 2, Painted Steel
Indoor Dry Non-process Area	NEMA 2, Painted Steel
All Outdoor Areas	NEMA 3R, Painted Steel

- M. The enclosure shall be made of heavy gauge steel and shall be degreased, cleaned, primed, and finished with a baked weather-resistant enamel using the manufacturer's standard painting process.
- N. Transformers shall be provided with transformer manufacturer's wall mounting kit where indicated on the Drawings.
- O. Manufacturer shall be:
 - 1. Square D (Schneider Electric)
 - 2. General Electric
 - 3. Eaton
 - 4. Siemens Energy and Automation
 - 5. Or ENGINEER Approved Equal

PART 3 EXECUTION

3.01 INSTALLATION

- A. The transformers shall be furnished and installed as shown on the Drawings and as recommended by the equipment manufacturer.
- B. Conduit routed to and from the transformer shall be arranged for easy removal of the transformer access covers.
- C. Where transformers 50 kVA and smaller are shown to be wall mounted, a transformer manufacturer supplied wall mounting kit shall be used. The lowest point of the wall mounting bracket shall be no lower than 7'-0" above the finished floor. Field fabricated mounting hardware is not acceptable unless reviewed and approved in writing by the ENGINEER.
- D. Prior to final completion of the work, all metal surfaces of the equipment shall be cleaned thoroughly, and all scratches and abrasions shall be retouched with the same lacquer as used for shop finishing coats.

3.02 TESTING AND STARTUP

- A. All tests shall be performed in accordance with the requirements of the General Conditions and Division 1. The following tests are required:
 - 1. Factory Shop Tests
 - a. The transformers shall be given routine factory tests in accordance with the requirements of the ANSI and NEMA standards. Temperature rises may be certified from basic design.
 - b. As a minimum, the following tests shall be made on all transformers:
 - 1) Ratio tests on the rated voltage connection and on all tap connections.
 - 2) Polarity and phase-relation tests on the rated voltage connection.
 - 3) Applied potential tests.
 - 4) Induced potential tests.

- 5) No-load and excitation current at rated voltage on the rated voltage connection.

2. Field Tests

- a. Field testing shall be done in accordance with the requirements specified in the General Conditions, Division 1, and NETA Acceptance Testing Specifications, latest edition.
- b. Insulation between windings shall be tested by 1000 VDC Megohmmeter for one (1) minute. Resistance value shall be no less than 100 Megaohms.

END OF SECTION

SECTION 26 24 16

PANELBOARDS

PART 1 GENERAL

1.01 SCOPE OF WORK

- A. The CONTRACTOR shall furnish and install panelboards of voltage and current ratings as specified herein and indicated on the Drawings. Panelboards shall be furnished with circuit breaker ratings, number of breakers, number of poles and locations conforming to the panelboard schedules on the Drawings.
- B. All power distribution equipment shall be UL Listed.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 43 00 – SURGE PROTECTIVE DEVICES
- E. Section 26 05 26 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

1.03 REFERENCES

UL 67	Panelboards
UL 50	Cabinets and Boxes
NEMA PB1	NEMA Standard for Panelboards
NECA 407	NECA Standard for Installing and Maintaining Panelboards
NFPA 70	National Electric Code
UL 489	UL Standard for Circuit Breakers

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Product Datasheets.
- C. Layout Drawings - Show complete panel layout, including materials, sizes, classes, locations, and dimensions.
- D. Results of shop tests, if required.
- E. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or

written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

1.05 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:
 - 1. Manufacturer's equipment warranty.
 - 2. Copies of Submittals.
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety.
 - 4. Contact information for local representative and supplier.

1.06 TOOLS AND SPARE PARTS

- A. For each panelboard, the CONTRACTOR shall furnish to Owner all spare parts as recommended by the equipment manufacturer. All spaces in the panelboards shall be furnished with a spare breaker as indicated in the panelboard schedules shown on the Drawings.
- B. Spare parts lists, included with the shop drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.
- C. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size shall have the same parts number.

1.07 HANDLING AND STORAGE

- A. Equipment shall be carefully transported, stored, handled, and set in place in a manner that will prevent damage, misalignment, and distortion to the equipment.
- B. Follow manufacturer's recommendations regarding handling and storage at all times prior to placing the equipment in service.

PART 2 PRODUCTS

2.01 GENERAL

- A. The Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.
- B. All main bus shall be tin plated copper sized in accordance with UL standards to limit the temperature rise on any current carrying part to a maximum of 50 degrees C above a maximum ambient temperature of 40 degrees C.

- C. All circuit breakers shall be fully rated for the full short circuit rating shown on the drawings. Series ratings are not acceptable.

2.02 LIGHTING PANELBOARDS

A. General

1. Lighting panelboards shall be dead-front type with automatic trip-free, non-adjustable, thermal-overload, branch circuit breakers. Panelboards shall be of the configuration and rating as specified herein and indicated on the Drawings. Panelboards shall be service entrance rated where indicated on the Drawings.
2. Lighting panelboards shall be equipped with a main breaker, or main lugs complete with branch circuit breakers, as indicated on the Drawings. The panelboards shall be suitable for flush or surface mounting.
3. Lighting panelboards shall be fully rated and shall have a minimum short circuit rating of 22,000 amperes symmetrical, unless otherwise indicated on the Drawings.
4. Lighting panelboards shall be Eaton Pow-R-Line Series, the Square D Company equivalent, the General Electric Company equivalent.

B. Enclosures

1. Enclosures shall have a NEMA rating as indicated on the Drawings. The minimum NEMA rating for panels in dry locations is NEMA 1 (Gasketed).
2. Enclosures shall be constructed of No. 12 U.S.S. code gauge galvanized steel. The door shall be fastened to the enclosure with concealed hinges and shall be equipped with flush-type catches and locks. The CONTRACTOR shall equip cabinet doors exceeding 40 inches in height with vertical bolt three-point locking mechanism. All locks shall be keyed alike. The panelboard trim shall have a removable hinge assembly, in addition to the door hinge, that allows work inside the enclosure without the need to remove the trim. The enclosure shall have wiring gutters on sides and shall be at least 5-3/4 inches deep. The panelboard shall be provided with an information label. The information label shall include the panelboard designation, voltage, phase, wires, and bus rating.
3. All metal surfaces of the panelboard enclosures shall be thoroughly cleaned and given one prime of zinc chromate primer. All interior surfaces shall then be given one shop finishing coat of a lacquer of the nitro cellulose enamel variety. All exterior surfaces shall be given three coats of the same lacquer. The color of finishing coats shall be manufacturer's standard light gray. Stainless steel panelboards are not required to be painted unless indicated otherwise on the Drawings.
4. An Underwriter's Laboratories, Inc. inspection label shall appear on the interior of the cabinet.

C. Bus Work

1. Main bus bars shall be of ample size so that a current density of not more than 1000 amperes per square inch of cross section will be attained. This current density shall be based on the application of the full load connected to the panel plus approximately 25% of the full load for spare capacity. The main bus shall be full capacity as based on the preceding for the entire length of the panel to provide full flexibility of circuit arrangement.
2. Solid neutral bus bars are required, and neutral bus ampacity shall be the same as the main bus bars unless otherwise noted. Ratings shall be in accordance with applicable standards.

3. A separate ground bus shall be provided with lugs for termination of equipment grounding conductors.
4. Branch bus work shall be rated to match the maximum branch circuit breaker which may be installed in the standard space.
5. All bus shall be tin plated copper and shall extend the entire useable length of the panelboard, including spaces. Silver plated busswork is not an acceptable alternative.

D. Circuit Breakers

1. Circuit breakers shall be bolt-on, molded-case type conforming to UL 489. All circuit breakers shall have quick-make, quick-break, toggle mechanism for manual as well as automatic operation. Tandem or half-size circuit breakers are not acceptable
2. Where indicated on the Drawings, or where required by Code, circuit breakers shall be equipped with integrally mounted ground fault interrupters (GFCI) complete with "TEST" push button and shall be of a type which fit standard panelboard spaces for the breaker continuous current rating required. Trip rating for ground fault shall be 6mA or less as required by UL and the NEC.
3. Where indicated on the Drawings, or where required by Code, circuit breakers shall be equipped with integrally mounted ground fault protection equipment (GFPE or E-GFCI) complete with "TEST" push button and shall be of a type which fit standard panelboard spaces for the breaker continuous current rating required. Trip rating for ground fault shall be 30mA or less as required by UL and the NEC. All heat tracing shall be protected by a GFPE breaker regardless of whether or not it is shown on the Drawings.
4. Circuit breakers used for lighting circuit switching shall be approved for the purpose and shall be marked "SWD".
5. Where required by Article 440 of the NEC, circuit breakers installed for air conditioning units shall be HACR type.
6. Circuit breaker voltage ratings shall meet or exceed the panelboard voltage indicated on the Drawings. Trip elements of circuit breakers shall be 20A unless otherwise indicated on the Drawings. Circuit breakers shall have an interrupting rating that matches the panelboard short circuit rating.
7. Where indicated on the Drawings, branch circuit breakers shall be provided with a padlockable hasp or handle padlock attachment for padlocking in the off position as required to meet the NEC requirement for disconnecting means and/or OSHA lock-out/tagout standard. Locking hardware shall remain in place even when the padlock is removed. Branch circuit breakers used for control, instrumentation, telephone, fire alarm, or auxiliary equipment circuits requiring continuous operation shall be provided with a similar lock on device where indicated on the Drawings.

E. Directories

1. Approved directories with noncombustible plastic cover, and with typewritten designations of each branch circuit, shall be furnished and installed in each panelboard. The CONTRACTOR shall maintain in each panel, during the duration of the Contract, a handwritten directory clearly indicating the circuit breakers in service. This directory shall be updated as work progresses, and final, typewritten directories, as specified above, shall be installed at the end of the project. Designations and circuit locations shall conform to the panelboard schedules on the Drawings, except as otherwise authorized by the ENGINEER.

2.03 SURGE PROTECTIVE DEVICE - INTERNALLY MOUNTED

- A. The panelboards shall be furnished with integrated Type II surge protective devices (SPD). SPDs shall be provided in the location and quantity as shown on the Drawings.
- B. The SPD shall be rated, designed, tested, listed, and labeled in accordance with UL-1449, latest edition.
- C. The SPD shall be factory installed by the panelboard manufacturer using a direct bus connection. There shall be no cable connection between the bus bar and the SPD device.
- D. The SPD shall have a fault current rating equal to or greater than that of the fault current rating of the panelboard. The SPD shall employ metal-oxide varistor (MOV) technology. If integral fusing is used, the fuses shall allow the maximum rated surge current to pass without fuse operation.
- E. The SPD shall have a maximum continuous operating voltage (MCOV) of at least 115% of the nominal voltage of the panelboard. The Voltage Protection Rating (VPR) of each SPD shall not exceed the following:

SYSTEM VOLTAGE	L-N	L-G	L-L	N-G
208Y/120	600V	1000V	1000V	600V
480Y/277	1200V	1800V	2000V	1000V
480Δ	N/A	1800V	3000V	N/A
240Δ	N/A	1200V	1500V	N/A
120/240	600V	1000V	100V	600V

- F. The Nominal Discharge Current (In) of the SPD shall be 20kA. Peak surge current ratings shall not be used as a basis for applying the SPD to the system.

The surge current rating for each SPD shall be as indicated on the Drawings. Surge current ratings are indicated in panel schedules. Surge current rating indicated is on a per phase basis.

- G. Each SPD system shall provide surge protection in all possible modes. Surge protection shall be as follows:

SYSTEM CONFIGURATION	MODES OF PROTECTION	NUMBER OF MODES
3-Phase Wye	L-N, L-G, N-G	7
3-Phase Delta	L-L, L-G	6
3-Phase Impedance Grounded	L-L, L-G	6
Single-Phase	L-N, L-G, N-G	3

- H. The SPD shall be furnished with an audible alarm and silence pushbutton, integral SPD status LEDs (one per phase), and a Form C dry contact for remote indication of alarm. A surge counter shall also be provided.
- I. The SPD equipment shall be SPD Series by Eaton, SurgeLogic by the Square D Company, or engineer approved equivalent.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Panelboards shall be furnished and installed as shown on the Drawings and as recommended by the equipment manufacturer, and as required by NECA 407.
- B. Panelboards shall be set true and plumb in locations as shown on the Drawings. The top of panelboard enclosure shall not exceed six (6) feet above finished floor elevation.
- C. Enclosures shall not be fastened to concrete or masonry surfaces with wooden plugs. Appropriate stainless-steel bolts shall be used with expansion shields or other metallic type concrete insert for mounting on concrete or solid masonry walls. Stainless steel toggle bolts shall be used for mounting on concrete block or other hollow masonry walls. Bolt diameter shall be as required considering the size and weight of the completed panelboard and enclosure to provide adequate structural support.
- D. The CONTRACTOR shall not use factory furnished knockouts with surface mounted back boxes. The CONTRACTOR shall punch, or drill required openings during installation and shall equip flush mounted back boxes with manufacturer's standard pattern of knockouts.
- E. The CONTRACTOR shall install cabinets (and other enclosure products) in plumb with the building construction. Flush mounted enclosures shall be installed so that the trim will rest against the surrounding surface material and around the entire perimeter of the enclosure.
- F. Prior to final completion of the work, all metal surfaces of the equipment shall be cleaned thoroughly, and all scratches and abrasions shall be retouched with the same lacquer as used for shop finishing coats.
- G. Upon completion of installation, all Spare circuit breakers shall be set to the "OFF" position.

3.02 TESTING AND STARTUP

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 - 1. Prior to termination of any conductors to the circuit breakers, all bus work and circuit breakers shall be tested from phase to phase and phase to ground with a 1000 VDC megohmmeter for 1 minute in accordance with NECA 407. Resistance values shall be recorded and shall not be less than 100 megohms.
 - 2. Prior to terminating any wires to the circuit breakers, the resistance of the connection between the bus work and each circuit breaker shall be tested using a low-resistance ohmmeter. Record the resistance values for each circuit breaker.

END OF SECTION

SECTION 26 29 00

LOW VOLTAGE CONTROLLERS

PART 1 GENERAL

1.01 THE REQUIREMENT

- A. The CONTRACTOR shall furnish, install, test, and place in satisfactory operation, the motor control centers as specified herein and indicated on the Drawings.
- B. The CONTRACTOR shall obtain the motor control centers from one manufacturer who shall also manufacture the enclosure and major equipment components, which includes, but is not limited to, combination starters, reduced voltage solid state starters, circuit breakers, power monitoring equipment, and other components of the equipment assembly.
- C. The motor control center shall be assembled using NEMA rated components. Components designed and built to International Electrotechnical Commission (IEC) standards are not recognized. Equipment designed, manufactured, and labeled in compliance with IEC standards is not acceptable.

1.02 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions - SUBMITTALS
- C. Section 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 26 05 26 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS
- E. Section 26 05 33.16 – BOXES FOR ELECTRICAL SYSTEMS
- F. Section 26 43 00 – SURGE PROTECTIVE DEVICES
- G. Section 26 09 16 – ELECTRICAL CONTROLS AND RELAYS

1.03 REFERENCES

NEMA ICS 18	Motor Control Centers
UL 845	Standard for Safety Motor Control Centers
ISO 9001	Standard for Quality Management Systems

1.04 ACTION SUBMITTALS

- A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.
- B. Partial, incomplete, or illegible submittals will be returned to the CONTRACTOR without review for resubmittal.
- C. Shop drawings for each motor control center shall include but not be limited to:

1. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the CONTRACTOR AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.
 2. Product data sheets.
 3. Example equipment nameplate data sheet.
 4. Approximate total shipping weight of each shipping split.
 5. Plan, front, and side view drawings, including overall dimensions of each motor control center. Identify shipping splits and show conduit stub-up area locations on the Drawings.
 6. Internal schematic and point-to-point wiring diagrams of each motor control unit including reduced voltage solid state starters integrated into the motor control center. Standard wiring diagrams that are not custom created by the manufacturer for the motor control centers for this project are not acceptable. One wiring diagram which is typical for an equipment group (e.g., screw pump, backwash pumps) is not acceptable. Each wiring diagram shall include wire identification and terminal numbers. Indicate all devices, regardless of their physical location, on the diagrams. Identify on each respective wiring diagram specific equipment names and equipment numbers consistent with those indicated on the Drawings.
 7. Complete single-line diagrams for each motor control center showing circuit breakers, motor circuit protectors, motor controllers, instrument transformers, meters, relays, timers, control devices, and other equipment comprising the complete assembly. Indicate electrical ratings of equipment and devices on these single-line diagrams. Ratings include starter size and type, motor circuit protector continuous current rating, circuit breaker frame size and trip rating, motor horsepower and full load current, and similar information.
 8. Bill of material list for each motor control center and each motor control unit.
 9. Nameplate schedule for each motor control center.
 10. Manufacturer's installation instructions.
 11. Key interlock scheme drawing and sequence of operations.
 12. Manufacturer's Warranty Statement
 13. Table listing all motor loads connected to the motor control center. Table shall include the full load amps of the APPROVED motors. Final approval of MCC shop drawings cannot be given until all motor loads for MCC have been reviewed, approved, and shown in this table.
- D. The shop drawing information shall be complete and organized in such a way that the ENGINEER can determine if the requirements of these Specifications are being met. Copies of technical bulletins, technical data sheets from "soft-cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the CONTRACTOR intends to provide are acceptable and shall be submitted.

- E. Prior to completion and final acceptance of the project, the CONTRACTOR shall furnish and install "as-built" wiring diagrams for each motor control center unit of each motor control center. These final drawings shall be included in the O&M manuals.

1.05 INFORMATIONAL SUBMITTALS

- A. In accordance with the procedures and requirements set forth in the General Conditions and the CONTRACTOR shall obtain from the equipment manufacturer and submit the following:
1. Proposed Testing Methods and Reports of Certified Shop and Field Tests.
 2. Manufacturers Startup Certification.
 3. Operation and Maintenance Manuals.
- B. Each submittal shall be identified by the applicable specification section.
- C. The CONTRACTOR shall submit operation and maintenance manuals in accordance with the procedures and requirements set forth in the General Conditions.

1.06 SPARE PARTS

- A. All spare parts as recommended by the equipment manufacturer shall be furnished to the Owner by the CONTRACTOR.
- B. In addition to the manufacturer recommended spare parts, the CONTRACTOR shall furnish the following spare parts for each motor control center:

<u>No. Required</u>	<u>Description</u>
2 sets	Fuses of each size provided
2	Relay of each size and type used.
1	Control power transformer of each size used.
2	Lamps and lenses for indicating lights, each color.
1	Indicating lamp sockets for each type used.
1	Pilot device (e.g., pushbutton, selector switch, etc.) complete with contact blocks and legend plates for each type, color, size, and rating used.
1	Motor circuit protector for each type, size, and rating used.
1	Molded case circuit breaker for each type, size, and rating used (except main circuit breakers).
1	Set of replacement surge protection modules

- C. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.

- D. Spare parts shall be delivered at the same time as the equipment to which they pertain. The CONTRACTOR shall properly store and safeguard such spare parts until completion of the work, at which time they shall be delivered to Owner.
- E. Spare parts lists, included with the shop drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Term such as "1 lot of packing material" are not acceptable.
- F. Parts shall be completely identified with a numerical system to facilitate parts control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same parts number.

1.07 IDENTIFICATION

- A. Each motor control center shall be identified with the identification number indicated on the Drawings (e.g., PS-MCC, etc.). A nameplate shall be securely affixed in a conspicuous place on each motor control center. Nameplates shall be engraved black background with white lettering, affixed by #10 screws.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. The equipment covered by this Specification is intended to be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, constructed and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.
- B. It is the intent of these specifications that all components of the motor control center be provided by one manufacturer who shall have the sole responsibility of matching all components and providing equipment which functions together as a system. The manufacturer of the motor control center shall also be the manufacturer of the motor controllers. The use of third-party supply and assembly of these components is not acceptable.
- C. Motor control centers shall be Centerline 2100 as manufactured by Allen-Bradley, Freedom as manufactured by Eaton, Model 6 as manufactured by Schneider Electric using NEMA contactors and starters, or Engineers approved equal.

2.02 MOTOR CONTROL CENTER

- A. General
 - 1. The motor control centers shall be 600 VAC class suitable for operation on a three-phase, 60 Hz system. The motor control centers, and their components shall conform to the requirements of applicable standards of NEMA Part ICS 2-322 and Underwriters' Laboratories, Inc. UL-845. Wiring shall be NEMA Class II, Type B. Each vertical section shall be a NEMA 1A (gasketed) unless otherwise specified or indicated on the Drawings.
 - 2. The enclosures shall be cleaned, primed, and finish coated in accordance with the manufacturer's standard process. The pre-treatment process shall be a zinc chromate primer followed by a "One Coat" paint process that is monitored to meet the manufacturer's specifications for paint color, texture, thickness, and durability. Enclosure interior and exterior finish color shall be manufacturer's light grey. The color of the back panel/bucket located within the MCC enclosure shall be white.

3. The motor control centers shall be capable of withstanding the fault current available at its line terminals. Minimum bus bracing, withstand, and interrupting ratings are specified herein.
4. Unless otherwise specified or indicated on the Drawings, each vertical section shall be approximately 20 inches wide, and 90 inches high, 20 inches deep, and shall not contain more than six NEMA Size 1 starters. Motor control centers shown "back-to-back" on the Contract Drawings shall be complete motor control assemblies placed back-to-back in the location shown. Motor control center sections with common horizontal and/or vertical bus systems are unacceptable.
5. Continuous horizontal wiring troughs shall be provided at both the top and bottom of each section. These troughs shall line up to form a continuous wireway for the full length of the motor control center. Each section shall be provided with a large, continuous, full height vertical wiring trough in the right side of each section. Each vertical wiring trough shall be furnished complete with tie bars for conductor support.
6. All control wiring shall be No. 14 AWG (minimum) labeled at each end in accordance with the wiring numbers shown on the accepted shop drawings. Power wiring shall be sized to suit the maximum horsepower rating of unit; No. 12 AWG (minimum). Wiring shall be type MTW rated for 105°C. Wire color coding shall be red for control and black for power. Wire numbers shall not be repeated in a motor control center.
7. Starter units shall contain the number of auxiliary contacts, unit-mounted pilot devices and indicating lights, control relays, elapsed time meters, and other devices as shown on the Drawings and required for the applications. A minimum of two (2) normally open (NO) and two (2) normally closed (NC) spare contacts shall be provided for each magnetic starter. These spare contacts shall be shown on the submittal wiring diagrams.
8. The motor control centers shall be furnished with warning signs to notify maintenance personnel of multiple sources of power within the motor control units.

B. Power

1. The motor control centers shall be supplied from a 480V, 3-phase, 3 or 4 wire as indicated on the Drawings, 60 Hz power source. The incoming power feeders shall be sized as shown on the Drawings. All terminals for incoming and outgoing power cables shall be provided with long barrel compression lugs.

C. Bus

1. Power shall be distributed by means of a continuous, tin plated copper horizontal bus, rated as shown on the Drawings. The bus shall be braced for 65,000A rms symmetrical at 480V unless otherwise indicated on the Drawings. The horizontal bus shall be effectively isolated from all wiring troughs and other working areas. Vertical bus extensions shall be tin plated copper, isolated by rigid, glass-polyester moldings to be a separate self-supported assembly. Full height vertical bus shall be installed in all sections including those containing spare units and "prepared" spaces. No extra safety jacks or similar devices shall be required to obtain an essentially dead-front condition. Access shall be provided for inspection and maintenance from the front. Minimum horizontal bus rating shall be 600A. Minimum vertical bus rating shall be 600A.

D. Incoming Line Units

1. Each incoming line unit shall contain buswork and fittings as required with cable lugs for cables of sizes and quantities shown on the Drawings. Cable lugs shall be suitable for their respective conductors. Incoming lugs shall be long barrel, crimp type only. Mechanical lugs are not permitted.

2. A neutral landing pad shall be furnished in the main circuit breaker section. A neutral landing pad is required to terminate the grounded conductor from the utility transformer in accordance with the NEC. The neutral landing pad shall be capable of serving as the neutral-ground bonding location where shown on Drawings.

E. The Unit Compartments

1. Each unit compartment shall be provided with an individual front door hinged to the vertical structure. Each plug-in unit shall be supported and guided by a removable unit support pan, so that the unit rearrangement is easily accomplished. The rearrangement of the unit support pan from one location to the other shall be accomplished without use of tools. After insertion, each plug-in unit shall be held in place by at least one multi-turn latch, located at the front of the unit. The latch shall be located for front accessibility and installation convenience. An additional mechanical interlock shall be provided to prevent withdrawal of the unit from the stationary structure with the operating mechanism in the ON position.
2. The unit plug in power stabs shall be electromagnetically tin plated copper to yield a low resistance connection and designed to tighten during heavy current surges and short circuits. The stab shall be backed by spring steel clips to provide and maintain a high pressure, two point connection to the vertical bus. They shall be free floating and self loading plug-in. Wiring from the unit disconnecting means to the plug-in stab shall be exposed at the rear of the unit. The power cable terminations at the plug-in stab shall be mounted in a two-piece, glass polyester support assembly. This support assembly shall provide a separate isolated pathway for each phase, minimizing the probability of a unit fault condition reaching the power bus system.
3. NEMA Size 1 through Size 5 non-reversing starters shall be plug-in units. Size 1, 2, and 3 shall utilize stab assembly rated 100A. Stab assemblies for Size 4 and Size 5 starters shall be rated for the starters maximum output current rating.
4. An industrial, heavy-duty flange handle mechanism shall be supplied for the control of each disconnecting means. This mechanism shall be engaged with the disconnect device at all times as an integral part of the unit regardless of the unit door position. The operator handles shall have an up-down motion with the down position as off. The ON-OFF condition of the disconnecting means shall be permanently marked on the handle operator. It shall be possible to lock the handle in the "OFF" position with up to three (3) 3/8-inch diameter shackle padlocks and in the "ON" position with one (1) 3/8-inch diameter shackle padlock.
5. The operator handle of all units shall be interlocked with the door units so that the disconnect means cannot be switched unless the door unit is closed. A means shall be provided for purposely defeating the interlock during maintenance or testing. This interlock shall also prevent opening the unit door unless the disconnecting means is in the off position. An externally operated defeater requiring the use of a screwdriver shall provide access to the unit without interrupting service.
6. The overload relays shall be resettable from the outside of the enclosure by means of an insulated bar or button.

F. Ground Bus

1. The horizontal ground bus shall be tin plated copper and located in the bottom horizontal wireway. The minimum size of the horizontal ground bus shall be 1/4-inch x 2-inch (6.35mm x 50.8mm).
2. Compression lugs shall be mounted on the ground bus in each section, in the size and quantity as required for the termination of system and equipment grounding conductors.

3. The vertical ground bus shall be tin plated copper and solidly connected to the horizontal ground bus. This ground bus, in combination with the unit ground bus stab, establishes unit grounding before the plug-in power stabs engage the power bus, and conversely, as the unit is withdrawn, grounding is maintained until after the plug-in power stabs are disengaged.
4. The vertical load ground bus shall be tin plated copper and solidly connected to the horizontal ground bus. The vertical load ground bus assembly, comprised of the vertical load ground bus and the unit load ground bus connector, shall provide a termination point for the load equipment grounding conductor at the unit. This fixed connection shall not have to be removed when the unit is withdrawn from the motor control center.

G. Isolation and Insulation

1. Horizontal bus access covers and vertical bus covers shall isolate the energized buses to guard against the hazard of accidental contact. These covers shall be molded of a glass polyester material.
2. The horizontal bus shall be isolated.
3. The vertical bus cover shall provide unit plug-in openings which shall permit unit plug-in stab assemblies to pass through and engage the vertical bus. The unit plug-in openings shall be sized to minimize the probability of inadvertent contact with the vertical bus.
4. Isolation of unused stab openings shall be accomplished by use of a manual shutter to close off the stab opening. These shutters shall be attached to the structure so that when they are removed (to allow a stab connection) they are retained in the structure and are readily accessible for use should a plug-in unit be removed from the motor control center.
5. All units shall be isolated from one another, above and below, by unit support pans or steel barriers, which can remain in place when the units are withdrawn.
6. Incoming line compartments shall be isolated from horizontal and vertical wireways by steel barriers. These barriers shall ensure that switching off the incoming circuit breaker isolates the load side for servicing as de-energized equipment as required by NFPA 70E.
7. A molded unit isolating barrier shall be provided to isolate the unit from the vertical wireway.

H. Combination Motor Control Units

1. Motor branch circuits shall be protected by a motor circuit protector (MCP). The motor circuit protector shall be NEMA design and rated, and of phenolic resin construction. IEC design devices and devices with thermoplastic construction are not permitted.
2. The motor circuit protector shall be operated by a toggle type handle and shall have a quick make, quick break over center switching mechanism that is mechanically trip free from the handle, so that the contacts cannot be held closed against short circuits and abnormal currents. Tripping shall be clearly indicated by the handle automatically assuming a position midway between the manual ON and OFF positions. All latch surfaces shall be ground and polished. All poles shall be so constructed that they open, close, and trip simultaneously.
3. Each pole of these motor circuit protectors shall provide instantaneous short circuit protection by means of an adjustable magnetic only element. Thermal magnetic circuit breakers are not an acceptable substitution and will be rejected.
4. The motor circuit protectors in combination with a contactor and overload relay shall have an interrupting rating that matches the motor control center short circuit rating at the motor control center rated voltage. Series ratings are not acceptable.

5. Motor circuit protector's ratings, modifications, etc., shall be as specified herein and as indicated on the Drawings.
6. Motor circuit protectors shall be completely enclosed molded case devices with a current sensing coil in each of the 3 poles and have a magnetic trip adjustment located on the front. The motor circuit protector shall be manually operable. The protector shall be designed to meet the NEC requirement concerning motor full load and locked-rotor current. Ampere ratings shall be clearly visible. Contacts shall be of non-welding silver alloy. Arc extinction must be accomplished by means of arc chutes, consisting of metal grids mounted in an insulating support.

I. Motor Starters

1. Motor starters shall conform to NEMA Standard IC1 and shall be for across-the-line starting, unless otherwise indicated. IEC rated equipment is not acceptable and shall be used as a basis for rejection of the equipment. The size of the starter shall be as required for the particular load. Minimum starter size shall be NEMA Size 1. Size 1 and 2 starters shall be completely drawout type, so that units may be withdrawn without disconnecting any wiring. Size 3 and 4 full-voltage, non-reversing starters shall be drawout type after disconnecting power leads only. Starters over three-space units high may be bolt-on type. A positive guidance system shall be provided to assure proper alignment of wedge-shaped power stabs in dead front openings in vertical power bus.
2. A suitable control disconnect device(s) to comply with the requirements of the NEC shall be provided.
3. Magnetic starters and contactors shall be electromagnetic vertical or horizontal lift design with double break cadmium oxide silver contacts. Design shall meet or exceed the requirements of UL and NEMA Standards. Coils shall be hot molded construction to protect the coils from mechanical and environmental damage. Contacts and coils shall be separately replaceable without replacing the entire starter assembly.
4. Each starter shall be able to accommodate a minimum of three (3) auxiliary contacts in addition to the hold-in contact.
5. Each starter shall be supplied with a 3 pole, manual reset overload relay. The relays shall be solid state type, with at least one isolated normally open and one isolated normally closed auxiliary contact that operates when a trip condition has occurred. Relays shall be self-powered, have a visible trip indicator, have a trip test function, and have selectable Class 10 or 20 operation. Overload relays shall be set for Class 10 operation unless otherwise directed by the ENGINEER. Overload relay shall have phase loss protection built in to trip the unit and protect the motor against single phasing. The CONTRACTOR shall provide the overload relay model with the correct current range for each application. Overload relay shall have adjustable current range dial. Eutectic alloy or bi-metallic type overload relays are not acceptable.
6. Each motor starter coil shall be equipped with a surge-suppression device for protection of the solid-state equipment (e.g. programmable logic controller) wired as part of the control circuit.
7. The minimum control power transformer VA requirements are shown below. Control power transformers shall be sized as required for the connected loads, plus 25% spare capacity.
 - a. Size 1 75 VA
 - b. Size 2 75 VA
 - c. Size 3 200 VA
 - d. Size 4 300 VA

e. Size 5 500 VA

8. The CONTRACTOR and motor control center manufacturer is advised to review the Contract Documents for additional requirements for space heaters, power factor correction capacitors, and similar equipment which may not be specified in this Division or shown on the Drawings. Control power transformers shall be protected on both the primary and secondary sides as indicated on the Drawings.
9. Reduced voltage solid state starters shall be provided for the motor loads as specified herein and as indicated on the Drawings.

J. Circuit Breakers

1. Where specified herein, indicated on the Drawings, or required, the main circuit breaker shall be rated for service entrance and bear a service entrance label.
2. Unless otherwise indicated, circuit breakers shall be manually operable and shall provide thermal-magnetic, inverse-time-limit overload, and instantaneous short-circuit protection.
3. Circuit breakers shall be molded case type, rated 480 VAC, 2 or 3 pole and have 100 ampere or larger frames. The interrupting rating shall match that of the motor control center short circuit rating at 480V.
4. Overload protection shall be provided on all poles with trip settings as indicated on the Drawings. Breakers of 225-ampere frames and larger shall have interchangeable trip units and adjustable magnetic trip elements.
5. Horizontally mounted operator handles for feeder circuit breaker units up to 225A are not accepted unless indicated on Drawings.
6. Where indicated on the Drawings, shunt trip devices shall be provided to trip a circuit from a remote location by means of a trip coil energized from a separate circuit. A 120V shunt trip shall be capable of operating 55% or more of rated voltage. All other shunt trips shall be capable of operating at 75% or more of rated voltage. CONTRACTOR is responsible for coordinating shunt trip voltages.

K. Terminal Blocks

1. Terminal blocks associated with removable units within the motor control center shall be provided as follows:
 - a. Terminal blocks shall be mounted within the unit insert and in the front for ease of accessibility.
 - b. Pull-apart style terminal block assemblies shall be provided. Terminal block assembly shall consist of a male and female component held together with captive screws. The terminal block assembly shall be designed to withstand the effects of vibration, yet able to be pulled apart without difficulty. The terminals of the assembly shall be recessed to isolate them from accidental contact. Terminal markings shall be provided for the purpose of identifying terminations. Terminal strips shall be suitable for use as a disconnecting means of foreign interlock voltages.
 - c. For starters Size 2 and smaller, terminate all starter wiring (power and control) and external field wiring on terminal blocks provided in each unit.
 - d. For starters Size 3 and larger, terminate control wiring and external field control wiring on terminal blocks provided in each unit.

2. Terminal blocks associated with non-removable units within the motor control center shall be provided in accordance with Electrical Controls and Relays (See Referenced Sections).
3. Provide a minimum of four (4) spare terminals in each terminal block assembly.

L. Control Devices

1. Furnish and install control devices as required and/or shown on the Drawings. The following control devices shall be provided as specified in Electrical Controls and Relays (See Referenced Sections):
 - a. Pilot devices (switches, indicating lights, etc.)
 - b. Relays and timers

M. Nameplates

1. Provide engraved plastic nameplates to identify the motor control center, each unit compartment, door mounted devices, and internal components.
2. Equipment names and numbers as indicated on the single line diagrams shall be used as the basis to engrave the nameplates.
3. Provide a master nameplate giving motor control center designation, voltage rating, ampere rating, short circuit rating, manufacturer's name, general order number and item number.
4. Control components mounted as part of the assembly, such as fuse blocks, control relays, pushbuttons, switches, and similar devices, shall be suitably marked for identification corresponding to appropriate designations on the manufacturer's wiring diagrams.

N. Future Space Requirements

1. Provide spaces for future combination starter and other units in the motor control centers. Furnish spaces with hardware to accommodate future plug-in control unit without modification of vertical sections. Provide the number of spaces required for future units as indicated on the Drawings, minimum.
2. Provide additional vertical sections to ensure total number of spaces as indicated on the Drawings. The number of vertical sections is contingent upon specific manufacturer's final proposed and ENGINEER-accepted configuration of motor control center units.

O. Motor Control Center Additions

1. The CONTRACTOR shall furnish and install complete motor control center sections or individual motor control center units to be added to existing motor control centers in accordance with these Specifications and as indicated on the Drawings.
2. These additions shall be of the same manufacturer, type, rating, and color as the existing motor control centers. Furnish and install all hardware necessary to connect the buses of the new and existing motor control centers, including ground buses. Enclosures shall match existing.

P. Motor Control Center Modifications

1. The CONTRACTOR shall modify existing motor control centers and specific motor control center units as specified herein and indicated on the Drawings. These

modifications include, but are not limited to, additions of door mounted pilot devices, modifications to existing motor control circuits and other work.

2.03 SURGE PROTECTIVE DEVICES

- A. The motor control center shall be furnished with integrated Type II surge protective devices (SPD). SPDs shall be provided in the location and quantity as shown on the Drawings.
- B. The SPD shall be rated, designed, tested, listed, and labeled in accordance with UL-1449, latest edition.
- C. The SPD shall be factory installed by the motor control center manufacturer using a direct bus connection. There shall be no cable connection between the bus bar and the SPD device.
- D. The SPD shall have a fault current rating equal to or greater than that of the fault current rating of the motor control center. The SPD shall employ metal-oxide varistor (MOV) technology. If integral fusing is used, the fuses shall allow the maximum rated surge current to pass without fuse operation.
- E. The SPD shall have a maximum continuous operating voltage (MCOV) of at least 115% of the nominal voltage of the motor control center. The Voltage Protection Rating (VPR) of each SPD shall not exceed the following:

SYSTEM VOLTAGE	L-N	L-G	L-L	N-G
208Y/120	700V	700V	1200V	700V
480Y/277	1200V	1200V	1800V	1200V
LTA	N/A	1200V	2000V	N/A
LTA	N/A	1200V	1200V	N/A
120/240	700V	700V	1200V	700V

- F. The Nominal Discharge Current (In) of the SPD shall be 20kA. Peak surge current ratings shall not be used as a basis for applying the SPD to the system.
- G. The surge current rating for each SPD shall be as indicated on the Drawings. Surge current ratings are indicated on single line diagrams. Surge current rating indicated is on a per phase basis.
- H. Each SPD system shall provide surge protection in all possible modes. Surge protection shall be as follows:

SYSTEM CONFIGURATION	MODES OF PROTECTION	NUMBER OF MODES
3-Phase Wye	L-N, L-G, N-G	7
3-Phase Delta	L-L, L-G	6
3-Phase Impedance Grounded	L-L, L-G	6
Single-Phase	L-N, L-G, N-G	3

- I. The SPD shall be furnished with an audible alarm and silence pushbutton, integral SPD status LEDs (one per phase), and a Form C dry contact for remote indication of alarm. A surge counter shall also be provided.

- J. The SPD equipment shall be SPD Series by Eaton, SurgeLogic by the Square D Company, Tranquell by the General Electric Company, Siemens Energy and Automation Inc. equivalent, or approved equal.

2.04 VARIABLE FREQUENCY DRIVES

- A. Refer to Specification 26 29 23

PART 3 EXECUTION

3.01 INSTALLATION

- A. The motor control centers shall be installed as shown on the Drawings and in accordance with the manufacturer's installation instructions.
- B. Install motor control centers to allow complete unit door swing required for unit removal. This is specifically required where a vertical section of motor control center is set next to a wall to the left of the motor control center section.
- C. Where motor control center structures are located away from walls to allow bottom conduit entry, the CONTRACTOR shall furnish and install sheet metal coverings for openings along the sides and top of the motor control center line-up. The purpose of the coverings is to minimize dust, dirt, and undesirable materials from collecting behind the equipment. The sheet metal coverings shall be of the same material, gauge, and finish as the motor control center.
- D. Motor control centers shall be furnished with anchor bolts as required for aligning and mounting. Floor channels with end covers shall be of type recommended by the manufacturer and shall be furnished for installation in a concrete pad.
- E. All field wiring that is terminated directly to a unit within the motor control center shall be neatly routed in a manner that does not hinder the ability to service, adjust, or replace components within that unit. Field wiring shall be properly anchored to the motor control center and individual unit structures.
- F. Prior to final completion of the work, all metal surfaces of the equipment shall be cleaned thoroughly, and all scratches and abrasions shall be retouched with the same lacquer as used for shop finishing coats.
- G. Prior to energizing, CONTRACTOR shall vacuum out motor control center compartments and floor underneath motor control center fully. CONTRACTOR shall also wipe all surfaces with a lint free cloth to ensure no dust or metal particles remain.

3.02 TESTING

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 - 1. Certified Shop Tests and Reports
 - a. As a minimum, the entire motor control center shall go through a quality inspection before shipment. This inspection shall include, but is not limited to, the following:
 - 1) Physical inspection of the structure and the electrical conductors including bussing, general wiring, and units.

- 2) General electrical tests including power circuit phasing, control circuit wiring, instrument transformers, meters, ground fault system, and device electrical operation.
 - 3) AC dielectric tests of the power circuits and control circuits.
 - 4) Markings/labels, including instructional type, Underwriters Laboratory (UL), and inspector's stamps.
- B. The manufacturer shall use integral quality control checks throughout the manufacturing process to maintain the correctness of the motor control center.
- C. Field Tests
 1. Field tests shall be performed in accordance with the requirements specified in the General Conditions and NETA Acceptance Testing Specifications, latest edition.

3.03 FIELD ADJUSTMENTS

- A. All adjustable settings of circuit breakers shall be set in the field by a qualified representative of the manufacturer, or an outside testing company retained by the CONTRACTOR, in accordance with the settings designated in the coordination study. See Basic Electrical Requirements (See Referenced Sections).
- B. The settings of the motor circuit protectors and overload relays for existing equipment shall be set based on the coordination study and the motor nameplate data of the motors installed.
- C. The settings of the motor circuit protectors and overload relays for all equipment installed in this contract shall be determined and provided by the Manufacturer of the connected equipment. CONTRACTOR is responsible for guaranteeing that settings meet criteria for connected equipment Manufacturer's warranty.

3.04 SERVICES OF MANUFACTURER'S REPRESENTATIVE

- A. The CONTRACTOR shall provide the services of a qualified, factory-trained manufacturer's technical representative who shall adequately supervise the installation and testing of all equipment furnished under this Contract. The manufacturer's representative shall certify in writing that the equipment has been installed in accordance with the manufacturer's recommendations. No further testing or equipment startup may take place until this certification is accepted by Owner.
- B. The manufacturer's technical representative shall perform startup and functional testing of the equipment as specified herein.
- C. The CONTRACTOR shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory-trained representative who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section. Training shall be provided for one (1) session of two (2) hours. Training shall be at times coordinated with Owner. Training shall be provided in accordance with the requirements of the General Conditions.
- D. The services of the manufacturer's representative shall be provided for a period of not less than as follows:
 1. One (1) trip of one (1) working day during the installation and startup of the equipment.
 2. One (1) trip of one (1) working day two (2) months before the warranty expiration to identify any issues to be corrected under warranty.

3. One (1) trip of one (1) working day to perform training as specified herein.
- E. Any additional time required to achieve successful installation and operation shall be at the expense of the CONTRACTOR.

END OF SECTION

SECTION 26 29 23
VARIABLE FREQUENCY MOTOR CONTROLLERS

PART 1- GENERAL

1.01 SCOPE OF WORK

- A. The Contractor shall furnish and install all switches, occupancy sensors, and receptacles of the type and at the locations as shown on the Drawings.

1.02 RELATED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 260500 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 260916 – ELECTRICAL CONTROLS AND RELAYS
- E. Section 262900 – LOW VOLTAGE CONTROLLERS

1.03 REFERENCES

UL 50	Enclosures for Electrical Equipment
UL 508	Industrial Control Equipment
UL 508A	Standard for Industrial Control Panels
UL 508C	UL Standard for Safety Power Conversion Equipment
UL 991	Safety Tests for Safety Related Controls Employing Solid State Devices
IEEE 519-2014	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

1.04 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Harmonic Study Report
 - 1. Harmonic Study and Data shall include but not be limited to:
 - a. Report of Harmonic Study to determine the harmonic distortion present in the voltage and current waveforms on motor terminals and in the electrical distribution system(s) caused by the variable frequency drive system as specified herein.
 - b. Voltage and current waveforms supplied by variable frequency drive at the motor leads.
 - c. Necessary descriptions regarding calculation method, assumptions, values and notations, basis for input information, manufacturer's harmonic content data, and calculation results interpretation.
- C. Testing

1. Witnessed Shop Tests

- a. The VFD's specified in this Section shall be witness shop tested and inspected in accordance with the equipment manufacturer's standard procedures. The testing and inspection procedures shall demonstrate that the equipment tested conforms to the requirements specified and shall be approved by the Engineer. At least 10 days notice shall be given the Engineer prior to such tests and inspection dates.
- b. Factory test the complete variable frequency drive system in accordance with IEEE and NEMA standards with these Specifications. In addition, the variable frequency drive system shall be tested for efficiency as defined in this Specification and for operational integrity during output short circuit conditions. Short circuit test shall demonstrate that the equipment will successfully protect against and survive a minimum of three (3) successfully repeated phase-to-phase short circuits at the drive output terminals.
- c. Variable frequency drive system components, including power transistors, GTOs, SCRs, IGBT's, diodes shall be 100 percent inspected and tested, including temperature cycling and inspected and tested including temperature cycling and ambient high temperature of 65 degrees Celsius load testing. All integrated circuits shall be inspected, pass/fail tested, temperature cycled and ambient high temperature tested. Small components, including small signal semiconductors, resistors, capacitors, diodes, etc. shall be lot sampled and tested for functionality. Test printed circuit boards under a temperature cycled 20 hour load test and functionally bench test prior to unit installation. Inspect all final assemblies and test at full load with application of line-to-line and line-to-ground bolted faults. The variable frequency drive system shall electrically trip off line under these conditions without device failure.
- d. After the specified inspections and tests have been successfully completed, the variable frequency drive system shall undergo an 8 hour burn-in test. Burn system in at 100 percent inductive or motor load for 40 hours without an unscheduled shutdown.

2. Certified Shop Tests and Reports

- a. Submit description of proposed testing methods, procedures, and apparatus.
- b. Submit notarized and certified copies of all test reports.
- c. Submit factory bench-test data to indicate that the manufacturer's proposed equipment has been tested in the specified arrangement and found to achieve specified accuracy.

3. Field Tests

- a. Field tests shall be performed in accordance with requirements specified in the General Conditions, and Common Work Results for Electrical (See Referenced Sections).
4. Authorized representatives of the Owner shall be allowed free access to the shop at all times while work is in progress for the purpose of inspection, witnessing of tests, and obtaining information on the progress of the work. The Owner shall give the Contractor 72 hours prior notice.
5. Acceptance of a shop test does not relieve Contractor from requirements to meet field installation tests under specified operating conditions, nor does the inspection relieve the Contractor of responsibilities.
6. The Contractor shall successfully complete acceptance test procedures on the assembled

drive system that demonstrate compliance with the requirements of this Specification. The test plan shall be submitted for acceptance at least 30 days prior to the planned test date.

7. Drive system shall not be shipped from the manufacturing and assembly facility until the acceptance tests are completed and the acceptance tests are completed, and the results approved by the test representative.
8. Tests shall be witnessed by a representative of the Engineer. Variable frequency drive manufacturer shall notify the Engineer 2 weeks in advance and shall provide testing procedures to the Engineer 4 weeks prior to actual testing. Failure of a test shall result in rejection of the equipment until performance is in compliance with these Specifications.
9. Certification on materials and records of shop tests necessary for the inspector to verify that the requirements of the Specifications are met, shall be made available to the inspector.
10. Submit signed and dated certification that all of the factory inspection and testing procedures described herein have been successfully performed by the Contractor prior to shipment.

D. Shop Drawings

1. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.
2. Partial, incomplete, or illegible submittals will be returned to the Contractor without review for resubmittal.
3. Drawings submitted by the manufacturer shall be complete and documented to provide the Owner with operations and maintenance capabilities.
4. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the Contractor AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.
5. Shop drawings for each VFD shall include but not be limited to:
 - a. Layout drawings of the variable frequency drive system that include all cabinet or enclosure dimensions, access details, and weights.
 - b. Layout drawings of panels or enclosures showing size, arrangement, color, and nameplates. Drawings shall include the physical arrangement of door mounted devices located on the variable frequency drive enclosure. Sufficient detail shall be provided for locating conduit stub-ups. General "catalog data sheet" layout drawings which are not specific to the systems specified herein are not acceptable.
 - c. Custom schematic and interconnection wiring diagrams of all electrical work, including

terminal blocks and identification numbers, wire numbers and wire colors. Standard schematics and wiring diagrams that are not custom created by the manufacturer for the variable frequency drives for this project are not acceptable. These drawings shall be circuit specific for each motor-load combination. Indicate all devices, regardless of their physical location, on these diagrams. Specific equipment names consistent with the Drawings shall appear on each respective diagram.

- d. Complete single line diagrams indicating all devices comprising the variable frequency drive system including, but not limited to, circuit breakers, motor circuit protectors, contactors, instrument transformers, meters, relays, timers, control devices, and other equipment comprising the complete system. Electrical ratings of all equipment and devices shall be clearly indicated on these single line diagrams.
 - e. Complete Bills of Material and catalog data sheets for all equipment and devices comprising the variable frequency drive system.
 - f. A complete list of recommended spare parts, including item descriptions, recommended quantities, and unit costs. The recommended list should be based on a maintenance plan where the Owner will remove and replace failed items to the lowest replaceable module/component level.
6. The shop drawing information shall be completed and organized in such a way that the Engineer can determine if the requirements of these Specifications are being met. Copies of technical bulletins, technical data sheets from "Soft Cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the Contractor intends to provide are to provide are acceptable and shall be submitted.
7. Prior to completion and final acceptance of the project, the Contractor shall furnish and install "as-built" wiring diagrams for each VFD. These final drawings shall be plastic laminated and securely placed inside each VFD and starter door and included in the O&M manuals.
8. Product Data shall include, but not be limited to:
- a. Functional diagrams that identify major system functional blocks and interfaces.
 - b. Special requirements or restrictions of the motor-load combination that may result from operation on the variable frequency drive system.

1.05 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list in accordance with the procedures and requirements set forth in the General Conditions (See Referenced Sections) including but not limited to:
 - 1. Manufacturer's equipment warranty
 - 2. Copies of Submittals
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, programming guides, safety
 - 4. Contact information for local representative and supplier

1.06 QUALITY ASSURANCE

- A. Manufacturer's Qualifications: Firms regularly engaged in the manufacture of variable frequency drive systems of the types and sizes required, whose products have in satisfactory use in similar service for not less than 5 years.
- B. Installer's Qualifications: Firms with at least 3 years of successful installation experience on projects with variable frequency drive work similar to that required for this project.
- C. Codes and Standards:
 - 1. Electrical Code Compliance: Comply with applicable local code requirements of the authority having jurisdiction and the National Electrical Code, NFPA 70.
 - 2. NEMA Compliance: Comply with applicable requirements of NEMA Standards publications pertaining to raceways, conduits, and cable trays.
 - 3. UL Compliance and Labeling: Comply with applicable requirements of UL safety standards pertaining to electrical raceway systems. Provide raceway products and components which have UL-listed and labeled.

1.07 TOOLS AND SPARE PARTS

- A. The VFD's and accessories shall be furnished with all special tools necessary to disassemble, service, repair, and adjust the equipment. All spare parts as recommended by the equipment manufacturer shall be furnished by the Contractor to the Owner.
- B. The Contractor shall furnish the following spare parts for each VFD:
 - 1. One set of all power and control fuses for each variable frequency drive.
 - 2. One fully functional main control circuit board for each variable frequency drive.
 - 3. One of each inverter power semiconductor for each rating supplied for each variable frequency drive.
 - 4. Spare auxiliary equipment as specified Herein.
- C. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.
- D. Spare parts shall be delivered at the same time as the equipment to which they pertain. The Contractor shall properly store and safeguard such spare parts until completion of the Work, at which time they shall be delivered to the Owner.
- E. Spare parts lists, included with the shop drawing submittal shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.
- F. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same parts number.

1.08 IDENTIFICATION

- A. Each VFD shall be identified by the circuit number and equipment name as indicated on the Drawings. A nameplate shall be securely affixed in a conspicuous place on each VFD. Nameplates shall be as specified in Common Work Results for Electrical (See Referenced Sections).

1.09 TRAINING

- A. The Contractor shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory trained specialists who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section.
- B. Provide the services of an experienced, factory trained technician or service engineer of the variable frequency drive manufacturer at the jobsite for minimum of 3 days for training of Owner personnel, beginning at a date mutually agreeable to the Contractor and the Owner. The technician shall be on duty at the site for at least 8 hours per day and shall be available 24 hours per day when required to advise concerning special problems with equipment and systems.
- C. Include in the bid the training of personnel in the operation and maintenance of each furnished variable frequency drive pump control system. For the purpose of this training section of the Specifications, a system is by definition a group of pumps or equipment which all serve a common function. Training shall include at least one session for 2 designated employees for each system.

1.10 HANDLING AND STORAGE

- A. Equipment shall be carefully transported, stored, handled, and set in place in a manner that will prevent damage, misalignment, and distortion to the units.
- B. Follow manufacturer's recommendations regarding handling and storage at all times prior to placing the pump in service.

1.11 GUARANTEES AND WARRANTY

- A. Contractor shall warrant that the material and workmanship of all components and the operation of the variable frequency drive system and auxiliary equipment is in accordance with the latest design practices and meets the requirements of this Specification.
- B. Warranty work shall include, but not be limited to, the following:
 - 1. Replace components found to be faulty and make changes in equipment arrangement or adjustments necessary to meet the equipment or functional requirements of this Specification.
 - 2. Warranty shall include system rewiring and substitution and rebuilt or additional equipment required during trial operation or subsequent operation of the unit during the period of this warranty.
 - 3. Warranty shall be in effect for a period of 24 months following final acceptance of the system.

PART 2- PRODUCTS

2.01 MANUFACTURERS

- A. The equipment covered by this Specification is intended to be standard equipment of proven performance. Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.
- B. The Contractor shall obtain the VFD's from one manufacturer who shall also manufacture the enclosure and major equipment components. "Bare" VFDs are not acceptable. The manufacturer shall have a minimum of five years experience in the manufacture of similar units and shall have a general distribution to the electrical trade. Subcontracting of wiring will not be acceptable.
- C. The VFD's for shall be as manufactured by:
 - 1. Rockwell/Allen-Bradley
 - 2. Eaton/Cutler-Hammer
 - 3. Or Engineer Approved Equal
- D. Motor control circuits shall be wired in accordance with the requirements specified herein or indicated on the Drawings. Where not indicated, the control circuits shall be standard three-wire "start-stop" and the Contractor shall furnish wiring accordingly.
- E. Variable frequency drive manufacturer shall be responsible for the successful application and operation of the entire drive and control system serving the motor and driven equipment. This includes the responsibility for obtaining all load, torque, speed and performance requirements from the respective sources and integrating these into a variable frequency drive system that fulfills the requirements of this Specification.
- F. The Contractor and variable frequency drive system manufacturer are cautioned regarding the review and compliance with the total Contract Documents. Typical examples are circuit breakers, motor circuit protectors, magnetic starters, relays, timers, control and instrumentation products, pilot devices including pushbuttons, selector switches and pilot lights, enclosures, conduit, disconnect switches, terminal boxes, and other equipment.

2.02 PRODUCT REQUIREMENTS

- A. Variable speed drives shall be adjustable frequency, adjustable voltage, pulse width modulated (PWM) design. The units shall be microprocessor controlled, fully digitally programmable, and capable of precise and repeatable speed regulation of three phase 480 volt AC NEMA Design B induction motors. If other NEMA designs are used, the Contractor shall coordinate VFD sizing accordingly. Contractor holds final responsibility for coordinating the drives submitted with conduit and wire, overcurrent protection, and motor loads. Contractor shall include all costs associated with VFD sizing in bid.
- B. Drive units shall perform continuous self-diagnostics as well as load and drive self-check on startup.
- C. All drives shall have permanently mounted programming and display modules. These

modules shall provide programming access to all drive parameters, display all fault codes to assist with diagnostics and provide a display of output speed in percent or load.

- D. This specification describes variable speed motor control which includes the design, fabrication, testing, installation and support requirements for variable frequency drive systems for 3-phase, squirrel cage rotor, induction motors driving pumps or other equipment.
- E. Each variable frequency drive to be a complete alternating current electric drive system including hardware, software, technical data, and spare parts necessary to accomplish variable speed operation of an induction motor and load combination in accordance with the requirements as indicated on the Drawings and as described in these Specifications. Contractor shall refer to Instrumentation and Controls Sections of the Specifications for a functional control description of each variable frequency drive system.
- F. Variable frequency drive system manufacturer shall be responsible for the design and performance of the entire drive system and shall either manufacture all items of equipment or supply them using coordinated specifications furnished to the original equipment manufacturers to insure compatibility and performance in accordance with this Specification. Variable frequency drive manufacturer shall coordinate with suppliers of the drive motors and driven equipment. Motors shall be as specified in specific equipment Sections of the Specifications.
- G. Variable frequency drive system shall be suitable for operation as part of a 480 VAC, 3 phase, 60 Hertz power distribution system, unless otherwise shown on Drawings. The complete variable frequency drive system shall withstand the mechanical forces exerted during short circuit conditions when connected directly to a power source having available fault current of 65,000 amperes symmetrical at rated voltage.
- H. The variable frequency drive system shall be suitable to operate, at times, on a limited power source engine-generator set. The system shall be provided with equipment and devices to prevent waveform distortion as specified herein.
- I. Provide control and sequence logic as specified herein and indicated on the Drawings. Control and sequence logic shall be designed such that the motor-load combination can be operated in the manual mode upon control and sequence logic failure, including all necessary personnel and equipment safety interlocks.
- J. Design each variable frequency drive motor drive speed control system so that through simple programming by either factory engineers or Owner's trained operating personnel, specific control and protection functions can be attained.

2.03 DESIGN REQUIREMENTS

- A. Each variable frequency drive system shall meet the requirements of this Specification without derating any of the induction motor operating parameters including service factor and nameplate horsepower. The variable frequency drive system manufacturer shall specifically identify special requirements or restrictions of the motor-load combination that may result from operation on the variable frequency drive system.
- B. The variable frequency drive shall consist of a 6 diode semiconductor rectifier system, direct current link, and pulse width modulated inverter. The inverter shall invert the direct current voltage into an alternating current voltage at a frequency which shall be proportional to the desired speed. This alternating current voltage and frequency shall

both vary simultaneously at a constant "Volts-Per-Hertz" ratio to operate the induction motor at the desired speed.

- C. Variable frequency drive shall operate from fixed frequency power supply and convert this input power into variable speed induction motor shaft power as required by this Specification. Provide each variable frequency drive with a motor circuit protector as indicated on the Drawings which shall be padlockable. Provide each variable frequency drive with 5% line reactors at the input. Include the necessary drive controllers and output contactors to accomplish the intended control of the variable frequency drive system.
- D. The drive shall operate the motor and produce full rated nameplate horsepower at the motor output shaft without exceeding motor nameplate full load current and with the motor not exceeding rated total temperature not including the additional temperature increment that constitutes the motor service factor. Motor shall retain its service factor when operated by the variable frequency drive.
- E. The overall drive system efficiency shall be a minimum of 95 percent when operating the specified motor-load combination at rated voltage, frequency, and current. The efficiency shall be calculated as follows: $Efficiency (\%) = \frac{Power (Load)}{Power (Supply)} * 100$
- F. Power (Load) is the total 3-phase power delivered to the motor, measured at the output terminals of the drive system, including output filters or transformers. Power (Supply) is the total electrical power delivered to the drive system, measured at the input terminals of the variable frequency drive including input filters, line reactors, isolation transformers, or other harmonic distortion suppression equipment. Include power input required for auxiliary equipment (e.g., controls, fans, air conditioning, pumps) for complete system operating in this Power (Supply) total.
- G. Variable frequency drive shall provide smooth, stepless changes in motor speed and acceleration over the entire operating speed range from minimum to maximum speed (revolutions per minute). The variable frequency drive shall be provided with maximum and minimum frequency limits.
- H. Variable frequency drive system to maintain a desired output frequency (setpoint) with a steady state accuracy of 0.5 percent of rated frequency of 60 Hertz for a 24 hour period.
- I. Variable frequency drive to have an automatic current limit feature to control motor currents during startup and provide a "soft start" torque profile for the motor-load combination. The variable frequency drive shall also limit current due to motor winding or motor lead phase-to-phase short circuit or phase-to-ground short circuit. The current limit protection setting shall be field adjustable. Variable frequency drive shall be furnished with programmable electronic overload and torque limits.
- J. Drive system shall achieve a desired output frequency (setpoint) with a repeatability of 0.1 percent of rated frequency of 60 Hertz.
- K. Drive system to be capable of operating the specified load continuously at any speed within the operating speed range of 10 percent to 100 percent of rated speed. The minimum and maximum continuous operating speeds shall each be adjustable within this speed range. The variable frequency drive shall provide for field adjustment of these setpoints.
- L. Drive system controls to be microprocessor-based and have controlled linear

acceleration capability to ramp up the speed, revolutions per minute, of the motor-load combination from the minimum selected operating speed to the maximum selected operating speed in a minimum of 30 seconds. Provide two (2) field-adjustable speed setpoints for the variable frequency drive to skip equipment resonant frequencies. Provide controlled linear deceleration capability. The acceleration and deceleration time limits shall be field adjustable to values up to 120 seconds.

- M. Voltage or current unbalance between phases of the variable frequency drive output voltage shall not exceed 3 percent of the instantaneous values. The variable frequency drive system shall continuously monitor the output voltages and generate an alarm condition when the unbalance exceeds 3 percent. The system shall detect and generate a separate alarm for loss of any output phase voltage (single phasing). Phase unbalance shall be as defined by NEMA Standard MG-1.
- N. Variable frequency drive system to operate continuously without interruption of service or damage to equipment during transient input voltage variations of plus or minus 10 percent for a duration of 15 cycles. Unacceptable voltage fluctuations on the supply bus shall cause under or overvoltage protection to trip and remove supply voltage from the drive system. Variable frequency drive output voltage regulation shall be plus or minus 2 percent. The variable frequency drive system shall be furnished with line surge protection.
- O. The Contractor shall size variable frequency drive system and components to provide, indefinitely, motor load current equal to 125 percent of the motor nameplate full load current. The Contractor is fully responsible for the review of the mechanical specifications to determine specified motor speed, horsepower and full load amperes. This information is available in the applicable mechanical specifications for each pump, drive, conveyor, blower, etc. Reference the Table of Contents.
- P. The VFD shall have an adjustable thermostat internally mounted to activate fans if the VFD temperature reaches 85F or greater. The VFD shall only run the fans when this condition exists or the drive is active. Cooling fans shall not run whenever the drive is energized, but only when running or with an elevated internal temperature.
- Q. The VFD shall be provided with a time delay relay for the Fail logic so that the Fail operation is not latched in immediately at startup when power is applied to the VFD enclosure. The manufacturer shall ensure that the VFD does not automatically operate the Fail logic at powering up.
- R. The audible noise (sound pressure) level of a motor when operated from no load to full load with the variable frequency drive described herein shall not increase more than 5 decibels (dbA), at 5 feet in any direction from the motor, above its noise level when operated from a utility power source without the variable frequency drive.
- S. Variable frequency drives shall be provided with output reactors or filters to prevent elevated voltage levels at the motor terminals.

2.04 OPERATING CONDITIONS

- A. The following operating conditions are applicable for all equipment of this Specification.
 - 1. Humidity: 0-95 percent.
 - 2. Ambient Temperature: Minus 20 degrees Celsius to plus 50 degrees Celsius.

3. Altitude: up to 4,583 feet
4. Power Supply: 480 volts, 3-phase, 60 Hertz
5. Available Short Circuit Duty: as specified herein.

2.05 SYSTEM FEATURES AND CHARACTERISTICS

A. Controls and indicators to accomplish operation and maintenance shall be located on the variable frequency drive equipment assembly as specified herein and indicated on the Drawings. As a minimum, each VFD shall provide indication of the following:

1. Digital Speed Indicator: Revolutions per minute (input from tachometer).
2. Variable Frequency Drive Mode Indicator: Red; as required.
3. Input Voltage
4. Output Voltage
5. Output Current
6. Output Frequency
7. Output Speed: 0-100%
8. Drive Ready Indicator: White
9. Run Indicator: Red.
10. Stop Indicator: Green.
11. Running Time Meter.
12. Enclosure Overtemperature.
13. Alarm Indicator: Amber.
14. Alarm Read-out: Display.

B. Each VFD shall provide the following automatic and manual controls:

1. Hand-Off-Auto Selector Switch (as required).
2. Start and Stop pushbuttons (as required).
3. Local Speed Potentiometer.
4. Alarm Reset Pushbutton.
5. 24 VDC coil pilot relay for remote run command.
6. Alarm auxiliary contacts and other devices as indicated on the Drawings and specified.

7. Provision for a run permissive from other equipment when the drive is in "Auto".
- C. Each VFD shall provide "potential-free" output contacts for the following conditions:
 1. Drive running.
 2. Drive in "Auto" and all trip conditions cleared.
- D. Variable frequency drive system shall provide a 4-20 mADC output signal that is proportional to the drive output frequency for use as speed feedback or control and remote speed indication.
- E. Variable frequency drive system shall accept a 4-20 mADC input command signal to control the output frequency in the automatic and/or manual control modes as specified herein or indicated on the Drawings. The system shall accept the input increase/decrease command with a resolution that permits incremental changes in speed, revolutions per minute, equal to or less than 0.1 percent of rated speed.
- F. When operating in the automatic mode, the variable frequency drive system shall shut down during a power outage. Upon restoration of normal power and after an adjustable time delay (0-2 minutes; motor has coasted to zero speed and there is no backspin), the variable frequency drive system shall automatically restart and then ramp up to speed as required by the control system. The process operator shall not be required to reset the system manually after a shutdown caused by a power outage.
- G. Variable frequency drive shall be furnished with a multiple attempt restart feature.
- H. Furnish a door mounted selector switch or other pilot device for those variable frequency drives where an additional speed reference signal (e.g., from a remote potentiometer, an analog output from a setpoint (PID) controller, an analog output from a programmable logic controller, or similar analog signal) is to be supplied to the variable frequency drive in addition to the door mounted manual speed control.
- I. Provide a motor circuit protector for each variable frequency drive. Provide each variable frequency drive with its respective drive controller and output contactors for each motor.
- J. Include in each variable frequency drive system an automatic trip feature which will open the output contactor and remove the drive output from the motor and allow it to decelerate safely. This automatic system shall trip and indicate the fault only upon the following conditions:
 1. Output voltage unbalance (trip threshold field set).
 2. Open phase.
 3. Motor overload.
 4. Motor stator winding fault (phase-to-ground, phase-to-phase).
 5. Loss of input power to the variable frequency drive or unacceptable voltage variation.
 6. High variable frequency drive equipment temperature.

7. Variable frequency drive system failure as determined by the manufacturer.
 8. Component failure.
 9. Overcurrent.
 10. Undercurrent.
- K. Provide variable frequency drive system with transmitted and received radio interference protection. In addition, provide protection against starting a rotating motor, both directions (coasting to zero speed and backspin). In the event that a motor automatic restart feature (catch the motor "on-the-fly") is provided in the drive controller as standard, this feature shall be capable of being disabled.
- L. Variable frequency drive design shall include on-line diagnostics, with an automatic self-check feature that will detect a variable frequency drive failure which in turn affects motor operation and generates an alarm contact output rated for 125 VDC suitable for interfacing with the control system.
1. Diagnostics shall operate a visual alarm indicator that is visible on the variable frequency drive equipment cabinets without opening the cabinet doors.
 2. Diagnostics shall provide an easily readable output that will isolate a failure.
 3. Provide an event and diagnostic recorder to printout in narrative English of the specific fault(s) and the sequence in which the faults occurred. An indication of the "First Out" failure is a minimum for fault sequence detection.
 4. Provide a normally open dry contact for each alarm function to enable remote indication. A communication port shall be provided for possible future link to the collections control system.

2.06 ENCLOSURES

- A. Unless otherwise specified or indicated on the Drawings, the variable frequency drive enclosures shall be NEMA 12, force ventilated, dead-front, with front accessibility. VFDs integrated into motor control center structures shall meet the enclosure requirements for MCCs as specified in Low Voltage Controllers (See Referenced Sections). Design enclosures for both bottom and top entry of cables. Design variable frequency drive system so that rear cabinet access is not required for operations, maintenance, and repair tasks. Other enclosure requirements are:
1. Treat metal surfaces and structural parts by phosphatizing prior to painting.
 2. Apply a gun-metal gray undercoat to enclosures which is equal to zinc chromate.
 3. Finish exterior of the enclosures in Manufacturer's standard gray enamel or furnish in a color to match the complete line-up of equipment as indicated on the Drawings and accepted by the Engineer.
 4. The doors shall have full length piano type hinges.
 5. Brace each door to prevent sag when fully open.

The Contractor shall reference the Drawings for maximum dimensions of the VFDs.

- B. Furnish each variable frequency drive system with the control switches, alarm lights and indicators as specified herein and as indicated on the Drawings. Furnish main circuit breakers with an external operating handle interlocked with the door so that the door cannot be opened unless the disconnect is in the OFF position. Power supply to the motor from both the variable frequency drive shall be capable of being positively locked in the OFF position. The disconnect shall be interlocked so that equipment cannot be energized when the door is open.
- C. Electrical bus, including ground bus, shall be tin-plated copper. Power and control wiring shall be copper, color coded and identified in accordance with these Specifications.
- D. Equipment shall be of modular construction allowing normal maintenance and repair to be done with ordinary hand tools. Design and install power electronic component assemblies so that, where practicable, components can be individually removed and replaced.

2.07 HARMONIC DISTORTION SUPPRESSION

- A. A comprehensive pre-equipment-selection harmonic study shall be prepared by the Contractor. The results of this pre-equipment selection study shall be submitted to the Engineer as part of the submittals specified herein. Should this study indicate the need for tuned filters, line reactors, isolation transformers, or other harmonic distortion suppression equipment, these shall be supplied at no additional cost to the Owner. Indicate the location of the harmonic suppression equipment in the submittal data. Location is subject to acceptance by the Engineer.
- B. At minimum each VFD assembly shall be provided with an input line reactor and a drive output dV/dT filter.
- C. The harmonic distortion values resulting from operation of all or any variable frequency drive-driven motor-load combinations operating at full load shall be as defined in IEEE Standard 519-2014.
 - 1. Maximum allowable total harmonic voltage distortion (THD): within the limits of IEEE Standard 519-2014, Table 1.
 - 2. Maximum allowable individual frequency harmonic voltage distortion: within the limits of IEEE standard 519-2014.
 - 3. Maximum allowable total demand distortion (TDD): within the limits of IEEE Standard 519-2014, Table 2.
 - 4. Maximum allowable individual frequency harmonic demand distortion: within the limits of IEEE Standard 519-2014, Table 2.
 - 5. The harmonic distortion levels shall be specific to the "Point of Common Coupling" (PCC) as defined in IEEE Standard 519-2014 and indicated on the Drawings.
- D. System single line diagrams and field access to the plant site will be provided to the Contractor for the purpose of providing this study. Contractor shall obtain from others other information that may be necessary to perform this study. Input data and other pertinent information used in harmonic study shall be coordinated by the Contractor with the following:

1. Input data/information/results of the short circuit fault analysis specified herein.
 2. Electrical system configuration and electrical equipment shop drawing submittal data including, but not being limited to new non-linear loads, new linear loads, and new capacitors.
- E. Preparation of this pre-equipment selection study does not relieve the requirement for the Contractor to perform and submit the results of a second, final comprehensive study prepared by a recognized independent authority acceptable to the Owner after equipment installation.
- F. In addition, the Contractor shall field measure actual harmonic distortion and verify with tests performed by an independent authority acceptable to the Owner after satisfactory full-load operation.
- G. As part of the specified harmonic studies and other work for this project, identify and correct resonance conditions in the electrical distribution system at no additional cost to the Owner. Shop drawings, data, location of the respective equipment and its connection to the electrical distribution system shall be acceptable to the Engineer.
- H. Reference Common Work Results for Electrical (See Referenced Sections) for information gained from the electric utility company during the design period which could be used for the purpose of the harmonic study. Inclusion of this information, however, does not relieve the Contractor nor his suppliers of the responsibility of obtaining all the necessary information required to perform the harmonic study.

2.08 MISCELLANEOUS

- A. Encapsulate critical components in ceramic or metal.
- B. Auxiliaries, including fans, that are required for rated load operation at maximum ambient temperature, shall be 100 percent redundant. A new and unused spare replacement fan(s) or air conditioning unit(s), shipped in original carton, may be acceptable.
- C. Circuit boards and electrical components shall meet the corrosion protection requirements specified in these Specifications. Varnished or epoxy encapsulated circuit boards and tropicalized contactors suitable for corrosive environments shall be furnished where the VFDs are not located in climate controlled areas.

PART 3- EXECUTION

3.01 GENERAL

- A. Painting
1. All metal surfaces of the motor control equipment shall be thoroughly cleaned and given one prime coat of zinc chromate primer. All interior surfaces shall then be given one shop furnished coat of a lacquer of the nitro-cellulose enamel variety. All exterior surfaces shall be given three coats of the same lacquer. The color of finishing coats shall be as approved by the Engineer. Color chips shall be forwarded to the Engineer for color selection and approval prior to finish painting. The interior of the VFD enclosure shall be painted white.
 2. Prior to final completion of the work, all metal surfaces of the equipment shall be

cleaned thoroughly, and all scratches and abrasions shall be retouched with the same coating as used for factory finishing coats.

B. Rubber Mats

1. A three foot wide rubber mat shall be furnished and installed on the floor and in front of each VFD assembly. The mat shall be long enough to cover the full length of each VFD system. The mat shall be 1/4 inch thick with beveled edges, canvas back, solid type with corrugations running the entire length of the mat. The mat shall be guaranteed extra quality, free from cracks, blow holes or other defects detrimental to their mechanical or electrical strength. The mat shall meet OSHA requirements and the requirements of ANSI/ASTM D-178 J6-7 for Type 2, Class 2 insulating matting.

3.02 INSTALLATION

- A. The VFD's shall be installed as shown on the Drawings and in accordance with the manufacturer's installation instructions.
- B. Install VFD's to allow complete door swing required for component removal. This is specifically required where a VFD is set in the corner of a room.
- C. Include in the bid an allowance for factory-trained service personnel, other than sales representatives, to supervise field installation, inspect, make final adjustments and operational checks, make functional checks of spare parts, and prepare a final report for record purposes. Adjust control and instrument equipment until this equipment has been field tested by the Contractor and the results of these tests have been accepted by the Engineer.

3.03 TESTING AND STARTUP

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:
 1. Witnessed Shop Tests
 - a. The VFD's specified in this Section shall be witness shop tested and inspected in accordance with the equipment manufacturer's standard procedures. The testing and inspection procedures shall demonstrate that the equipment tested conforms to the requirements specified and shall be approved by the Engineer. At least 10 days notice shall be given the Engineer prior to such tests and inspection dates.
 - b. Factory test the complete variable frequency drive system in accordance with IEEE and NEMA standards with these Specifications. In addition, the variable frequency drive system shall be tested for efficiency as defined in this Specification and for operational integrity during output short circuit conditions. Short circuit test shall demonstrate that the equipment will successfully protect against and survive a minimum of three (3) successfully repeated phase-to-phase short circuits at the drive output terminals.
 - c. Variable frequency drive system components, including power transistors, GTOs, SCRs, IGBT's, diodes shall be 100 percent inspected and tested, including temperature cycling and inspected and tested

including temperature cycling and ambient high temperature of 65 degrees Celsius load testing. All integrated circuits shall be inspected, pass/fail tested, temperature cycled and ambient high temperature tested. Small components, including small signal semiconductors, resistors, capacitors, diodes, etc. shall be lot sampled and tested for functionality. Test printed circuit boards under a temperature cycled 20 hour load test and functionally bench test prior to unit installation. Inspect all final assemblies and test at full load with application of line-to-line and line-to-ground bolted faults. The variable frequency drive system shall electrically trip off line under these conditions without device failure.

- d. After the specified inspections and tests have been successfully completed, the variable frequency drive system shall undergo an 8 hour burn-in test. Burn system in at 100 percent inductive or motor load for 40 hours without an unscheduled shutdown.

2. Certified Shop Tests and Reports

- a. Submit description of proposed testing methods, procedures, and apparatus.
- b. Submit notarized and certified copies of all test reports.
- c. Submit factory bench-test data to indicate that the manufacturer's proposed equipment has been tested in the specified arrangement and found to achieve specified accuracy.

3. Field Tests

- a. Field tests shall be performed in accordance with requirements specified in the General Conditions and Common Work Results for Electrical (See Referenced Sections).
-
- B. Authorized representatives of the Owner shall be allowed free access to the shop at all times while work is in progress for the purpose of inspection, witnessing of tests, and obtaining information on the progress of the work. The Owner shall give the Contractor 72 hours prior notice.
 - C. Acceptance of a shop test does not relieve Contractor from requirements to meet field installation tests under specified operating conditions, nor does the inspection relieve the Contractor of responsibilities.
 - D. The Contractor shall successfully complete acceptance test procedures on the assembled drive system that demonstrate compliance with the requirements of this Specification. The test plan shall be submitted for acceptance at least 30 days prior to the planned test date.
 - E. Drive system shall not be shipped from the manufacturing and assembly facility until the acceptance tests are completed and the acceptance tests are completed and the results approved by the test representative.
 - F. Tests shall be witnessed by a representative of the Engineer. Variable frequency drive manufacturer shall notify the Engineer 2 weeks in advance and shall provide testing procedures to the Engineer 4 weeks prior to actual testing. Failure of a test shall result in rejection of the equipment until performance is in compliance with these Specifications.

- G. Certification on materials and records of shop tests necessary for the inspector to verify that the requirements of the Specifications are met, shall be made available to the inspector.
- H. Submit signed and dated certification that all of the factory inspection and testing procedures described herein have been successfully performed by the Contractor prior to shipment.

3.04 SERVICES OF MANUFACTURER'S REPRESENTATIVE

- A. Provide services of the equipment manufacturer or their approved representative in accordance with the General Conditions (See Referenced Sections) and as specified herein.
- B. The Contractor shall provide the services of a qualified manufacturer's technical representative who shall adequately supervise the installation and testing of all equipment furnished under this Contract and instruct the Contractor's personnel and the Owner's operating personnel in its maintenance and operation as outlined in the General Conditions (See Referenced Sections). The services of the manufacturer's representative shall be provided for a period of not less than as follows:
 - 1. One trip of one (1) working day during installation and start-up/configuration of the equipment.
 - 2. One trip of one (1) working day after acceptance of the equipment.
 - 3. One trip of one (1) working day during the warranty period.
- C. Any additional time required to achieve successful installation and operation shall be at the expense of the Contractor. The Manufacturer's representative shall sign in and out at the office of the Resident representative on each day he is at the project.

END OF SECTION

SECTION 26 43 00

SURGE PROTECTIVE DEVICES

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. The Contractor shall furnish, install, and place in satisfactory operation, the surge protective devices (SPD) as specified herein and indicated on the Drawings.
- B. The surge protective devices specified under this Section shall be provided as a stand-alone unit, separate from the enclosure of the equipment to which they are connected. The requirements of this Section shall not apply to equipment where an integral SPD is specified.

1.2 REFERENCED SECTIONS

- A. General Conditions – COORDINATION AND MEETINGS
- B. General Conditions – SUBMITTALS
- C. Section 264300 – COMMON WORK RESULTS FOR ELECTRICAL
- D. Section 260526 – GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS
- E. Section 260519 – LOW VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES
- F. Section 262900 –LOW VOLTAGE CONTROLLERS
- G. Section 262416 - PANELBOARDS

1.3 REFERENCES

UL 1449	Surge Protective Devices
UL 1283	Electromagnetic Interference Filters
IEEE C62.41.1	Guide for Surge Voltages in Low-Voltage AC Power Circuits
IEEE C62.41.2	Recommend Practice on Characterization of Surges in Low Voltage (100V and Less) AC Power Circuits.
IEEE C62.45	IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000V and Less) AC Power Circuits
IEEE C62.62	IEEE Standard Test Specifications for Surge Protective Devices for Low Voltage (1000V and Less) AC Power Circuits
NFPA 70	National Electric Code (NEC)

1.4 ACTION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Product Datasheets.
- C. Layout Drawings - Show complete layout, including materials, sizes, locations, and dimensions.
- D. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted

without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Drawings and Specifications by the Contractor AND Equipment Manufacturer/Supplier. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter "C", "D", or "E" shall be typed or written in. The letter "C" shall be for full compliance with the requirement. The letter "D" shall be for a deviation from the requirement. The letter "E" shall be for taking exception to a requirement. Any requirements with the letter "D" or "E" beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable. The CD&E letter shall also address deviations, and exceptions taken to each Drawing related to this Specification Section.

- E. Proof that all products provided under this Section are UL listed and labeled by Underwriters Laboratories to UL1449, latest Edition. This proof shall be a copy of the data listed under the UL File Number for the manufacturer, which may be obtained from the UL Online Certification Directory. No other means of proving compliance (such as manufacturer data sheets, marketing material, etc) will be considered acceptable.
- F. Proof of Short Circuit Current Ratings (SCCR), Voltage Protection Ratings (VPRs) for all modes, Maximum Continuous Operating Voltage rating (MCOV), Nominal Discharge Current (In), and device listing Type shall be submitted using the same means as described in the paragraph above.
- G. Proof that all products provided under this Section are UL listed and labeled by Underwriters Laboratories to UL 1283, latest Edition. This proof shall be a copy of the data listed under the UL File Number for the manufacturer, which may be obtained from the UL Online Certification Directory. No other means of proving compliance (such as manufacturer data sheets, marketing material, etc.) will be considered acceptable.
- H. The shop drawing information shall be complete and organized in such a way that the Engineer can determine if the requirements of these Specifications are being met. Copies of technical bulletins, technical data sheets from "Soft Cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the Contractor intends to provide are to provide are acceptable and shall be submitted.

1.5 INFORMATION SUBMITTALS

- A. Submittals shall be in accordance with the General Conditions, and as specified herein.
- B. Prior to start-up, submit manufacturer's operation and maintenance manuals and recommended spare parts list, including but not limited to:
 - 1. Manufacturer's equipment warranty.
 - 2. Copies of Submittals
 - 3. Functional descriptions, operating instructions, calibration and adjustment, recommended maintenance, safety.
 - 4. Contact information for local representative and supplier.

1.6 FACTORY TESTING

- A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:

1. Factory Shop Tests

- a. Standard factory tests shall be performed on the equipment under this section. All tests shall be in accordance with the latest version of NEMA, ANSI, and UL standards.
- b. All surge protective devices, subassemblies, and components shall be 100% tested and certified by the manufacturer to meet their published performance parameters. Single impulse testing shall be done according to NEMA 1.1.2019 section 3.3.8 with manufacturer's test report provided.

1.7 TOOLS AND SPARE PARTS

- A. All spare parts as recommended by the equipment manufacturer shall be furnished by the Contractor to the Owner.
- B. The Contractor shall furnish three (3) spare field replacement module of each rating provided under this Contract.
- C. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.
- D. Spare parts shall be delivered at the same time as the equipment to which they pertain. The Contractor shall properly store and safeguard such spare parts until completion of the Work, at which time they shall be delivered to the Owner.
- E. Spare parts lists, included with the shop drawing submittal shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.
- F. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same part number.

1.8 HANDLING AND STORAGE

- A. Equipment shall be carefully transported, stored, handled, and set in place in a manner that will prevent damage, misalignment, and distortion to the equipment.
- B. Follow manufacturer's recommendations regarding handling and storage at all times prior to placing the equipment in service.

1.9 GUARANTEES AND WARRANTY

- A. All SPDs, associated hardware, and supporting components shall be warranted to be free from defects in materials and workmanship, under normal use and in accordance with the instructions provided, for a period of five (5) years after acceptance of the equipment by the Owner.
- B. Any component or subassembly contained within the surge protection system that shows evidence of failure or incorrect operation during the five (5) year warranty period, shall be replaced by the manufacturer at no additional cost to the Owner.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The SPD units shall be UL 1449 Listed and must bear the UL mark. Units that are "manufactured in accordance with" UL 1449 or tested by other testing agencies "in accordance with" UL 1449 are not acceptable and will be rejected.
- B. Type II SPD units shall be UL 1283 Listed and must bear the UL mark. Units that are "manufactured in accordance with" UL 1283 or tested by other testing agencies "in accordance with" UL 1283 are not acceptable and will be rejected. Further, SPD units using UL 1283 capacitors but not tested to UL 1283 will be rejected.
- C. SPDs shall be provided internal to the equipment to which it is connected unless otherwise specified. SPDs mounted externally shall have the shortest possible cable length between the SPD and the device it is connected to.
- D. All SPDs furnished and installed under this Contract shall be from the same manufacturer.

2.2 PRODUCTS

- A. Type I surge protective devices (SPD) shall be furnished and installed when shown without upstream overcurrent protection on the Drawings. Type II SPDs shall be provided in all other locations. Type II SPDs shall not require the use of a specific upstream overcurrent device. SPDs shall be provided in the location and quantity as shown on the Drawings.
- B. Each SPD shall be rated for the voltage and configuration of the equipment to which it is connected.
- C. Each Type II SPD shall have UL 1283 EMI/RFI filtering with minimum attenuation of -50dB at 100kHz.
- D. The short circuit current rating of each SPD shall match or exceed the rating of the equipment to which it is connected. The Contractor shall reference the Drawings for short circuit current rating of each piece of equipment.
- E. Each SPD system shall provide surge protection in all possible modes. Surge protection shall be as follows:

SYSTEM CONFIGURATION	MODES OF PROTECTION	NUMBER OF MODES
3-Phase Wye	L-N, L-G, N-G	7
3-Phase Delta	L-L, L-G	6
3-Phase Impedance Grounded	L-L, L-G	6
Single-Phase	L-N, L-G, N-G	3

- F. Each SPD shall have a Maximum Continuous Operating Voltage (MCOV) of at least 115% of the nominal voltage of the equipment to which it is connected.
- G. The Nominal Discharge Current (In) of each SPD shall be 20kA. Peak surge current ratings shall not be used as a basis for applying the SPD to the system.
- H. The Voltage Protection Rating (VPR) of each SPD shall not exceed the following:

SYSTEM VOLTAGE	L-N	L-G	L-L	N-G
208Y/120	600V	1000V	1000V	600V
480Y/277	1200V	1800V	2000V	1000V
480 DELTA	N/A	1800V	3000V	N/A
240 DELTA	N/A	1200V	1500V	N/A
120/240	600V	1000V	100V	600V

- I. The surge current rating for each SPD shall be as indicated on the Drawings. Surge current ratings are indicated on single line diagrams and in panel schedules. Surge current rating indicated is on a per phase basis.
- J. Each SPD shall be provided in an enclosure to match or exceed the NEMA rating of the equipment enclosure that it is serving (i.e., NEMA1, NEMA 12, NEMA 4X, etc.).
- K. Each SPD shall be provided with the following accessories:
 - 1. Each individual module shall feature an LED indicating the individual module has all surge protection devices active. If any single component is taken off-line, the LED shall turn off and another LED shall illuminate, providing individual module as well as total system status indication.
 - 2. Surge counter and audible alarm with reset/silence switch.
 - 3. One set of Form C (SPDT) dry contacts rated for at least 5A at 120VAC.
- L. Manufacturer shall be:
 - 1. Eaton
 - 2. Schneider Electric (Square D)
 - 3. Thor Systems
 - 4. Or Engineer Approved Equal

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The SPD units shall be furnished and installed as shown on the Drawings and in accordance with the manufacturer's installation instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.
- B. The SPD units shall be mounted such that the conductor lengths are as short as possible, but no greater than 36 inches. Any installation resulting in a conductor length of greater than 36 inches shall be reviewed with the Engineer as a special type of cable may need to be installed. For equipment such as panelboards, the Contractor shall relocate the circuit breaker that is to be connected to the SPD as needed to achieve the shortest conductor length possible.
- C. The Contractor shall use a close nipple to enclose the conductors between the SPD and the equipment served.
- D. Conductors between the equipment served and the SPD shall be 600V power wire and cable as specified in Low-Voltage Electrical Power Conductors and Cables (See Referenced Sections).

The individual conductors shall be gently twisted and shall be sized as indicated on the Drawings.

3.2 TESTING AND STARTUP

- A. Prior to energizing, the Contractor shall verify that the SPD unit voltage and configuration is suitable for the system to which it is connected.
- B. Prior to energizing, the Contractor shall also verify that any Neutral to Ground bonding jumpers are installed as required.
- C. Prior to energizing, the Contractor shall also verify that the impedance of the equipment grounding conductor between the SPD and the grounding electrode system is less than 1 ohm.

END OF SECTION