

**SOUTH VALLEY WATER RECLAMATION FACILITY
MISCELLANEOUS ELECTRICAL UPGRADES**

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SECTION 16262

VARIABLE FREQUENCY DRIVES 0.50 – 50 HORSEPOWER

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes:
 - 1. Variable frequency drives (VFD) 0.5 to 50 horsepower for control of NEMA Design B squirrel cage induction motors.

1.02 REFERENCES

- A. International Organization for Standardization (ISO):
 - 1. 9001 - Quality Management Systems - Requirements.
- B. National Electrical Manufacturers Association (NEMA):
 - 1. MGI, Part 31 - Motors with higher peak voltage capability.
- C. Underwriters' Laboratories (UL):
 - 1. 508A - Standard for Safety for Industrial Control Panels.
 - 2. 508C - Standard for Power Conversion Equipment.

1.03 DEFINITIONS

- A. As specified in Section 16050.

1.04 SYSTEM DESCRIPTION

- A. Design requirements:
 - 1. Each VFD system consists of all components required to meet the performance, protection, safety, testing, and certification criteria of this Section.
 - 2. The VFD system:
 - a. Is a fully integrated package.
 - b. Includes all material necessary to interconnect all VFD system elements, even if shipped separately.
- B. Any modifications to a standard product necessary to meet this Section shall be made only by the VFD manufacturer:
 - 1. Each VFD shall be completely factory pre-wired, assembled, and then tested as a complete system by the VFD manufacturer to ensure a properly coordinated, fully integrated drive system.
The VFD shall be capable of operating standard NEMA Design B motors.
- C. Performance:
 - 1. Operating envelope:
 - a. Speed and torque requirements:
 - 1) Provide a variable torque or constant torque VFD as required by the driven load.

- 2) The VFD shall be capable of producing a variable alternating voltage/frequency output to provide continuous operation over the 40 to 200 percent (15 to 120 hertz) speed range.
- b. Current requirements:
 - 1) Full rated current output on a continuous basis.
 - 2) Variable torque VFD:
 - a) Minimum 110 percent current overload for 1 minute.
 - 3) Constant torque VFD:
 - a) Minimum 150 percent current overload for 1 minute.
2. Minimum VFD system efficiency:
 - a. Ninety-six percent when operating at the rated kW output.
 - b. VFD system efficiency shall be calculated as follows:

$$\text{Efficiency (\%)} = \frac{\text{Power (Load)}}{\text{Power (Supply)}} \times 100$$

Power (Load) is the total power measured at the output terminals of the drive system, including VFD, output filters or transformers. Power (Supply) is the total power measured at the input terminals of the VFD including input filters, line reactors, isolation transformers, harmonic distortion attenuation equipment and auxiliary equipment (e.g., controls, fans) for complete system operation.

3. Total power factor:
 - a. Minimum of 0.96 lagging across the entire speed range.
 - b. At no speed shall the VFD have a leading power factor.
4. Frequency accuracy:
 - a. Minimum of within 0.01 percent.
5. Speed regulation:
 - a. Minimum of within 0.5 percent across the entire speed range.

1.05 SUBMITTALS

- A. Furnish submittals as specified in Sections 01330.
 1. Custom prepared by the VFD manufacturer and specific for the equipment furnished.
- B. Product data:
 1. Manufacturer of the VFD.
 2. Manufacturer of all components of the VFD.
 3. Dimensions:
 - a. Height.
 - b. Width.
 - c. Depth.
 - d. Weight.
 4. Nameplate schedule.
 5. Bill of material.
 6. Ratings:
 - a. Voltage.
 - b. Phase.
 - c. Input current.
 - d. Output current.

- e. Interrupting rating.
 - f. Momentary current rating.
 - 7. List of recommended spare parts.
 - 8. Catalog cut sheets for major components.
 - 9. Design data:
 - a. Efficiency and power factor values.
 - b. Certification that the drive is sized for the full nameplate motor horsepower and current of the driven load at the installed altitude and ambient temperature.
 - c. Certification that all electronic circuits and printed circuit boards are conformally coated.
 - 10. For equipment installed in structures designated as seismic design category C, D, E, or F submit the following as specified in Section 16050:
 - a. Manufacturer's statement of seismic qualification with substantiating test data.
 - b. Manufacturer's special seismic certification with substantiating test data.
- C. Shop drawings:
- 1. Complete plan and elevation drawings showing:
 - a. All dimensions.
 - b. Panel, sub-panel and component layout indexed to the bill of material.
 - c. Conduit connections.
 - 2. Block diagram showing the basic control and protection systems specifying the protection, control, trip and alarm functions, the reference signals and commands and the auxiliary devices.
 - 3. Complete schematic, wiring and interconnection diagrams showing connections to both internal and external devices:
 - a. Include terminal number and wire numbers.
 - 4. Complete single-line and 3-line diagrams 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:
 - a. Clearly indicate device electrical ratings on the drawings.
- D. Operation and maintenance manuals:
- 1. Spare parts list with supplier names and part numbers.
 - 2. Startup and commissioning instructions and data.
 - 3. Operating manuals:
 - a. Submit operating instructions and a maintenance manual presenting full details for care and maintenance of each model of VFD provided under this Contract.
 - 4. Operating instructions:
 - a. Written descriptions detailing the operational functions of all controls on the front panel.
 - 5. Maintenance manual:
 - a. Furnish maintenance manuals with instructions covering all details pertaining to care and maintenance of all equipment as well as identifying all parts.
 - b. Manuals shall include, but are not limited to the following:
 - 1) Adjustment and test instructions covering the steps involved in the initial test, adjustment and start-up procedures.

- 2) Detailed control instructions which outline the purpose and operation of every control device used in normal operation.
 - 3) All schematic wiring and external diagrams:
 - a) Furnish drawings in a reduced 11-inch by 17-inch format that are fully legible at that size.
- E. Test forms and reports.
1. Submit complete factory acceptance test procedures and all forms used during the test.
- F. Manufacturer's field reports:
1. Report listing the setting of all VFD adjustable parameters and their values after start-up.
- G. Record Documents:
1. Certified Record Documents of equipment with information listed above.

1.06 QUALITY ASSURANCE

- A. As specified in Section 16050.
- B. Qualifications:
1. Any third party certification, safety or protection requirements shall be applied to the VFD system as a whole. Certification or protection of system elements or individual components by themselves is not acceptable.
 2. VFDs shall be UL 508C listed and labeled:
 - a. UL 508C for individual units.
 - b. UL 508A for VFD systems in control panels.
 3. Variable frequency drives shall be manufactured by the VFD manufacturer at its own facility which shall have a quality assurance program that is certified in conformance with ISO 9001.
- C. The VFD manufacturer shall be responsible for start-up of the VFDs in the presence of the Owner.

1.07 DELIVERY, STORAGE, AND HANDLING

- A. Ship the VFDs and associated equipment to the job site on a dedicated air ride vehicle that will allow the Owner to utilize on site off-loading equipment:
1. VFDs shall be delivered to the site preassembled and wired.
- B. Furnish temporary equipment heaters within the VFD to prevent condensation from forming.

1.08 PROJECT OR SITE CONDITIONS (NOT USED)

1.09 SEQUENCING

- A. Conduct factory acceptance test and submit certified test results for Engineer's review.
- B. Ship equipment to project site after successful completion of factory acceptance test.

- C. Assemble equipment in the field.
- D. Conduct Owner's training sessions.

1.10 SCHEDULING

- A. As specified in Section 16050.

1.11 WARRANTY (NOT USED)

1.12 SYSTEM START-UP

- A. As specified in Section 16050.

1.13 OWNERS INSTRUCTIONS (NOT USED)

1.14 MAINTENANCE

- A. Spare parts:
 - 1. List prices for all spare parts on the bid schedule.
 - 2. The following spare parts shall be furnished:
 - a. One complete 30 horsepower VFD.
 - b. Two complete 5 horsepower VFDs.
 - c. Any special dedicated tools for emergency service and troubleshooting.
 - d. All hardware and software required for configuration, maintenance, troubleshooting and inquiry of all drive parameters.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. One of the following or equal:
 - 1. General Electric.
 - 2. Toshiba.

2.02 EXISTING PRODUCTS (NOT USED)

2.03 MATERIALS (NOT USED)

2.04 MANUFACTURED UNITS (NOT USED)

2.05 EQUIPMENT

- A. General:
 - 1. Sinusoidal pulse width modulated (PWM) type drive.
 - a. Six-pulse insulated gate bipolar transistor (IGBT) power section.
 - b. Microprocessor based controls.
 - c. Line and load reactors.
- B. Ratings:
 - 1. Voltage:
 - a. Input voltage as indicated on the Drawings.

- C. Operational features:
1. Protective features:
 - a. Provide the following minimum protective features:
 - 1) Motor overload protection.
 - 2) Instantaneous overcurrent.
 - 3) Instantaneous overvoltage.
 - 4) Undervoltage.
 - 5) Power unit overtemperature.
 - 6) Phase loss.
 - 7) VFD output short circuit.
 2. Control mode:
 - a. Operation in either a constant volts/hertz or sensorless vector mode:
 - 1) The control mode selectable using the programming keypad.
 3. Frequency control:
 - a. Minimum of 3 selectable skip frequencies with adjustable bandwidths.
 - b. Programmable minimum frequency.
 - c. Programmable maximum frequency.
 4. Acceleration/deceleration:
 - a. Separately adjustable acceleration and deceleration rates:
 - 1) Each rate adjustable from 0.01 to 1,800 seconds.
 5. Spinning load:
 - a. The VFD shall be capable of determining the speed and direction of a spinning load, "catch" the load and accelerate or decelerate it without damage to the load.
 6. Programmable loss of signal:
 - a. Upon loss of speed reference the VFD shall be programmable to either:
 - 1) Stop.
 - 2) Maintain current speed.
 - 3) Default to pre-selected speed.
 7. Power interrupt ride-through:
 - a. The VFD shall be capable of continuous operation in the event of a power loss of 5 cycles or less.
 8. Inputs/Outputs:
 - a. Manufacturer's standard number the following:
 - 1) Analog inputs:
 - a) Configurable as either 0 to 10 volts or 4 to 20 milliamperes.
 - 2) Analog outputs:
 - a) Programmable 4 to 20 milliamperes isolated.
 - 3) Discrete inputs:
 - a) Programmable.
 - 4) Discrete outputs:
 - a) Programmable.
 - b) Form C relay contacts.
 - 5) Potentiometer 3-wire input.
 - b. Provide additional inputs/outputs as required to meet the control functions indicated on the Drawings.
 9. Communications:
 - a. Provide each VFD with a Profinet communications interface module.
 10. Diagnostics:
 - a. Store a minimum of 4 fault conditions in non-volatile memory on a first in-first out basis.

- b. Operational parameters stored at the time of a the fault:
 - 1) Operating frequency.
 - 2) Drive status.
 - 3) Power mode.
 - c. Fault memory accessible via RS-232, RS-422 or RS-485.
11. Automatic restart:
- a. User selectable automatic restart feature allowing the VFD to restart following a momentary power failure or other VFD fault:
 - 1) Programmable for up to 9 restart attempts.
 - 2) Adjustable time delay between restart attempts.

2.06 COMPONENTS

- A. Enclosure:
 - 1. NEMA Type 12. Provide cooling devices required to maintain the VFD within the manufacturer's specified temperature limits for the Project conditions:
 - a. Provide cooling device failure alarm.
- B. Power disconnect:
 - 1. Flange mounted motor circuit protector, MCP.
 - 2. Lockable in the OFF position.
- C. Reactors:
 - 1. Line reactors: 3 percent input and 3 percent output.
- D. Keypad:
 - 1. Provide each VFD with a keypad for programming and control.
 - 2. Keypad requirements:
 - a. Password security to protect drive parameters.
 - b. Mounted on the door of the VFD.
 - c. Back-lit LCD:
 - 1) Minimum of 2 lines with a minimum of 16 characters per line.
 - d. Programming and display features language: English.
 - e. Capable of displaying the following parameters:
 - 1) Speed (percent).
 - 2) Output current (amperes).
 - 3) Output frequency (hertz).
 - 4) Input voltage.
 - 5) Output voltage.
 - 6) Total 3-phase kilowatt.
 - 7) Kilowatt-hour meter.
 - 8) Elapsed run time meter.
 - 9) Revolutions per minute.
 - 10) Direct current bus voltage.
 - 3. In addition to all keys required for programming, provide the following controls on the keypad:
 - a. Auto/manual selector.
 - b. Start pushbutton.
 - c. Stop pushbutton.
 - d. Jog pushbutton.
 - e. Speed increment.
 - f. Speed decrement.

- g. Forward/reverse selector.
 - h. Run LED indicator.
 - i. Program LED indicator.
 - j. Fault LED indicator.
- 4. Provide the VFD with the hardwired controls as indicated on the Drawings.
- E. Control power transformer:
 - 1. Furnish a control power transformer mounted and wired inside the VFD enclosure.
 - 2. With primary and secondary fusing.
 - 3. Sized to power all VFD controls and options as well as any external devices indicated on the Drawings including the motor winding heater.
- F. Bypass starter:
 - 1. Where indicated on the Drawings, furnish the VFD with an integral full voltage non-reversing bypass starter:
 - a. Motor overload protection for bypass operation shall be provided.
 - 2. Provide mechanically/electrically interlocked input and output contactors for bypass operation.
 - 3. Provide a VFD/Off/Bypass selector switch on the VFD front panel.

2.07 ACCESSORIES

- A. Metal oxide varistors:
 - 1. Provide protection for the VFD against:
 - a. Line transients: 5,000 volt peak minimum.
 - b. Line to ground transients: 7,000 peak minimum.
- B. Conformal coating:
 - 1. Provide conformal coating material applied to electronic circuitry and printed circuit boards to act as a protection against moisture, dust, temperature extremes, and chemicals such as H₂S and chlorine.

2.08 MIXES (NOT USED)

2.09 FABRICATION (NOT USED)

2.10 FINISHES

- A. Enclosure finish shall be manufacturer's standard gray.

2.11 SOURCE QUALITY CONTROL (NOT USED)

PART 3 EXECUTION

3.01 EXAMINATION (NOT USED)

3.02 PREPARATION (NOT USED)

3.03 INSTALLATION (NOT USED)

3.04 ERECTION, INSTALLATION, APPLICATION, CONSTRUCTION (NOT USED)

3.05 REPAIR/RESTORATION (NOT USED)

3.06 RE-INSTALLATION (NOT USED)

3.07 COMMISSIONING

- A. Source testing (Factory Acceptance Tests):
 - 1. General:
 - a. Incoming inspection of components and raw materials based on strategic supplier base and experience.
 - b. All VFDs furnished under this Section shall be tested and inspected as specified below. Testing of VFDs based on sampling plans is not allowed.
 - c. The testing procedures specified are the minimum acceptable requirements. The manufacturer may perform additional tests at its discretion.
 - 2. Failure of any component during testing requires repair of the faulted component and complete retest.
 - 3. Tests:
 - a. Perform manufacturer's standard factory acceptance tests.

3.08 FIELD QUALITY CONTROL

- A. As specified in Section 16050.
- B. Provide the services of a VFD manufacturer representative for startup assistance and training:
 - 1. Inspection and field adjustment:
 - a. Supervise the following and submit written certification that the equipment and controls have been properly installed, aligned, adjusted, and readied for operation.
 - 2. Startup field testing:
 - a. Provide technical direction for testing, checkout, and startup of the VFD equipment in the field.

3.09 ADJUSTING

- A. Provide the services of a VFD manufacturer factory technician to make all drive parameters and protective device settings:
 - 1. Protective device settings provided by the VFD manufacturer in accordance with the manufacturer of the driven equipment requirements.
 - 2. Provide documentation of VFD settings included but not limited to:
 - a. Minimum speed.
 - b. Maximum speed.
 - c. Current limit.
 - d. Acceleration time.
 - e. Deceleration time.
 - f. Carrier frequency.
 - g. Assignments of VFD inputs and outputs.
 - h. Analog scaling and offset.
 - i. Motor parameters.

3.10 CLEANING (NOT USED)

3.11 PROTECTION (NOT USED)

3.12 SCHEDULES (NOT USED)

END OF SECTION

SECTION 16264

VARIABLE FREQUENCY DRIVES 60 – 500 HORSEPOWER

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes:
 - 1. Clean power 18 pulse variable frequency drives (VFD), 60 to 500 horsepower for control of standard NEMA Design B squirrel cage induction motors.

1.02 REFERENCES

- A. National Electrical Manufacturers Association (NEMA):
 - 1. MGI, Part 31 - Motors with higher peak voltage capability.
- B. Institute of Electrical and Electronics Engineers (IEEE):
 - 1. 519 - IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
- C. Underwriters' Laboratories (UL):
 - 1. 50 - Standards for Enclosures for Electrical Equipment.
 - 2. 508A - Standard for Safety for Industrial Control Panels.

1.03 DEFINITIONS (NOT USED)

1.04 SYSTEM DESCRIPTION

- A. Design requirements:
 - 1. Each VFD system shall consist of all components required to meet the performance, protection, safety, testing, and certification criteria of this Section.
 - 2. The VFD system:
 - a. Is a fully integrated package.
 - b. Includes all material necessary to interconnect VFD system elements, even if shipped separately.
 - 3. Any modifications to a standard product necessary to meet this Section shall be made only by the VFD manufacturer.
 - 4. Each VFD shall be completely factory pre-wired, assembled, and then tested as a complete package by the VFD manufacturer to ensure a properly coordinated, fully integrated drive system.
 - 5. The VFD shall be capable of operating standard NEMA Design B motors
- B. Performance:
 - 1. Operating envelope:
 - a. Speed and torque requirements:
 - 1) Provide a variable torque or constant torque VFD as required by the driven load.

- 2) The VFD shall be capable of producing a variable alternating voltage/frequency output to provide continuous operation over the 40 to 110 percent (25 to 66 Hertz) speed range.
- b. Current requirements:
 - 1) Provide 100 percent of rated output current on a continuous basis.
 - 2) Variable torque VFD:
 - a) Minimum 110 percent current overload for 1 minute.
 - 3) Constant torque VFD:
 - a) Minimum 150 percent current overload for 1 minute.
2. Harmonics:
 - a. The VFD shall meet the following distortion limits:
 - 1) Voltage harmonics: Individual or simultaneous operation of the VFD(s) shall not add more than 3 percent total harmonic voltage distortion THD, while operating from the utility source or more than 5 percent total harmonic voltage distortion while operating from standby generation at the input terminals of the VFD system.
 - 2) Current harmonics: The maximum allowable total harmonic current distortion limit, TDD, for each VFD shall not exceed 5 percent as measured at the input terminals of the VFD system.
3. Efficiency:
 - a. VFD system minimum efficiency shall be 93 percent at rated kilowatt output of the VFD. VFD system efficiency shall be calculated as follows:

$$\text{Efficiency (\%)} = \frac{\text{Power (Load)}}{\text{Power (Supply)}} \times 100$$
 - b. Power:
 - 1) Load power is the total 3-phase power measured at the output terminals of the drive system, including output filters.
 - 2) Supply power is the total power measured at the input terminals of the VFD including input filters, line reactors, phase shifting transformer, harmonic distortion attenuation equipment, and auxiliary equipment (e.g., controls, fans) for complete system operation.
4. Total power factor:
 - a. Minimum of 0.96 lagging across the entire speed range.
 - b. Under no operating conditions shall the VFD have a leading power factor.
5. Frequency accuracy:
 - a. Minimum of within 0.01 percent.
6. Speed regulation:
 - a. Minimum of within 0.5 percent across the entire speed range.

1.05 SUBMITTALS

- A. Furnish submittals as specified in Sections 01330:
 1. Custom prepared by the VFD manufacturer and specific for the equipment furnished.
- B. Product data:
 1. Manufacturer of the VFD.
 2. Manufacturer of all components of the VFD.
 3. Dimensions:
 - a. Height.

- b. Width.
 - c. Depth.
- 4. Weight.
- 5. Nameplate schedule.
- 6. Bill of material.
- 7. Ratings:
 - a. Voltage.
 - b. Phase.
 - c. Input current.
 - d. Output current.
 - e. Interrupting rating.
 - f. Momentary current rating.
- 8. Catalog cut sheets for major components.
- 9. Surge protection data.
- 10. Design data:
 - a. Efficiency and power factor values.
 - b. Certification that the drive is sized for the full nameplate motor horsepower and current (at rated RPM) of the driven load at the installed altitude.
 - c. Certification that based upon VFD design, cable length to motor, and motor dielectric insulation level that the VFD will not damage motor insulation due to carrier frequency, reflected wave, dv/dt, or other VFD produced characteristics.
 - d. Certification that all electronic circuits and printed circuit boards are conformably coated.
- 11. List of recommended spare parts.
- 12. For equipment installed in structures designated as seismic design category C, D, E, or F submit the following as specified in Section 16050:
 - a. Manufacturer's statement of seismic qualification with substantiating test data.
 - b. Manufacturer's special seismic certification with substantiating test data.

C. Shop drawings:

- 1. Complete plan and elevation drawings showing:
 - a. All dimensions.
 - b. Panel, sub-panel and component layout indexed to the bill of material.
 - c. Conduit connections.
 - d. Required clearance around equipment.
- 2. Block diagram showing the basic control and protection systems identifying the protection, control, trip and alarm functions, the reference signals and commands and the auxiliary devices.
- 3. Complete schematic, wiring and interconnection diagrams showing connections to both internal and external devices:
 - a. Wiring diagrams shall include terminal number and wire numbers.
- 4. Complete 1-line and 3-line diagrams 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:
 - a. Device electrical ratings shall be clearly indicated on the Drawings.

- D. Calculations:
 - 1. Detailed calculations or details of the actual physical testing performed on the VFD to prove the VFD is suitable for the seismic conditions at the Project Site.
- E. Test forms and reports:
 - 1. Submit complete factory acceptance test procedures and all forms used during the test.
 - a. For VFD units less than 250 horsepower, provide certified test results for the actual VFD being furnished or prototype units. For VFD units 250 horsepower and larger, provide certified test results for the actual VFD being furnished.
 - b. Provide the following certified test reports:
 - 1) Efficiency at rated power output and output frequency of 60 hertz.
 - 2) Power factor at 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent speed.
 - 3) Harmonics at the input terminals of the VFD at 100 percent speed and 100 percent load.
 - a) Voltage distortion: Measure individual harmonics up to and including the 50th harmonic and total harmonic distortion.
 - b) Current distortion: Measure individual harmonics up to and including the 50th harmonic and total demand distortion.
- F. Record documents:
 - 1. Certified record documents of all equipment with information listed above.
- G. Manufacturer's field reports:
 - 1. Certification letter from the VFD manufacturer that the VFD(s) has been inspected and installed in accordance with the manufacturer's requirements.
 - 2. Report listing the setting of all VFD adjustable parameters and their values after start-up.
- H. Operation and maintenance manuals:
 - 1. Spare parts list with supplier names and part numbers.
 - 2. Start-up and commissioning instructions and data.
 - 3. Complete bill of material indexed to the drawings, identifying the catalog or part numbers, manufacturer, and quantities of components of the VFD system.
 - 4. Operating manuals:
 - a. Submit operating instructions and a maintenance manual presenting full details for care and maintenance of each model of VFD provided under this Contract.
 - 5. Operating instructions:
 - a. The written descriptions shall detail the operational functions of all controls on the front panel including keypad functions and parameters.
 - 6. Maintenance manual:
 - a. Furnish maintenance manuals with instructions covering all details pertaining to care and maintenance of all equipment as well as identifying all parts.
 - b. Manuals shall include but are not limited to the following:
 - 1) Adjustment and test instructions covering the steps involved in the initial test, adjustment, and start-up procedures.
 - 2) Detailed control instructions that outline the purpose and operation of every control device used in normal operation.

- 3) All schematic wiring and external diagrams:
 - a) Furnish drawings in a fully legible reduced 11-inch by 17-inch format.

1.06 QUALITY ASSURANCE

- A. Qualifications:
 1. Any third party certification, safety, or protection requirements shall be applied to the VFD system as a whole. Certification or protection of system elements or individual components by themselves is not acceptable.
 2. VFDs shall be UL 508C listed and labeled.
 3. VFD systems (packaged VFD panels) shall be UL 508A listed and labeled.
 4. VFDs shall be manufactured by the VFD manufacturer at its own facility, which shall have a quality assurance program that is certified in accordance with ISO 9001.
- B. The VFD manufacturer shall be responsible for start-up of the VFDs in the presence of the Owner.

1.07 DELIVERY, STORAGE, AND HANDLING

- A. As specified in Section 16050.
- B. Ship VFDs to the job site on a dedicated air ride vehicle that will allow the Owner to utilize onsite offloading equipment:
 1. VFDs shall be delivered to the site pre-assembled and wired.
 2. Ship each VFD with 2 tamperproof accelerometers that record the maximum shock and vibration experienced by the VFD during shipping and handling.
- C. Furnish temporary equipment heaters within the VFD to prevent condensation from forming.

1.08 PROJECT OR SITE CONDITIONS (NOT USED)

1.09 SEQUENCING

- A. Conduct factory acceptance test and submit certified test results for Engineer's review.
- B. Ship equipment to Project Site after successful completion of factory acceptance test.
- C. Assemble equipment in the field.
- D. Submit manufacturer's certification that equipment has been properly installed and is fully functional.
- E. Conduct Owner's training sessions.

1.10 SCHEDULING

- A. As specified in Section 16050.

1.11 WARRANTY (NOT USED)

1.12 SYSTEM START-UP

- A. As specified in Section 16050.
- B. The VFD manufacturer shall be responsible for start-up of the VFDs in the presence of the Owner.

1.13 OWNERS INSTRUCTIONS (NOT USED)

1.14 MAINTENANCE

- A. As specified in Section 16050.
- B. Maintenance service: Manufacturer shall describe the field service system available to support the proposed VFD system. As a minimum describe:
 - 1. Type of technical support available (e.g., system engineering and technician).
 - 2. Location of field service personnel.
 - 3. Field service daily rates in dollars per hour and dollars per day.
 - 4. Guaranteed response times to service requests.
- C. Spare parts:
 - 1. List prices for all spare parts on the bid schedule.
 - 2. The following spare parts shall be furnished:
 - a. 1 complete 75 horsepower VFD.
 - b. Any special dedicated tools for emergency service and troubleshooting.
 - c. All hardware and software required for configuration, maintenance, troubleshooting, and inquiry of all drive parameters.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. One of the following or equal:
 - 1. General Electric.
 - 2. Toshiba

2.02 EXISTING PRODUCTS (NOT USED)

2.03 MATERIALS (NOT USED)

2.04 MANUFACTURED UNITS (NOT USED)

2.05 EQUIPMENT

- A. General:
 - 1. Sinusoidal pulse width modulated, (PWM), voltage source type drive shall consist of the following:
 - a. Input line reactors.

- b. Integral phase shifting auto-transformer:
 - 1) Converts 3-phase utility power to 3 sets of 3 power circuits with each set phase shifted and powering its own 3-phase bridge rectifier.
 - c. Direct current link with capacitors.
 - d. Minimum 18-pulse diode rectifier section consisting of 3 three-phase bridge rectifiers.
 - 1) Specifically designed as a system to share currents between the bridges to within 1 percent.
 - e. Insulated gate bipolar transistor (IGBT), inverter section.
 - f. Microprocessor based controls.
 - g. Load reactors.
2. VFDs that have an active input section for either harmonic or voltage control are not acceptable.

B. Ratings:

- 1. Voltage:
 - a. Input voltage: 480 Volts plus or minus 10 percent, 3-phase 60 hertz.
- 2. Short-circuit rating:
 - a. 65 kA RMS symmetrical.

C. Operational features:

- 1. Protective features:
 - a. Include the following protective features:
 - 1) Motor overload protection.
 - 2) Instantaneous overcurrent.
 - 3) Instantaneous overvoltage.
 - 4) Undervoltage.
 - 5) Power unit overtemperature.
 - 6) Phase loss.
 - 7) VFD output short circuit.
 - 8) VFD output ground fault.
 - 9) Blown fuse.
- 2. Control mode:
 - a. The VFD shall operate in either a constant volts/hertz or sensorless vector mode. Selectable using the programming keypad.
- 3. Frequency control:
 - a. Minimum of 3 selectable skip frequencies with adjustable bandwidths.
 - b. Programmable minimum frequency.
 - c. Programmable maximum frequency.
- 4. Acceleration/Deceleration:
 - a. Separately adjustable acceleration and deceleration rates.
 - b. Each rate shall be adjustable from 0.01 to 1,800 seconds.
- 5. Spinning load:
 - a. Capable of determining the speed and direction of a spinning load, "catch" the load and accelerate or decelerate it without damage to the load.
- 6. Programmable loss of signal:
 - a. Upon loss of reference speed signal the VFD shall be programmable to either stop, maintain current speed, or default to preselected speed.
- 7. Power interrupt ride-through:
 - a. Capable of continuous operation in the event of a power loss of 5 cycles or less.

8. Hardwired inputs and outputs:
 - a. Manufacturer's standard number the following:
 - 1) Analog inputs.
 - a) Configurable as either 0 to 10 volts or 4 to 20 milliamperes.
 - 2) Analog outputs.
 - a) Programmable 4 to 20 milliamperes isolated.
 - 3) Discrete inputs.
 - a) Programmable.
 - 4) Discrete outputs.
 - a) Programmable.
 - b) Form C relay contacts.
 - 5) Potentiometer 3-wire input.
 - b. Provide additional inputs and outputs as required to meet the control functions indicated on the Drawings.
9. Communications:
 - a. Provide each VFD with a Profinet communications interface module.
10. Diagnostics:
 - a. Minimum of 4 fault conditions in memory on a first in - first out basis.
 - b. Operating frequency, drive status and power mode shall also be stored at the time of the fault.
 - c. Fault memory shall be maintained in the event of a power outage.
 - d. The fault memory shall be accessible via RS-232, RS-422 or RS-485.
11. Automatic restart:
 - a. User selectable, automatic restart feature allowing the VFD to restart following a momentary power failure or other VFD fault:
 - 1) Programmable for up to 9 automatic restart attempts with an adjustable time delay between restart attempts.

2.06 COMPONENTS

- A. Enclosure:
 1. NEMA Type 12 enclosure.
 2. Provide cooling devices required to maintain the VFD within the manufacturer's specified temperature limits for the Project conditions:
 - a. Provide cooling device alarm.
- B. Power disconnect:
 1. Flange mounted thermal magnetic circuit breaker:
 - a. Lockable in the OFF position.
- C. Phase shifting transformer:
 1. Auto-transformer.
 2. Integral part of the VFD assembly and factory mounted and wired within the VFD enclosure.
 3. Rated for rectifier duty.
 4. Copper or aluminum windings with 180-degree Celsius insulation.
- D. Reactors:
 1. Provide 3 percent output load reactors.
 2. Provide input line reactors.

- E. Keypad:
1. Furnished with a keypad for programming and control.
 2. Password security to protect drive parameters.
 3. Mounted on the door of the VFD.
 4. Back-lit LCD with a minimum of 2 lines of a minimum of 16 characters each.
 5. Programming and display features language: English.
 6. Capable of displaying the following parameters:
 - a. Speed (percent).
 - b. Input current (Amperes).
 - c. Output current (Amperes).
 - d. Output frequency (Hertz).
 - e. Input voltage.
 - f. Output voltage.
 - g. Total 3-phase kilowatt.
 - h. Kilowatt hour meter.
 - i. Elapsed run time meter.
 - j. Revolutions per minute.
 - k. Direct current bus voltage.
 7. In addition to all keys required for programming, the keypad shall have the following:
 - a. Automatic/Manual selector.
 - b. Start pushbutton.
 - c. Stop pushbutton.
 - d. Jog pushbutton.
 - e. Speed increment.
 - f. Speed decrement.
 - g. Forward/Reverse selector.
 - h. RUN indicator.
 - i. PROGRAM indicator.
 - j. FAULT indicator.
 - k. DRIVE READY indicator.
 - l. Diagnostics.
 8. Provide the VFD with the hardwired controls indicated on the Drawings.
- F. Control power transformer:
1. Furnish a control power transformer mounted and wired inside the drive enclosure:
 - a. Primary and secondary fusing.
 2. Size the transformer to supply power to all VFD controls and options as well as any external devices indicated on the Drawings including the motor winding heater.

2.07 ACCESSORIES

- A. Surge protection:
1. Metal oxide varistors:
 - a. Provide protection for the VFD against:
 - 1) Line transients: 5,000 volt peak minimum.
 - 2) Line to ground transients: 7,000 peak minimum.

- B. Conformal coating:
 - 1. Provide conformal coating material applied to electronic circuitry and printed circuit boards to act as protection against moisture, dust, temperature extremes, and chemicals such as H₂S and chlorine.
- C. Air filters:
 - 1. Mounted on the outside of the VFD enclosure:
 - a. Replaceable without requiring that the VFD be turned off or the door opened.
 - 2. Located on the front or top of the VFD enclosure.
 - a. Side or rear mounted air filters are not acceptable.

2.08 MIXES (NOT USED)

2.09 FABRICATION (NOT USED)

2.10 FINISHES

- A. Enclosure finish shall be manufacturer's standard gray.

2.11 SOURCE QUALITY CONTROL (NOT USED)

PART 3 EXECUTION

3.01 EXAMINATION (NOT USED)

3.02 PREPARATION (NOT USED)

3.03 INSTALLATION (NOT USED)

3.04 ERECTION, INSTALLATION, APPLICATION, CONSTRUCTION (NOT USED)

3.05 REPAIR/RESTORATION (NOT USED)

3.06 RE-INSTALLATION (NOT USED)

3.07 COMMISSIONING

- A. As specified in Section 01756.
- B. Factory testing:
 - 1. General:
 - a. All VFDs furnished under this Section shall be tested and inspected as specified below.
 - b. The testing procedures specified are the minimum acceptable requirements. The manufacturer may perform additional tests at its discretion.
 - 2. Failure of any component during testing requires replacement of the faulted component and a complete retest.
 - 3. Testing sequence:
 - a. Submit a detailed test procedure for the VFD factory test:
 - 1) A minimum of 8 weeks in advance of the proposed testing date.

- 2) No tests shall be performed until the test procedure is reviewed and accepted by the Engineer.
4. Component tests:
 - a. Preliminary inspection:
 - 1) Verify that all components are correct.
 - 2) Verify that all connections are properly torqued.
 - b. Printed circuit boards:
 - 1) Test each printed circuit board per the manufacturer's standard testing procedure.
 - c. Wiring:
 - 1) Control and power wiring continuity verified point-to-point.
 - 2) Hi-pot power and control wiring at manufacturer's recommended levels.
 - 3) Verify ground bond resistance.
 - d. Load testing:
 - 1) No load testing in accordance with the manufacturer's standard factory test procedure.
 - 2) Full load testing:
 - a) Test each VFD and all control logic with a representative motor or dynamometer load to simulate field operation conditions at 25 percent, 50 percent, and 100 percent full load current.
 - b) Tests shall be conducted in a manner in which the inverter (IGBT) section supplies all the output power (kw) of the VFD system. Control strategies using a contactor or other means of bypassing the VFD when operating at the line frequency shall not be permitted.
 - c) Tests shall be conducted using a minimum output frequency of 60 Hertz, and a minimum switching frequency of 2.5 kHz.

3.08 FIELD QUALITY CONTROL

- A. Provide the services of a VFD manufacturer representative for start-up assistance and training:
 1. Inspection and field adjustment:
 - a. Supervise the following and submit written certification that the equipment and controls have been properly installed, aligned, adjusted, and readied for operation.
 2. Start-up field testing:
 - a. Provide technical direction for testing, checkout, and startup of the VFD equipment in the field.
 - b. Under no circumstances are any portions of the drive system to be energized without authorization from the manufacturer's representative.
 - c. Compliance with the following specified parameters shall be verified by the VFD manufacturer:
 - 1) Motor terminal voltage:
 - a) Make field measurements at the motor connection box.
 - b) Make measurements of the full speed range of the VFD.
 - c) Make measurements with a recording type oscilloscope.

3.09 ADJUSTING

- A. Make all adjustments as necessary.

- B. Provide the services of a VFD manufacturer factory technician to make all drive parameter and protective device settings:
 - 1. Protective device settings provided by the VFD manufacturer in accordance with the manufacturer of the driven equipment requirements.
 - 2. Provide documentation of VFD settings included but not limited to:
 - a. Minimum speed.
 - b. Maximum speed.
 - c. Current limit.
 - d. Acceleration time.
 - e. Deceleration time.
 - f. Carrier frequency.
 - g. Assignments of VFD inputs and outputs.
 - h. Analog scaling and offset.
 - i. Motor parameters.

3.10 CLEANING (NOT USED)

- A. As specified in Section 16050.

3.11 PROTECTION (NOT USED)

3.12 SCHEDULES (NOT USED)

END OF SECTION

SECTION 16412

LOW VOLTAGE MOLDED CASE CIRCUIT BREAKERS

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes:
 - 1. Low voltage molded case circuit breakers.

1.02 REFERENCES

- A. As specified in Section 16050 - Common Work Results for Electrical.
- B. National Electrical Manufacturers Association (NEMA):
 - 1. AB 3 - Molded Case Circuit Breakers and Their Application.
- C. Underwriter's Laboratories (UL):
 - 1. 489 - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
 - 2. 943 - Ground Fault Circuit Interrupters.

1.03 DEFINITIONS

- A. In accordance with UL 489.

1.04 SYSTEM DESCRIPTION

- A. Molded case thermal magnetic or motor circuit protector type circuit breakers as indicated on the Drawings and connected to form a completed system.

1.05 SUBMITTALS

- A. Product data:
 - 1. Catalog cut sheets.
 - 2. Manufacturer's time-current curves for all molded case circuit breakers furnished.

1.06 QUALITY ASSURANCE

- A. Low voltage molded case circuit breakers shall be UL listed and labeled.

1.07 DELIVERY, STORAGE AND HANDLING

- A. As specified in Section 16050 - Common Work Results for Electrical.

1.08 PROJECT OR SITE CONDITIONS

- A. As specified in Section 16050 - Common Work Results for Electrical.

- 1.09 SEQUENCING (NOT USED)**
- 1.10 SCHEDULING (NOT USED)**
- 1.11 WARRANTY (NOT USED)**
- 1.12 SYSTEM START-UP (NOT USED)**
- 1.13 OWNER'S INSTRUCTIONS (NOT USED)**
- 1.14 MAINTENANCE (NOT USED)**

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. One of the following or equal:
 - 1. Eaton/Cutler-Hammer.
 - 2. General Electric Co.
 - 3. Schneider Electric/Square D Co.
 - 4. ABB.

2.02 EXISTING PRODUCTS (NOT USED)

2.03 MATERIALS (NOT USED)

2.04 MANUFACTURED UNITS

- A. General:
 - 1. Conforming to UL 489.
 - 2. Operating mechanism:
 - a. Quick-make, quick-break, non-welding silver alloy contacts.
 - b. Common Trip, Open and Close for multi-pole breakers such that all poles open and close simultaneously.
 - c. Mechanically trip free from the handle.
 - d. Trip indicating handle - automatically assumes a position midway between the manual ON and OFF positions to clearly indicate the circuit breaker has tripped.
 - e. Lockable in the "OFF" position.
 - 3. Arc extinction:
 - a. In arc chutes.
 - 4. Voltage and current ratings:
 - a. Minimum ratings as indicated on the Drawings.
 - b. Minimum frame size 100A.
 - 5. Interrupting ratings:
 - a. Minimum ratings as indicated on the Drawings.
 - b. Not less than the rating of the assembly (VFD.).
- B. Motor circuit protectors:
 - 1. Instantaneous only circuit breaker as part of a listed combination motor controller.

2. Each pole continuously adjustable in a linear scale with 'LO' and 'HI' settings factory calibrated.

2.05 EQUIPMENT (NOT USED)

2.06 COMPONENTS

- A. Terminals:
 1. Line and load terminals suitable for the conductor type, size, and number of conductors in accordance with UL 489.
- B. Case:
 1. Molded polyester glass reinforced.
 2. Ratings clearly marked.
- C. Trip units:
 1. Provide thermal magnetic trip units.
 2. Thermal magnetic:
 - a. Instantaneous short circuit protection.
 - b. Inverse time delay overload.
 - c. Ambient or enclosure compensated by means of a bimetallic element.

2.07 ACCESSORIES (NOT USED)

2.08 MIXES (NOT USED)

2.09 FABRICATION (NOT USED)

2.10 FINISHES (NOT USED)

2.11 SOURCE QUALITY CONTROL

- A. Test breakers in accordance with:
 1. UL 489.
 2. Manufacturer's standard testing procedures.

PART 3 EXECUTION

3.01 EXAMINATION (NOT USED)

3.02 PREPARATION (NOT USED)

3.03 INSTALLATION

- A. Install breakers to correspond to the accepted shop drawings.

- 3.04 ERECTION, INSTALLATION, APPLICATION, CONSTRUCTION (NOT USED)**
- 3.05 REPAIR/RESTORATION (NOT USED)**
- 3.06 RE-INSTALLATION (NOT USED)**
- 3.07 COMMISSIONING (NOT USED)**
- 3.08 FIELD QUALITY CONTROL (NOT USED)**
- 3.09 ADJUSTING (NOT USED)**
- 3.10 CLEANING (NOT USED)**
- 3.11 PROTECTION (NOT USED)**
- 3.12 SCHEDULES (NOT USED)**

END OF SECTION

SECTION 16422

MOTOR STARTERS

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes:
 - 1. Motor starters and contactors.

1.02 REFERENCES

- A. As specified in Section 16050 - Common Work Results for Electrical.
- B. International Electrotechnical Commission (IEC):
 - 1. 60 947-4 - Low-Voltage Switchgear and Control Gear.
 - 2. 801-1 - Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment - Part 1: General Information.
- C. National Electrical Manufacturer's Association (NEMA):
 - 1. ICS 2 - Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 V.
- D. Underwriters Laboratories (UL):
 - 1. 508 - Standard for Industrial Control Equipment.
 - 2. 508A - Standard for Industrial Control Panels.

1.03 DEFINITIONS

- A. Specific definitions and abbreviations:
 - 1. FVNR: Full voltage non-reversing.
 - 2. Overload relay class: A classification of an overload relay time current characteristic by means of a number which designates the maximum time in seconds at which it will operate when carrying a current equal to 600 percent of its current rating.

1.04 SYSTEM DESCRIPTION

- A. General requirements:
 - 1. Starters for motor control centers, individual enclosed starters, or control panels.

1.05 SUBMITTALS

- A. Product data:
 - 1. Manufacturer.
 - 2. Catalog cut sheets.
 - 3. Technical information.
 - 4. Complete nameplate schedule.
 - 5. Complete bill of material.

6. List of recommended spare parts.
 7. Confirmation that the overload relay class for each starter meets the requirements of the equipment and motor supplier.
 8. Electrical ratings:
 - a. Phase.
 - b. Wire.
 - c. Voltage.
 - d. Ampacity.
 - e. Horsepower.
 9. Furnish circuit breaker submittals as specified in Section 16412 - Low Voltage Molded Case Circuit Breakers.
- B. Shop drawings:
1. Elementary and schematic diagrams:
 - a. Provide 1 diagram for every starter and contactor.
 - b. Indicate wire numbers for all control wires on the diagrams:
 - 1) Wire numbering as specified in Section 16075 - Identification for Electrical Systems.
 - c. Indicate interfaces with other equipment on the drawings.
- C. Operation and maintenance manuals:
1. Submit complete operating and maintenance instructions presenting full details for care and maintenance of equipment furnished or installed under this Section. Including but not limited to:
 - a. Electrical ratings:
 - 1) Phase.
 - 2) Wire.
 - 3) Voltage.
 - 4) Ampacity.
 - b. Complete bill of material.
 - c. Manufacturer's operating and maintenance instructions starter and/or contactor component parts, including:
 - 1) Protective devices (fuses, breakers, overload relays, heater elements, etc.).
 - 2) Pilot devices.
 - d. Complete renewal parts list.
 - e. As-built drawings:
 - 1) Furnish as-built drawings for each starter and contactor indicating final:
 - a) Wire numbers.
 - b) Interfaces with other equipment.
 - 2) 11-inch by 17-inch format.

1.06 QUALITY ASSURANCE

- A. Regulatory requirements:
1. All starters and components shall be UL listed and labeled:
 - a. UL 508 - Industrial Control Equipment.
 - b. UL 508A - Industrial Control Panels.
 2. NEMA ICS 2 - Industrial Control and System Controllers; Contactors and Overload Relays Rated: 600 Volts.
 3. Combination starters shall be UL listed and labeled.

1.07 DELIVERY, STORAGE, AND HANDLING (NOT USED)

1.08 PROJECT OR SITE CONDITIONS (NOT USED)

1.09 SEQUENCING (NOT USED)

1.10 SCHEDULING (NOT USED)

1.11 WARRANTY (NOT USED)

1.12 SYSTEM START-UP (NOT USED)

1.13 OWNER'S INSTRUCTIONS (NOT USED)

1.14 MAINTENANCE

A. Spare parts:

1. Provide the following spare parts, suitably packaged and labeled with the corresponding equipment number:
 - a. 1 spare fuse of each size and type per starter.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or equal:

1. NEMA starters and contactors:
 - a. Allen-Bradley.
 - b. Schneider Electric/Square D.
 - c. General Electric.
 - d. Eaton/Cutler-Hammer.

2.02 EXISTING PRODUCTS (NOT USED)

2.03 MATERIALS (NOT USED)

2.04 MANUFACTURED UNITS

A. General:

1. Provide combination type starters with motor circuit protector or thermal-magnetic circuit breaker and control power transformer with ratings as indicated on the Drawings.
2. NEMA size, design, and rated:
 - a. NEMA Size 1 minimum.
3. Coordinate motor circuit protector, thermal magnetic circuit breaker, or fusible disconnect, and overload trip ratings with nameplate horsepower and current ratings of the installed motor:
 - a. If motors provided are different in horsepower rating than those specified or indicated on the Drawings, provide starters coordinated to the actual motors furnished.
4. Provide starters NEMA Size 2 and larger with arc quenchers on load breaking contacts.

5. Mount extended overload reset buttons to be accessible for operation without opening starter enclosure door.
- B. Full voltage starters:
1. Across-the-line full voltage magnetic starters.
 2. Rated for 600 volts.
 3. Electrical characteristics as indicated on the Drawings.
 4. Provide positive, quick-make, quick-break mechanisms, pad lockable enclosure doors.
 5. Furnish starter with solid state electronic overload relays.
 6. Double-break silver alloy contacts.

2.05 EQUIPMENT (NOT USED)

2.06 COMPONENTS

- A. Molded case circuit breakers:
1. Circuit breaker type and ratings as indicated on the Drawings.
 2. Provide as specified in Section 16412 - Low Voltage Molded Case Circuit Breakers.
- B. Contactors:
1. NEMA size as indicated on the Drawings.
 2. Electrically held:
 - a. For lighting loads designed to withstand the initial inrush currents of ballast and lamp loads.
 3. Factory adjusted and chatter free.
 4. Auxiliary contacts:
 - a. Contact ratings as per NEMA A 600 rating:
 - 1) Auxiliary contacts rated 10 amps at 600 volts.
 - b. Provide all contacts indicated on the Drawings, and any additional contacts required for proper operation.
 - c. Provide at least 1 normally open and 1 normally closed spare auxiliary contact.
 5. Constructed in accordance with the following standards:
 - a. UL 508.
 - b. IEC 947-4:
 - 1) Type 1 coordination when protected by a circuit breaker.
 - 2) Type 2 coordination when protected by a suitable UL listed fuse.
 - c. IEC 801-1 parts 2 through 6.
- C. Overloads:
1. Solid state electronic:
 - a. Selectable Class 10, 20, 30 protection.
 - b. Ambient insensitive:
 - 1) Operating temperature: -20 to 70 degrees Celsius.
 - c. Thermal memory.
 - d. Protective functions:
 - 1) Motor overcurrent.
 - 2) Phase unbalance (adjustable).
 - 3) Phase loss.
 - 4) Ground fault protection.

- e. Self-powered.
- f. Provide current transformers for metering of motor current.
- g. Visible trip indicator.
- h. Push-to-trip test.
- i. Isolated normally open alarm contact.
- j. Normally closed trip contact.
- k. Manual reset.

2.07 ACCESSORIES

- A. Lugs and terminals:
 - 1. For all external connections of No. 6 AWG and larger.
 - 2. UL listed for either copper or aluminum conductors.
- B. Surge protective devices:
 - 1. Furnish surge protection devices across the coil of each starter, contactor, and relay.
- C. Pilot devices:
 - 1. Provide pilot lights, switches, elapsed time meters, and other devices as specified or as indicated on the Drawings.
 - 2. As specified in Section 17710 - Control Systems: Panels, Enclosures, and Panel Components.
- D. Conformal coating:
 - 1. Provide conformal coating material applied to electronic circuitry and printed circuit boards to act as protection against moisture, dust, temperature extremes, and chemicals such as H₂S and chlorine.

2.08 MIXES (NOT USED)

2.09 FABRICATION (NOT USED)

2.10 FINISHES (NOT USED)

2.11 SOURCE QUALITY CONTROL (NOT USED)

PART 3 EXECUTION

3.01 EXAMINATION (NOT USED)

3.02 PREPARATION (NOT USED)

3.03 INSTALLATION (NOT USED)

3.04 ERECTION, INSTALLATION, APPLICATION, CONSTRUCTION (NOT USED)

3.05 REPAIR/RESTORATION (NOT USED)

3.06 RE-INSTALLATION (NOT USED)

3.07 COMMISSIONING (NOT USED)

3.08 FIELD QUALITY CONTROL (NOT USED)

3.09 ADJUSTING (NOT USED)

- A. Set all overloads and motor circuit protectors based on the nameplate values of the installed motor.

3.10 CLEANING (NOT USED)

3.11 PROTECTION (NOT USED)

3.12 SCHEDULES (NOT USED)

END OF SECTION

SECTION 17710

CONTROL SYSTEMS - PANELS, ENCLOSURES, AND PANEL COMPONENTS

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes requirements for:
 - 1. Design, fabrication and assembly of all instrumentation enclosures, control panels and components provided under this contract, including but not limited to:
 - a. Custom built instrumentation and control panels, including PLCs, LCPs, LCSs, Instrument and Power Junction Boxes (JBs).
 - b. Control panels furnished as part of equipment systems specified in other Divisions, such as vendor control panels (VCP) and chemical feed panels.
 - c. Control components.
 - d. Control panel installation.
- B. Related Sections:
 - 1. The Contract Documents are complementary; what is called for by one is as binding as if called for by all.
 - 2. It is the Contractor's responsibility for scheduling and coordinating the Work of subcontractors, suppliers, and other individuals or entities performing or furnishing any of Contractor's Work.
 - 3. The following Sections are related to the Work described in this Section. This list of Related Sections is provided for convenience only and is not intended to excuse or otherwise diminish the duty of the Contractor to see that the completed Work complies accurately with the Contract Documents.
 - a. Section 16412 - Low Voltage Molded Case Circuit Breakers.
 - b. Section 16422 - Motor Starters.

1.02 REFERENCES

- A. Specific References:
 - 1. National Electrical Manufacturer's Association (NEMA):
 - a. NEMA 250 - Enclosures for Electrical Equipment (1,000 Volts Maximum).
 - b. NEMA ICS 6 - Enclosures for Industrial Control and Systems.
 - 2. Underwriters Laboratories Inc. (UL):
 - a. UL 50 - Enclosures for Electrical Equipment.
 - b. UL 508 - Industrial Control Equipment.
 - c. UL 508A - Standard for Industrial Control Panels.
 - d. UL 1283 - Standard for Electromagnetic Interference Filters.
 - e. UL 1449 - Standard for Surge Protective Devices.

1.03 DEFINITIONS

- A. Specific Definitions:
 - 1. The term "panel" in this Section is interchangeable with the term "enclosure."

1.04 SYSTEM DESCRIPTION

- A. Panel Dimensions:
 - 1. Minimum dimensions are as indicated on the Drawings and are based upon manufacturer's non-certified information. It is the responsibility of the Contractor or Manufacturer to design and size all panels:
 - a. Size panels to provide space for all equipment, wiring, terminations, and other items in the panel, including space for future build out.
 - b. Panel sizes that substantially deviate (± 3 inches in any dimension) from the sizes shown on the Drawings must be approved by the Engineer.
 - c. Maximum panel depth: 30 inches, unless otherwise indicated.
- B. Structural Design:
 - 1. Completed and installed panel work shall safely withstand seismic requirements at the project site indicated in Section 16050. Enclosures and internal equipment shall be braced to prevent damage from specified forces.

1.05 SUBMITTALS

- A. Provide a control panel hardware submittal, for each control panel and enclosure being provided on this project, including but not limited to:
 - 1. Product Data:
 - a. Enclosure construction details and NEMA type.
 - b. Manufacturer's literature and specification data sheets for each type of equipment to be installed within or on the panel or enclosure.
 - 2. Shop Drawings:
 - a. Scaled, detailed exterior panel (front and side views) and interior panel layout showing equipment arrangement and dimensional information:
 - 1) Provide draft for review and approval by Engineer. The Engineer has the authority to substantially alter initial panel layouts.
 - b. Complete nameplate engraving schedule.
 - c. Structural details of fabricated panels.
 - 3. Calculations:
 - a. Provide installation details based on calculated shear and tension forces:
 - 1) Calculations shall be signed and sealed by a Professional Engineer licensed in the state where the cabinets and panels will be installed.
 - b. For assembled enclosures and other equipment with a weight of 200 pounds or more, provide calculations for:
 - 1) Weight including panel internal components.
 - 2) Seismic forces and overturning moments.
 - 3) Shear and tension forces in connections.
 - c. Cooling Calculations, to include but not limited to:
 - 1) Highest expected ambient temperature for the enclosure's location
 - 2) Internal heat load.
 - 3) Exposure to direct sunlight.
 - 4) Dimensions of the enclosure in inches.
 - 5) Maximum allowable temperature inside the enclosure, based on the lowest operating temperature limit of the installed components.

- B. Seismic Design:
 - 1. Seismic Panel Construction:
 - a. Seismic Anchorage: Provide seismic design calculations and installation details for anchorage of all panels, enclosures, consoles, etc.
 - 1) Stamped by a Professional Engineer registered in the state where the project is being constructed.
 - b. For floor mounted free standing panels weighing 200 pounds or more (assembled, including contents), submit calculations, data sheets, and other information to substantiate that panel, base, and framing meet minimum design strength requirements and seismic requirements. Calculations shall be signed and sealed by a Professional Engineer licensed in the state where the cabinets and panels will be installed.

1.06 QUALITY ASSURANCE

- A. Assemble panels, enclosures, and rack systems along with all internal and external devices, wiring, equipment, and materials in a facility that is recognized by Underwriters Laboratories to assemble and certify UL-labeled control panels:
 - 1. Provide all components and equipment with UL508 listing.
 - 2. All control panels shall be UL 508A labeled, unless the equipment in the panel and the design in the contract documents cannot be reasonably modified to meet the requirements for UL508A labeling:
 - a. Non-listed, complex and unique equipment may be evaluated and approved by a third party testing agency, with prior approval by the Owner. Provide report documenting the testing standard, specification, method of testing and that the equipment and materials meet appropriate designated standards or have been tested and found suitable for use in a specified manner.
 - 3. Provide fuses for all equipment that is not UL or UR listed.

1.07 DELIVERY, STORAGE AND HANDLING

- A. Crate all panels for shipment using a heavy framework and skids:
 - 1. Provide factory-wrapped waterproof flexible barrier material for covering materials, where applicable, to protect against physical damage in transit.
 - 2. Provide suitable shipping stops and cushioning material for all instruments shipped with the panel to prevent damage due to mechanical shock during shipment.
 - 3. Provide each separate panel unit with removable lifting lugs to facilitate handling.
- B. Ship all panels by dedicated air ride van, unless otherwise specified or approved.

1.08 PROJECT OR SITE CONDITIONS

- A. Provide enclosures suitable for the location and environmental conditions in which they are located, and in the NEMA types in accordance with Section 16050, unless otherwise indicated.

1.09 WARRANTY

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. As listed below in the individual component paragraphs.
- B. Provide instruments and other components performing similar functions of the same type, model, or class, and from one Manufacturer.

2.02 EXISTING PRODUCTS

- A. Provide labor and materials for complete modifications to existing panels as required.
- B. Field cut and refinish existing panel faces to original condition to accommodate installation of new instruments, removal of existing instruments and fitting of blanks to suit new layouts. New instrument supports shall be provided as required for complete installation.

2.03 MATERIALS

- A. Construct and finish enclosures using materials capable of withstanding the mechanical, electrical, and thermal stresses, as well as the effects of humidity and corrosion that are likely to be encountered in normal service:
 - 1. Enclosures shall have the following properties:
 - a. NEMA 1: Steel.
 - b. NEMA 4: Steel with gasketed door, rain tight.
 - c. NEMA 4X: Stainless steel 316 (unless indicated 304 on the drawings).
 - d. NEMA 4X: polycarbonate or fiberglass reinforced polyester (FRP) in corrosive areas where stainless steel is incompatible.
 - e. NEMA 12: Steel with gasketed door, dust-tight.
 - f. NEMA 7: Cast aluminum.
- B. Bolting Material:
 - 1. Commercial quality 1/2-inch diameter, stainless steel hex-head grade 5 bolts, nuts and washers, with unified coarse (UNC) threads.
 - 2. Carriage bolts for attaching end plates.
 - 3. All other bolted joints shall have S.A.E. standard lock washers.

2.04 MANUFACTURED UNITS

- A. Panels/Enclosures:
 - 1. Manufacturers: One of the following:
 - a. Rittal.
 - b. Pentair (formerly Hoffman Engineering).
 - c. Saginaw Control & Engineering.
 - 2. Panel assembly:
 - a. General guidelines for panel fabrication include:
 - 1) Continuous welds ground smooth.
 - 2) Exposed surfaces free of burrs and sharp edges.

- 3) Base formed of heavy channel iron, either galvanized or powder coated, minimum 1/2 inch holes at 12-inch spacing to accommodate anchoring of freestanding enclosures to floor.
- b. Construct enclosure and mounting panel using stretcher level sheet metal having minimum thickness not less than the following sizes (U.S. Standard Gauge):

Enclosure Height (inches)	Minimum Enclosure Steel Thickness (gauge)	Minimum Back Mounting Panel Thickness (gauge)
Up to 57	12	12
57 - 69	12	10
69 - 82	12, except 10 on back	10
82 or more	10	10

- 1) Use heavier sheet metal to meet seismic requirements at the project site or when required due to equipment requirements.
- c. Construct supporting frame structure with angled, channeled, or folded rigid section of sheet metal, rigidly attached to and having essentially the same outer dimensions as the enclosure surface and having sufficient torsional rigidity to resist the bending moments applied via the enclosure surface when it is deflected.
- d. Provide stiffeners for back mounting panels in enclosures larger than 4 feet. In addition, secure the panels in place by collar studs welded to the enclosure.
- e. Door construction:
 - 1) Turned-back edges suitably braced and supported to maintain alignment and rigidity without sagging.
 - 2) Sufficient width to permit door opening without interference with rear projection of flush mounted instruments.
 - 3) Heavy gauge piano type continuous stainless steel hinges.
 - 4) For NEMA 12, 4 and 4X, provide oil resistant neoprene sealing gasket and adhesive to seal cover to enclosure.
 - 5) Gasket installed to seal against roll lip on the enclosure opening.
- f. Latches:
 - 1) For panels each door provided with a 3-point latching mechanism and locking handle with rollers on the ends of the latch rods. Latch rods connected to a common door handle, hold doors securely, forming a compressed seal between door and gasket, at the top, side, and bottom.
 - a) Provide padlock for each enclosure with padlock provisions.
 - 2) Include an oil-tight key-locking, 3-point latching mechanism on each door:
 - a) Provide 2 keys per panel.
 - b) All locks keyed the same.
 - 3) For large type NEMA 4 and NEMA 4X cabinets, not available with 3-point latching hardware, provide multiple clips and padlock hasps.
 - 4) Provide quick release latches for all NEMA 4 and 4X enclosures.

- g. Panel cut-outs:
 - 1) Cut, punch, or drill cutouts for instruments, devices, and windows. Smoothly finish with rounded edges.
 - 2) Allow a minimum of 3-inch envelope around all displays, controllers, and monitors.
 - 3) Reinforce around cut-outs with steel angles or flat bars for the following:
 - a) Large panel cutouts; for example, openings for local operator interfaces.
 - b) Pilot device groupings, where the removed metal exceeds 50 percent of the available metal.
 - 3. In addition to the requirements specified above the following requirements for NEMA 4X powder coated stainless steel enclosures apply:
 - a. Minimum 14 gauge, Type 304.
 - b. Captive stainless steel cover screws threaded into sealed wells.
 - c. Finish: white polyester powder coating.
 - d. Specifically designed for use with flange-mounted disconnect handles where required or as indicated on the Drawings.
 - e. NEMA 4X powder coated stainless steel enclosures are not an acceptable substitute for stainless steel unless indicated on the Drawings.
 - 4. Outdoor Panels. Supplementary requirements for panels located outdoors are as follows:
 - a. All enclosures located outdoors shall be explicitly designed and rated for outdoor service by the manufacturer.
 - b. Door hardware: stainless steel.
 - c. Provide rain canopy and sun shield.
 - d. Bases: Heavy channel, gasketed iron bases, flanges up, for anchoring to pad.
- B. Arrangement of Components:
- 1. Arrange panel internal components for external conduit and piping to enter into panel either from above or below.
 - 2. Arrange panel instruments and control devices in a logical configuration associating pushbutton and selector switches with related readout devices, or as indicated on the Drawings.
 - 3. Mount internal control components on an internal back-panel. Devices may be mounted on the side-panel only by special permission from the Engineer.
 - 4. All control panel mounted operator interface devices shall be mounted between 3 feet and 6 feet above finished floor.
- C. Overcurrent Protection:
- 1. Main overcurrent device:
 - a. Where the electrical power supply voltage to the control panel is more than 120 VAC, provide the panel with a flange mounted disconnect handle operating a molded case circuit breaker, and provide a control power transformer for 120 VAC circuits:
 - 1) Door-mounted disconnect handles are not acceptable.
 - 2) Mechanically interlocked the disconnect switch with the control enclosure doors so that no door can be opened unless the power is disconnected, and the disconnect switch cannot be closed until all doors are closed.
 - 3) Provide means to defeat the interlock.

- b. Control panels supplied with 120 VAC:
 - 1) Provide an internal breaker with the line side terminals covered by a barrier.
 - 2) Provide a nameplate prominently positioned on the control panel identifying the location of the power source and a warning statement requiring the source to be disconnected before opening the door to the enclosure.
- 2. Provide circuit breakers in accordance with Section 16412.
- 3. Selection and ratings of protective devices:
 - a. Interrupting ratings: Not less than the system maximum available fault current at the point of application.
 - b. Voltage rating: Not less than the voltage of the application.
 - c. Select current rating and trip characteristics to be suitable for:
 - 1) Maximum normal operating current.
 - 2) Inrush characteristics.
 - 3) Coordination of the protective devices to each other and to the source breaker feeding the panel.
- 4. Provide a separate protective device for each powered electrical device:
 - a. An individual circuit breaker for each 120 VAC instrument installed within its respective control panel and clearly identified for function.
 - b. An individual fuse for each PLC discrete output. Provide with individual fuse with blown fuse indication external of the I/O card:
 - 1) Size external fuse to open before any I/O card mounted fuses.
 - c. An individual 5-ampere fuse for each discrete input loop.
 - d. An individual 1/2-ampere loop for each 4-20mA analog loop powered from the control panel.
 - e. Install protective devices on the back mounting panel and identify by a service nameplate in accordance with the wiring diagrams.
- 5. Fuses for 4 to 20 milliamperes signals:
 - a. Provide durable, readily visible label for each fuse, clearly indicating the correct type, size, and ratings of replacement fuse:
 - 1) Label shall not cover or interfere with equipment manufacturer's instructions.
 - b. An individual 1/2-ampere fuse for each 4 to 20 milliamperes analog loop powered from the control panel.
 - c. Provide fuses rated for the voltage and available short-circuit current at which they are applied.
 - d. Manufacturer: One of the following or equal:
 - 1) Ferraz Shawmut.
 - 2) Littelfuse.
 - 3) Bussmann.
- 6. Fuse holders:
 - a. Modular type:
 - 1) DIN rail mounting on 35mm rail.
 - 2) Touch safe design: All connection terminals to be protected against accidental touch.
 - 3) Incorporates blown fuse indicator.
 - 4) Plug-in style fuse terminals and fuse plugs are not acceptable.
 - b. Provide nameplate identifying each fuse:
 - 1) In accordance with Section 16075.

- c. Manufacturer: One of the following:
 - 1) Phoenix Contact.
 - 2) Allen Bradley 1492-FB Series B.
- 7. Control Circuit Breakers:
 - a. DIN rail mounting on 35mm rail.
 - b. Manual OPEN-CLOSE toggle switch.
 - c. Rated 250 VAC.
 - d. Interrupting Rating: 10kA or available fault current at the line terminal, whichever is higher.
 - e. Current ratings: As indicated on the Drawings or as required for the application.
 - f. Provide nameplate identifying each circuit breaker:
 - 1) In accordance with Section 16075.
 - g. Manufacturer: One of the following:
 - 1) Phoenix Contact.
 - 2) ABB.
 - 3) Allen Bradley Series.
 - 4) Square D.
- D. Conductors and Cables:
 - 1. Power and Control Wiring:
 - a. Materials: Stranded, soft annealed copper.
 - b. Insulation: 600V type MTW.
 - c. Minimum Sizes:
 - 1) Primary power distribution: 12 AWG.
 - 2) Secondary power distribution: 14 AWG.
 - 3) Control: 16 AWG.
 - d. Color:
 - 1) AC power (line and load): BLACK.
 - 2) AC power (neutral): WHITE.
 - 3) AC control: RED.
 - 4) AC control: Orange for foreign voltages.
 - 5) DC power and control (ungrounded): BLUE.
 - 6) DC power and control (grounded): WHITE with BLUE stripe.
 - 7) Ground: GREEN.
 - 2. Signal Cables:
 - a. Materials: Stranded, soft annealed copper.
 - b. Insulation: 600V, PVC outer jacket.
 - c. Minimum Size: 16 AWG paired triad.
 - d. Overall aluminum shield (tape).
 - e. Copper drain wire.
 - f. Color:
 - 1) 2 Conductor:
 - a) Positive (+): BLACK.
 - b) Negative (-): WHITE, RED.
 - 2) 3 Conductor:
 - a) Positive (+): BLACK.
 - b) Negative (-): RED.
 - c) Signal: WHITE.
 - g. Insulate the foil shielding and exposed drain wire for each signal cable with heat shrink tubing.

- E. Conductor Identification:
 - 1. Identify all conductors and cables with wire markers.
 - 2. Readily identified without twisting the conductor.

- F. General Wiring Requirements:
 - 1. Wiring Methods: Wiring methods and materials for panels shall be in accordance with the NEC requirements for General Purpose (no open wiring) unless otherwise specified.
 - 2. Install all components in accordance with the manufacturer's instructions included in the listing and labeling.
 - 3. Where the electrical power supply voltage to the control panel is more than 120 VAC, provide the panel with a flange mounted disconnect and control power transformer. Mechanically interlocked the disconnect switch with the control enclosure doors so that no door can be opened unless the power is disconnected, and the disconnect cannot be closed until all doors are closed.
 - a. Provide means to defeat this interlock.
 - 4. Control panels supplied with 120 VAC:
 - a. Provide an internal breaker with the line side terminals covered by a barrier.
 - b. Provide a nameplate prominently positioned on the control panel identifying the location of the power source and a warning statement requiring the source to be disconnected before opening the door to the enclosure.
 - 5. Provide a nameplate on the cover of the control panel identifying all sources of power supply and foreign voltages within the control panel.
 - 6. Provide transformers, protective devices, and power supplies required to convert the supply voltage to the needed utilization voltage.
 - 7. Provide power surge protection device on input supply power.
 - 8. Provide signal surge protection within control panels for each analog I/O, discrete I/O, and data line (Copper Ethernet, Coax, Fieldbus signals) that originates from outdoor devices.
 - 9. Provide nonmetallic ducts for routing and organization of conductors and cables:
 - a. Provide wiring separation plan.
 - b. Size ducts for ultimate build-out of the panel, or for 20 percent spare, whichever is greater.
 - c. Provide separate ducts for signal and low voltage wiring from power and 120 VAC control wiring:
 - 1) 120 VAC: Grey colored ducts.
 - 2) 24 VDC: White colored ducts.
 - 10. Cables shall be fastened with cable mounting clamps or with cable ties supported by any of the following methods:
 - a. Screw-on cable tie mounts.
 - b. Hammer-on cable tie mounting clips.
 - c. Fingers of the nonmetallic duct.
 - 11. The free ends of cable ties shall be cut flush after final adjustment and fastening.
 - 12. Wire Ties:
 - a. No wire ties inside wire duct.
 - b. Use Panduit Cable tie installation tool, with tension control/cutoff.
 - c. Verify cut ends are cut flush filed smooth after installed.

13. Provide supports at the ends of cables to prevent mechanical stresses at the termination of conductors.
14. Support panel conductors where necessary to keep them in place.
15. Wiring to rear terminals on panel-mount instruments shall be run in nonmetallic duct secured to horizontal brackets run adjacent to the instruments.
16. Conductors and cables shall be run from terminal to terminal without splice or joints. Exceptions:
 - a. Factory applied connectors molded onto cables shall be permitted. Such connectors shall not be considered as splices or joints.
17. The control panel shall be the source of power for all 120 VAC devices interconnected with the control panel including, but not limited to:
 - a. Solenoid valves.
 - b. Instruments and both mounted in the control panel and remotely connected to the control panel.

2.05 COMPONENTS

A. Pilot Devices:

1. General:
 - a. Provide operator pushbuttons, switches, and pilot lights, from a single manufacturer.
 - b. Size:
 - 1) 30.5mm.
 - c. Heavy duty.
 - d. Pushbuttons:
 - 1) Contacts rated:
 - a) NEMA A600.
 - 2) Furnish one spare normally open and normally closed contact with each switch.
 - e. Selector switches:
 - 1) Contacts rated:
 - a) NEMA A600.
 - b) Knob type:
 - 2) Furnish one spare normally open contact and normally closed contact with each switch.
 - 3) Provisions for locking in the OFF position where lockout provisions are indicated on the Drawings.
 - f. Pilot lights:
 - 1) Type:
 - a) LED for interior installations.
 - b) Incandescent for exterior installations.
 - 2) Push to Test.
 - 3) Lamp Color:
 - a) On/Running/Start: Red.
 - b) Off/Stop: Green.
 - c) Power: White.
 - d) Alarm: Amber.
 - e) Status or Normal Condition: White.
 - f) Opened: Amber.
 - g) Closed: Blue.
 - h) Failure: Red.

2. Indoor and Outdoor Areas:
 - a. NEMA type 4/13.
 - b. Manufacturer: One of the following:
 - 1) Allen Bradley Type 800T.
 - 2) Square D Class 9001 Type K.
 - 3) General Electric Type CR104P.
 - 4) IDEC TWTD.
 3. Corrosive Areas:
 - a. NEMA 4X.
 - b. Corrosion resistant.
 - c. Exterior parts of high impact strength fiberglass reinforced polyester or multiple-layer epoxy coated zinc.
 - d. Manufacturer: One of the following:
 - 1) Cutler Hammer Type E34.
 - 2) Square D Class 9001 Type SK.
 - 3) Allen Bradley Type 800H.
 - 4) IDEC TWTD.
- B. Potentiometer and Slidewire Transmitters:
1. Provide a DC output in proportion to a potentiometer input.
 2. Potentiometer input:
 - a. 100 ohms to 100K ohms.
 - b. Impedance $\geq 1M$ ohms.
 - c. Zero Turn-Up: 80 percent of full scale input.
 - d. Span Turn-Down: 80 percent of full scale input.
 3. Field configurable output:
 - a. Voltage and Current: All conventional current loops and voltage control signals.
 4. Accuracy including linearity and hysteresis ± 0.1 percent max at 25 degrees Celsius.
 5. Operating temperature: 0 degrees Celsius to 55 degrees Celsius.
 6. Supply power: 9 to 30 VDC.
 7. Manufacturer: One of the following:
 - a. Phoenix Contact.
- C. Signal isolators and converters:
1. Furnish signal isolators that provide complete isolation of input, output, and power input:
 - a. Minimum isolation level: 1.5 kV AC/50 Hz for at least 1 minute.
 - b. Adjustable span and zero.
 - c. Accuracy: ± 1.0 percent of span.
 - d. Ambient temperature range: -20 degrees Celsius to +65 degrees Celsius.
 2. Manufacturer: One of the following:
 - a. Phoenix Contact MCR Series.
 - b. Acromag 1500, 600T, 800T, Flat Pack or ACR Series.
 - c. Action Instruments Q500 Series or Ultra SlimPakII.
 - d. AGM electronics Model TA-4000.
- D. Relays:
1. General:
 - a. For all types of 120 VAC relays, provide transient surge protection across the coil of each relay.

- b. For all types of 24 VDC relays, provide a free-wheeling diode across the coil of each relay.
2. General Purpose:
- a. Magnetic control relays.
 - b. NEMA A300 rated:
 - 1) 300 Volts.
 - 2) 10 Amps continuous.
 - 3) 7,200 VA make.
 - 4) 720 VA break.
 - c. Plug-in type.
 - d. LED indication for relay energized.
 - e. Coil voltages: As required for the application.
 - f. Minimum poles: 2PDT.
 - g. Touch safe design: All connection terminals to be protected against accidental touch.
 - h. Enclose each relay in a clear plastic heat and shock-resistant dust cover.
 - i. Quantity and type of contact shall be as shown on the Drawings or as needed for system compatibility.
 - j. Relays with screw-type socket terminals.
 - k. Provide additional (slave/interposing) relays when the following occurs:
 - 1) The number or type of contacts shown exceeds the contact capacity of the specified relays.
 - 2) Higher contact rating is required in order to interface with starter circuits or other equipment.
 - l. DIN rail mounting on 35mm rail.
 - m. Ice Cube type relays with retainer clips to secure relay in socket.
 - n. Integrated label holder for device labeling.
 - o. Manufacturer: One of the following:
 - 1) Phoenix Contact PLC series.
 - 2) Potter and Brumfield Type KRP or KUP.
 - 3) IDEC R* series. (* = H, J, R, S, U).
 - 4) Allen Bradley Type 700 H Series.
 - 5) Square D Type K.
3. Latching:
- a. Magnetic latching control relays.
 - b. NEMA B300 rated:
 - 1) 300 Volts.
 - 2) 10 Amps continuous.
 - 3) 3,600 VA make.
 - 4) 320 VA break.
 - c. Plug-in type.
 - d. DIN rail mounting on 35mm rail.
 - e. Coil voltage: as required for the application.
 - f. Minimum poles: 2PDT; as required for the application. Plus 1 spare pole.
 - g. Touch safe design: All connection terminals to be protected against accidental touch.
 - h. Clear cover for visual inspection.
 - i. Provide retainer clip to secure relay in socket.
 - j. Manufacturer: One of the following, or equal:
 - 1) Square D type 8501 Type K.
 - 2) IDEC TWTD.

4. Time Delay:
 - a. Provide time delay relays to control contact transition time.
 - b. Contact rating:
 - 1) 240 Volts.
 - 2) 10 Amps continuous.
 - 3) 3,600 VA make.
 - 4) 360 VA break.
 - c. Coil voltage: as required for the application.
 - d. Provide Pneumatic or Electronic type with on-delay, off-delay, and on/off delay:
 - 1) For off delay use true power off time delay relays. Where the required timing range exceeds capability of the off delay relay use signal off delay where power loss will not cause undesirable operation or pneumatic time delay relays.
 - e. Minimum poles: 2PDT.
 - f. Units include adjustable dial with graduated scale covering the time range in each case.
 - g. Minimum timing range: 0.1 seconds to 10 minutes, or as required for the application.
 - h. Manufacturer: One of the following:
 - 1) Idec GT3 series.
 - 2) Agastat type Series 7000 (pneumatic).
 - 3) Allen Bradley type 700HR Series.

E. Terminal blocks:

1. Din rail mounting on 35mm rail.
2. Suitable for specified AWG wire.
3. Rated for 30 amperes at 600 Volts.
4. Screw terminal type.
5. Provide mechanism to prevent wire connection from loosening in environments where vibration is present. This mechanism shall not cause permanent deformation to the metal body.
6. Finger safe protection for all terminals for conductors.
7. Construction: Polyamide insulation material capable of withstanding temperature extremes from - 40 degree Celsius to 105 degrees Celsius.
8. Terminals: Plainly identified to correspond with markings on the diagrams:
 - a. Permanent machine printed terminal identification.
9. Disconnect type field signal conductor terminals with socket/screw for testing.
10. Identify terminals suitable for use with more than 1 conductor.
11. Position:
 - a. So that the internal and external wiring does not cross.
 - b. To provide unobstructed access to the terminals and their conductors.
12. Provide minimum 25 percent spare terminals.
13. Manufacturer: One of the following:
 - a. Phoenix Contact UK5 Series.
 - b. Allen Bradley Series 1492.

F. Wire duct:

1. Provide flame retardant plastic wiring duct, slotted with dust cover.
2. Type:
 - a. Wide slot.
 - b. Narrow slot.

- c. Round hole.
- d. Manufacturer: One of the following:
 - 1) Panduit.
- 3. Fuses (holders) and circuit breakers:
 - a. Fuse holders:
 - 1) Modular type:
 - a) DIN rail mounting on 35mm rail.
 - b) Touch safe design: All connection terminals to be protected against accidental touch.
 - c) Incorporates blown fuse indicator.
 - 2) Provide nameplate identifying each fuse:
 - a) In accordance with Section 16075.
 - 3) Manufacturer: One of the following:
 - a) Phoenix Contact.
 - b) Allen Bradley 1492-FB Series B.

G. Din Rail:

- 1. Perforated Steel.
- 2. 35 mm width.
- 3. 15 mm deep.
- 4. Provide 2 inch offset using one of the following:
 - a. Offset brackets.
 - b. Preformed standoff Din Rail Channel.

H. Surge Protection Devices:

- 1. Provide Surge Protection Device (SPD) for Power Entrances:
 - a. Nominal 120 VAC with a nominal clamping voltage of 200 Volts.
 - b. Non-faulting and non-interrupting design.
 - c. A response time of not more than 5 nanoseconds.
- 2. Control Panel Power System Level Protection, non-UPS powered:
 - a. Design to withstand a maximum 10 kA test current of an 8/20 μ s waveform according to ANSI/IEEE C62.41.1-2002 Category C Area.
 - b. Provide both normal mode noise protection (between current carrying conductors) and common mode (between current carrying conductor and neutral) surge protection.
 - c. DIN rail mounting.
 - d. Attach wiring to the SPD by means of a screw type cable-clamping terminal block:
 - 1) Gas-tight connections.
 - 2) The terminal block: Fabricated of non-ferrous, non-corrosive materials.
 - e. Visual status indication of MOV status on the input and output circuits.
 - f. Dry contact rated for at least 250 VAC, 1 Amp for remote status indication.
 - g. Meeting the following requirements:
 - 1) Response time: ≤ 100 ns.
 - 2) Attenuation: ≥ -40 dB at 100 kHz as determined by a standard 50 ohms insertion test.
 - 3) Safety approvals:
 - a) UL 1283 (EMI/RFI Filter).
 - b) UL 1449 2nd Edition.
 - h. Manufacturer: One of the following:
 - 1) Phoenix Contact type SFP TVSS/Filter.

- 2) Liebert Accuvar series.
- 3) Islatrol.
3. Instrument, data and Signal Line Protectors (traditional I/O)– Panel Mounted:
 - a. Surge protection minimum requirements: Withstand a 10 kA test current of an 8/20 μ s waveform in accordance with ANSI/IEEE C62.41.1-2002 Category C Area.
 - b. DIN rail mounting on 35mm rail (except field mounted SPDs).
 - c. SPDs consisting of 2 parts:
 - 1) A base terminal block.
 - 2) A plug protection module:
 - a) Replacing a plug does not require the removal of any wires nor interrupt the signal.
 - b) Base and plug coded to accept only the correct voltage plug.
 - d. SPD Manufacturer: One of the following:
 - 1) Phoenix Contact Plugtrab Series.
 - 2) Bournes Series 1800.
4. Instrument, data and Signal Line Protectors – Field Mounted:
 - a. Surge protection minimum requirements: Withstand a minimum 10 kA test current of an 8/20 μ s waveform in accordance with ANSI/IEEE C62.41.1-2002 Category C Area.
 - b. Manufacturer: One of the following:
 - 1) Phoenix Contact Pipetrab.
 - 2) Joslyn JMD Series.

2.06 ACCESSORIES

- A. Provide panels with an inside protective pocket to hold the panel Drawings. Ship panels with 1 copy of accepted Shop Drawings including, but not limited to, schematic diagram, connection diagram, and layout drawing of control wiring and components in a sealed plastic bag stored in the panel drawing pocket.
- B. Provide nameplate to each panel as indicated on the Drawings:
 1. Provide a nameplate with the following markings that is plainly visible after installation:
 - a. Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the panel can be identified.
 - b. Supply voltage, phase, frequency, and full-load current.
 - c. Short-circuit current rating of the panel based on one of the following:
 - 1) Short-circuit current rating of a listed and labeled assembly.
 - 2) Short-circuit current rating established utilizing an approved method.
 2. Provide enclosures with a flange mounted disconnect that is interlocked with the doors.
- C. Grounding:
 1. Provide the following:
 - a. Grounding strap between enclosure doors and the enclosure.
 - b. Equipment grounding conductor terminals.
 - c. Provide equipment ground bus with lugs for connection of all equipment grounding wires.
 - d. Bond multi-section panels together with an equipment grounding conductor or an equivalent grounding bus.

2. Identify equipment grounding conductor terminals with the word "GROUND," the letters "GND" or the letter "G," or the color green.
3. Signal (24 VDC) Grounding: Terminate each drain wire of a signal (shielded) cable to a unique grounding terminal block, or common ground bus at the end of the cable as shown on the Loop Drawings.
4. Ensure the continuity of the equipment grounding system by effective connections through conductors or structural members.
5. Design so that removing a device does not interrupt the continuity of the equipment grounding circuit.
6. Provide an equipment-grounding terminal for each incoming power circuit, near the phase conductor terminal.
7. Size ground wires in accordance with NEC and UL Standards, unless noted otherwise.
8. Connect all exposed, noncurrent-carrying conductive parts, devices, and equipment to the equipment grounding circuit.
9. Connect the door stud on the enclosures to an equipment-grounding terminal within the enclosure using an equipment-bonding jumper.
10. Bond together all PLC or RTU racks (remote or local) processor racks, and conductive enclosures of power supplies and connect to the equipment grounding circuit.

2.07 FINISHES

A. Finishes:

1. **Metallic (Non-Stainless):**
 - a. Metal surfaces of panels shall be prepared by chemical cleaning and mechanical abrasion in accordance with the finish manufacturer's recommendations to achieve a smooth, well-finished surface.
 - b. Scratches or blemishes shall be filled before finishing. One coat of zinc phosphate shall be applied per the manufacturer's recommended dry film thickness, and allowed to dry before applying the finish coat.
 - c. Finish coat shall be a baked polyester urethane powder, aliphatic air-dry polyurethane, or epoxy enamel to meet NEMA rating specified application.
 - d. Exterior of enclosures located outdoors shall be UV resistant polyester powder coating. Total dry film thickness shall be 3 mils, minimum.
2. **Stainless Steel:**
 - a. Stainless enclosures shall be provided with a Number 4 brushed finish, not painted.

B. Colors:

1. Exterior color of panels mounted indoors shall be manufacturer's standard light gray.
2. Exterior of panels mounted outdoors shall be manufacturer's standard white.
3. Panel interiors shall be manufacturer's standard white.
4. Color samples of finishes to the Engineer for color selection.

2.08 SOURCE QUALITY CONTROL

- A. Refer to Section 17050.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Install enclosures so that their surfaces are plumb and level within $\pm 1/8$ inch over the entire surface of the panel; anchor securely to wall and structural supports at each corner, minimum. Direct attachment to dry wall is not permitted.
- B. Install the enclosure per guidelines and submitted installation instructions to meet the seismic requirements at the project site.
- C. Provide floor stand kits for wall-mount enclosures larger than 48 inches high.
- D. Provide 3-1/2 inch high concrete housekeeping pads for free-standing enclosures.
- E. Install gasket and sealing material under panels with floor slab cutouts for conduit:
 - 1. Undercoat floor mounted panels.
- F. Provide a full size equipment-grounding conductor in accordance with NEC included with the power feeder. Terminate to the incoming power circuit-grounding terminal.
- G. All holes for field conduits, etc. shall be cut in the field, there shall be no additional holes, factory cut holes, or hole closers allowed. Incorrect holes, additional holes, or miss-cut holes shall require that the entire enclosure be replaced.
- H. Control panels that are adjacent to motor control centers shall be fully wired to the motor control centers using wireways integral to the motor control center or additional conduits as needed. These interconnections are not shown or reflected on the conduit schedule, but shall be shown on the Loop Drawings prepared by the Contractor.
- I. Provide individually fused analog input module points with blown-fuse indicator lights, mounted external of the module on the output terminal strip.
- J. Side Panels:
 - 1. Side panels shall be kept free off all control equipment and devices. Any deviation must be sent to the engineer in writing asking for a deviation.

3.02 FIELD QUALITY CONTROL (NOT USED)

3.03 CLEANING (NOT USED)

3.04 PROTECTION (NOT USED)

END OF SECTION

