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**PART 1 GENERAL****1.1 RELATED DOCUMENTS**

- A. The requirements of the General Conditions, Supplementary Conditions and the following Specification sections apply to all Work herein:
1. Section 22 00 10 - General Requirements
  2. Section 22 00 20 - Plumbing Scope of Work
  3. Section 22 05 07 - Design Conditions
  4. Section 22 05 93 - Testing, Balancing and Adjusting
  5. Section 22 10 00 - Domestic Water Systems
  6. Section 22 21 23 - Pumps
  7. Section 22 30 00 - Plumbing Equipment

**1.2 SUMMARY**

- A. Furnish and install all electric motors required for equipment furnished under this Division. Electric motors shall be factory mounted on equipment wherever possible and shall be constructed as specified in this Section. If electric motors are shipped loose and must be installed by the Division 26 Electrical Subcontractor, the Division 22 Subcontractor shall notify each Electrical Subcontractor in writing prior to the bid date. In general, all motor controllers will be furnished and installed under Division 26 unless the motor controller is an integral part of a piece of equipment, a variable speed drive controller and/or specifically required to be furnished under this Division.

**1.3 REFERENCE STANDARDS**

- A. Each motor, controller and all components shall be designed, manufactured and tested in accordance with the following latest applicable standards:
1. National Electric Manufacturers Association Standards (NEMA)
  2. ANSI/NEMA MG 1 -1978 - Motors and Generators
  3. NFPA 70 - National Electrical Code (NEC)
  4. IEEE-112, Test Method "B"
  5. IEEE Standard 519-1992
  6. NEMA - ICS-3-303
  7. IEEE STD 444 (ANSI C34.3)
  8. Energy Policy Act of 1992 (EP Act)
- B. All equipment and material to be furnished and installed on this Project shall be UL or ETL listed, in accordance with the requirements of the authorities having jurisdiction, and suitable for its intended use on this Project.

**1.4 SUBMITTALS**

- A. The following submittal data shall be furnished according to the General Conditions and Section 22 00 10 and shall include, but not be limited to:
1. Electric Motors - for all equipment not included under another Section. Shop Drawings shall state the motor manufacturer, frame size, horsepower, frequency, voltage, power factor, efficiency, speed starting torque class, insulation class, service factor and winding material. In addition, special shaft or mounting detail requirements as well as shaft limitation details and any other special requirements shall be listed on these Drawings.
  2. Motor Controllers - for all controllers not included under another Division.
  3. Variable Speed Drives\* - for all variable speed drives not included under other sections of Division 22 Specifications. Complete with enclosure construction details, line reactor or tuned filter data, design features, accessories, disconnect, capacitor, mechanical bypass, if specified, and spare parts data.
  4. Spare Parts and/or Spare Variable Speed Drives – shall be provided to the Owner as specified herein at substantial completion.
  5. Shaft Grounding Bushings – for all motors used in conjunction with variable speed drives.
  6. Proposed test procedures, recording forms, test equipment, and list of personnel and qualifications for all tests proposed.

7. Factory Test Schedule.
8. Factory Test Reports.
9. Field Test Schedule.
10. Field Test Reports.
11. Factory technician Variable Speed Drive commissioning and adjusting report.

- B. All items or equipment listed above with asterisks (\*) shall be certified by the manufacturer using Manufacturer Certification "MCA" as set forth in Section 22 00 10. See Section 22 00 10 for certification requirements.

## 1.5 WARRANTY

- A. Comply with the requirements of the General Conditions and Section 22 00 10.

## PART 2 PART 2 - PRODUCTS

### 2.1 ACCEPTABLE MANUFACTURERS

- A. If it complies with these Specifications, motors manufactured by one of the following manufacturers will be acceptable:
1. Baldor
  2. Century/ MagneTek
  3. General Electric
  4. Marathon
  5. Lincoln
  6. Reliance
  7. Siemens
  8. Toshiba
  9. Westinghouse
- B. If it complies with these Specifications, controllers manufactured by one of the following manufacturers will be acceptable:
1. Allen Bradley
  2. Cutler Hammer/Westinghouse
  3. General Electric
  4. Siemens
  5. Square D
- C. If it complies with these Specifications, variable speed drives manufactured by one of the following manufacturers will be acceptable:
1. ABB
  2. Allen Bradley
  3. Danfoss/Graham
  4. MagneTek
  5. Reliance
  6. Siemens
  7. Square D
  8. Toshiba

### 2.2 MOTORS

- A. In general, motor voltages shall be as follows, unless specified or indicated otherwise:
1. 3/4 hp and larger - 460V, three (3) phase, 60 hertz
  2. Smaller than 3/4 hp - 120V, one (1) phase, 60 hertz
- B. All motors shall be started across the line, unless specified otherwise. All motors 100 horsepower and larger shall be suitable for wye-delta starting unless specified otherwise. Motors shall be selected with low starting current and shall be designed for continuous duty to provide the running torque and pull in torque required to suit the load. Unless otherwise indicated on the Contract Documents, all motors shall be single speed (1750 rpm). All motors shall have standard open drip proof enclosures unless otherwise specified. All motors

exposed to or actually installed outside in the weather shall be of the totally enclosed fan cooled (TEFC) or totally enclosed air over (TEAO) types. All motors not utilized with variable speed drives shall have a minimum service factor of 1.15 and shall be selected to operate at design conditions without exceeding their nameplate rating (without exploiting the service factor rating). Motors used in conjunction with variable speed drives shall have a 1.00 service factor unless otherwise indicated. Two (2) speed motors shall be two (2) speed, two (2) winding or two (2) speed, single winding type as specified herein and as indicated on the Contract Documents.

1. Standard open drip proof three (3) phase motors ten (10) horsepower and smaller shall have cast aluminum end bells with steel frames. Three (3) phase motors fifteen (15) horsepower and larger shall have cast iron end bells and housings.
2. Standard open drip proof single phase motors shall have cast aluminum end bells with steel frames.
3. Totally enclosed fan cooled (TEFC) and totally enclosed air over (TEAO) three (3) phase motors shall have cast iron housings. TEFC motors shall have corrosion resistant fans.
4. Vertical pump motors shall have cast iron end bells and cast aluminum housing. These motors shall be sized to drive the pump through its characteristic curve without exceeding the rated motor full load horsepower.

C. Windings and Insulation:

1. All motors shall have copper windings.
2. Motors shall be equipped with Class B, 80°C (176°F) rise or Class F, 105°C (221°F) rise insulation suitable for use in a 40°C (104°F) ambient temperature. All motors used for cooling tower applications shall be equipped with Class F, 105°C (221°F) rise insulation suitable for use in a 40°C (104°F) ambient temperature. Windings shall be treated with an epoxy varnish to inhibit the absorption of moisture.

D. Bearings:

1. Single phase, fractional horsepower motors shall be equipped with quiet operating, all angle, babbitt lined sleeve bearings.
2. Polyphase motors shall be equipped with deep groove type ball bearings, generously sized for the loads to which applied and for severe duty application. Provide the necessary seals on the shaft to keep the bearing system free of contamination and moisture.
3. All motors shall be factory lubricated with high temperature, non-bleeding electrically conductive grease.
4. Provide inlet and outlet plugs on poly-phase motors so that grease fittings can be easily inserted for bearing re-lubrication except as otherwise specified. The end shields shall be carefully machined to add extra grease capacity. Lower outlet plugs shall be equipped with combination breather/drains on TEFC and TENV motors.

E. Motors shall be specifically designed for quiet operation and for severe duty. Standard open drip proof motors shall be equipped with aluminum or stainless steel stamped nameplates. Totally enclosed fan cooled and air over motors shall be equipped with stainless steel stamped nameplates with either zinc or cadmium plated hardware. Motor nameplates shall clearly indicate frame size, horsepower, frequency, voltage, speed, starting torque class, insulation class, service factor and winding material.

F. Premium™ efficiency, three (3) phase, general purpose, continuous duty, T-frame, squirrel cage induction motors shall be specifically designed per IEEE-112, test method “B” procedures and shall have at least the following efficiency:

Size Horsepower	ODP Motors Full Load Efficiency* 1800 RPM	TEFC Motors Full Load Efficiency* 1800 RPM
1	85.5	85.5
1-1/2	86.5	86.5
2	86.5	86.5
3	89.5	89.5
5	89.5	89.5
7-1/2	91.0	91.0
10	91.7	91.7
15	93.0	93.0
20	93.0	93.0

Size Horsepower	ODP Motors Full Load Efficiency* 1800 RPM	TEFC Motors Full Load Efficiency* 1800 RPM
25	93.6	93.6
30	94.1	94.1
40	94.1	94.1
50	94.5	94.5
60	95.0	95.0
75	95.0	95.0
100	95.4	95.4
125	95.4	95.4
150	95.8	95.8
200	95.8	95.8

\*Minimum efficiencies as per NEMA MG-1-1998, Rev 2, Table 12-12 for "Premium™ Efficient" motors.

- G. Refer to various Sections of this Division for special requirements for specific items of equipment requiring motors and for any other special requirements such as variable speed, multiple windings/speeds, reduced voltage starting, etc. Motors used in conjunction with variable speed drives shall be compatible with the drive and rated for inverter output duty. Inverter rated motors used in conjunction with variable speed drives shall be equipped with a set of shaft grounding bushings.

### 2.3 MOTOR CONTROLLERS

- A. In general, motor controllers for all motors will be furnished and installed under Division 26 unless indicated or specified otherwise. Any motor controller that is an integral part of a piece of equipment and all variable speed motor controllers shall be furnished under this Division and shall be in accordance with the following specifications.
- B. All motor controllers shall be UL and/or ETL listed. The motor controllers shall be steel mounted and front wired with all terminals accessible for wiring directly from the front. No slate or ebony asbestos shall be permitted on any size controller from Size 00 through Size 8. All contacts shall be solid silver cadmium oxide alloy, which will not require any filing, dressing or cleaning throughout the life of the control equipment. Bare copper or silver flashed type shall not be permitted. Operating coils shall be pressure molded and so designed that if accidentally connected to excessive voltage they will not expand, bubble, or melt. When a coil fails under over voltage conditions, the motor controller shall definitely drop out and not freeze the contacts in the "ON" position. All internal wiring in the motor controller shall be copper. See Section 26 05 19 titled "Electrical Conductors – 600 Volts" in Division 26 for termination requirements and space in the housing.
- C. All three (3) phase full voltage magnetic motor controllers shall have overload protection in all three (3) phases. All single phase full voltage magnetic motor controllers shall have overload protection in both phases. All two (2) speed full voltage magnetic motor controllers shall have overload protection in all six (6) legs of the controller. Overload relays shall be furnished for each phase and shall be of the hand reset, trip free variety so that blocking the reset mechanism in the reset position will not prevent the starter from dropping out if the motor is overloaded. This specifically excludes those overload relays, which change to automatic reset from hand reset when the reset mechanism is blocked unless the automatic reset feature can be removed or voided. Accidentally depressing the reset button or mechanism shall not shut off the motor. Overload relays shall not be field convertible from hand to automatic reset type.
- D. Motor Controllers shall be provided with auxiliary dry contacts as follows:
1. NEMA size 3 and larger: two (2) N.O. and two (2) N.C.
  2. NEMA size 2: two (2) N.O. and one (1) N.C.
  3. NEMA size 1 and 0: one (1) N.O. and one (1) N.C.
- Where required for interface with the Division 25 Building Control System, all motor controllers shall be provided with a separate box enclosure with a terminal strip and relays wired to the controller. Terminal strip requirements and relays shall be coordinated with Division 25 and with Division 28. Terminal strip and relay requirements generally are as follows:

- 4. Motor controllers controlled by Division 25, status indication by Division 25, and operation and status by the Fireman's Override Panel. Requirements are:
    - a. Terminal Strip (16 points minimum):
      - 1) Auxiliary contacts:
        - a) Eight (8) points for Auxiliary contacts.
        - b) Four (4) points for control of fireman's override relays.
      - 2) External safety controls:
        - a) Two (2) points for safety control wiring and adjustable freezestats, etc.
      - 3) Through "Auto" position of "HOA" (no "Off" position):
        - a) Two (2) points through auto position for automatic start.
    - b. Provide two relays that will operate from the Fireman's Override panel and provide operation as specified. Relays shall be G.E. CR120E01102.
    - c. Most air handling units will have this control.
  - 5. Motor controllers controlled by Division 25 with no status, and no operation or status from Fireman's Override Panel. Requirements are:
    - a. Terminal Strip (2 points minimum):
      - 1) Through "Auto" position of "HOA" (no "Off" position):
        - a) Two (2) points through auto position for automatic start.
    - b. Miscellaneous ventilation fans have this control.
  - 6. Motor controllers controlled by Division 25, status indication by Division 25, but no operation or status from Fireman's Override Panel Requirements are:
    - a. Terminal Strip (12 points minimum):
      - 1) Auxiliary contacts:
        - a) Eight (8) points for Auxiliary contacts.
      - 2) External safety controls:
        - a) Two (2) points for safety control wiring and adjustable freezestats, etc.
      - 3) Through "Auto" position of "HOA" (no "Off" position):
        - a) Two (2) points through auto position for automatic start.
    - b. Generally pumps, etc., have this control.
- E. Any full voltage magnetic motor controller to be furnished under this Division shall be similar and approved equal to Allen-Bradley Bulletin Numbers as follows:
- 1. Individual three (3) phase motor controller ..... AB Bul. 509.
  - 2. Individual single phase motor controller ..... AB Bul. 509SP.
  - 3. Combination three (3) phase motor controller with circuit breaker..... AB Bul. 513.
  - 4. Combination three (3) phase motor controller with non-fused switch ..... AB Bul. 512.
  - 5. Combination three (3) phase, two (2) speed, single winding motor controller with circuit breaker ..... AB Bul. 523F.
  - 6. Combination three (3) phase, two (2) speed, two (2) winding motor controller with circuit breaker ..... AB Bul. 523E.
- F. In general, motor controller enclosures shall be NEMA Type 1 general purpose unless exposed to the weather or otherwise indicated on the Drawings. Any motor controller exposed to the weather shall have NEMA Type 4X water tight, dust tight, corrosion resistant, stainless steel or fiber glass enclosures.
- G. Generally, holding coils in full voltage magnetic motor controllers shall be suitable for use on 120V, AC control voltage. Each controller shall have a control transformer with primary and secondary fuses. Control power transformer shall have 75 VA capacity over and above the standard capacity required for holding coil and LED pilot light duty. Sizing of control power transformers shall be coordinated with the Division 25 Subcontractor.
- H. Two (2) speed motor controllers for two (2) speed motors shall have "decelerating relay" between high and low speeds.
- I. Motor controllers shall be provided with accessories such as H.O.A.'s, selector switches, LED neon pilot lights, etc. All internal wiring shall be copper.
- J. Each motor controller shall be equipped with a 120V red running LED or neon pilot light, control transformer, auxiliary contacts and a hand-off-automatic switch. Two (2) speed motor controllers shall have "fast-slow" LED or neon lights as well as a fast-slow selector switch in conjunction with the H.O.A. Controllers for sump

pumps and sewage ejectors shall have "test" position in lieu of "hand" position. Neon or LED pilot lights will be operated by an interlock on the motor controller not placed across the operating coil. In addition to the "holding interlock and LED light interlocks", each controller shall have four extra interlock contacts - two (2) normally open and two (2) normally closed.

- K. Manual motor controllers where indicated on the Drawings, required and/or specified shall be similar and approved equal to Allen-Bradley Bul. 600 in NEMA Type 1 enclosure or as otherwise required for the location of the installation.

## 2.4 VARIABLE SPEED DRIVE CONTROLLERS

- A. A variable speed drive shall be provided by the Plumbing Subcontractor for pumps and/or as required in the schedules on the Contract Documents. Variable speed drives shall be mounted and installed by Division 26 unless they are an integral part of the equipment provided by the Division 22 Plumbing Subcontractor.
  - 1. Inverter duty motors and variable speed drives ("VSD") shall be provided by Division 22. Pump manufacturer shall certify in writing that the pump motors and VSD operate together as a system, fully compatible and without excessive noise or vibration. See Section 22 00 10 for certification requirements. Each VSD shall be commissioned and adjusted at the Project Site by a factory technician.
  - 2. The 1 through 100 HP, 460V AC VSD shall be a pulse width modulated (PWM) design that operates directly from three (3) phase, 460V AC  $\pm 10\%$ , 60 hertz utility power. The VSD shall generate a sine-coded, adjustable voltage/frequency three (3) phase output for complete speed control of any squirrel cage induction motor. The VSD shall maintain a one hundred and ten (110%) percent current overload capability for sixty (60) seconds with automatic stall prevention and voltage boost to prevent nuisance tripping during load or line side transient conditions. Provide an input line reactor or tuned line filter, adjusted as required, to minimize any electrical distortion back into the building electrical power supply system to less than three (3%) percent in accordance with IEEE Standard 519-1992 limits. The VSD shall maintain a power factor of not less than 0.95 throughout its speed range.
  - 3. The VSD shall have the following basic design:
    - a. Converter: Converter shall consist of a modularized diode rectifier and capacitor assembly, which will first convert, then filter and maintain a fixed DC voltage source from the fixed voltage and frequency input.
    - b. Inverter: Inverter uses IGBT semiconductors with a minimum rating of 1100V ac on 460V ac controls to invert the converter generator fixed dc voltage into a sine coded pulse width modulated output.
    - c. Control Logic: Consists of a single printed circuit board and incorporates a eight (8) bit or larger, microcomputer central processing unit to control all inverter, converter, base drive and external interface functions.
    - d. Terminal strip for interface with the Division 25 Building Management and Control System.
    - e. Enclosure: A single NEMA 12 enclosure to house the drive, three (3) contractor manual bypass (if specified herein) and all accessories.
    - f. All internal wiring within the variable speed drive shall be copper.
  - 4. The VSD shall have, as a minimum, the following design features as standard:
    - a. Sine coded, pulse width modulated output.
    - b. Eight (8) bit or larger, microcomputer control logic.
    - c. Maximum and minimum speed adjustment capability.
    - d. Controlled speed range of 20:1 or greater.
    - e. Overload capability of ten (10%) percent for sixty (60) seconds.
    - f. Process follower 4-20mA or 1-10V dc input.
    - g. Minimum of three (3) selectable output frequency ranges.
    - h. Minimum fifteen (15) selectable Volts/hertz patterns.
    - i. Touch pad operator controls or adjustable potentiometer with at least four (4) segment digital frequency/speedometer or digital readout displaying at a minimum: output frequency, output current and status.
    - j. Incoming electrical power disconnect/circuit breaker with through door handle.
    - k. Torque or current limiting circuit.
    - l. Coast or ramp to stop.
    - m. Adjustable acceleration and deceleration.
    - n. Fault indicators.
    - o. Proportion Integral (PI) Setpoint Controller.

- p. Provide a Modbus communication interface card at each VSD. The software communications interface shall be set up so as to provide, at minimum, the following monitoring and control points to the BMCS:
- 1) Speed reference feedback.
  - 2) Motor operating status.
  - 3) Fault diagnostics.
  - 4) Metered points:
    - a) Motor power in HP.
    - b) Motor power in kW.
    - c) Motor kWh.
    - d) Motor current.
    - e) Motor voltage.
    - f) Hours run.
    - g) DC link voltage.
    - h) Thermal load on motor.
    - i) Thermal load on VFD.
    - j) Heatsink temperature.
- q. Provide interfaces with Division 25 BMCS system as follows:
- 1) Pump start/stop: 24V DC contact.
  - 2) Pump run status: 24V DC contact.
  - 3) Speed signal input: 4 to 20mA or 0-10V DC.
- r. Provide pressure signal input for domestic water pumping systems.
5. The VSD shall have, as a minimum, the following protective features:
- a. Ground fault protection.
  - b. Electronic thermal motor overload or current limit control.
  - c. Current limited stall prevention during acceleration, deceleration and run conditions.
  - d. Automatic restart after momentary power loss or momentary over-voltage. No restart into ground fault.
  - e. Controls for start into a rotating motor.
  - f. Anti-windmill protection.
  - g. Fault indicators shall indicate the following fault conditions:
    - 1) Over current/overload.
    - 2) Over voltage.
    - 3) Over temperature.
    - 4) Control function error.
  - h. DC bus discharge indicator.
  - i. Current limiting DC bus fuse.
  - j. Isolated operator controls.
  - k. Phase-to-phase short circuit protection.
  - l. Heat sink over temperature protection.
6. The VSD shall have the following adjustments available:
- a. Acceleration - 0.2 to 1800 seconds or 0.1 to 300 seconds.
  - b. Deceleration - 0.2 to 1800 seconds or 0.1 to 300 seconds.
  - c. Volts/hertz adjustments.
  - d. Minimum frequency.
  - e. Maximum frequency.
  - f. Carrier frequency.
  - g. Torque limit.
  - h. Input line reactors or tuned line filters shall be provided by the inverter manufacturer to limit interference from the line to the drive and to limit any electrical distortion back to the building electrical power supply system in accordance with the recommendations of IEEE Standard 519-1992 to less than three (3%) percent. The filter or reactor assembly shall be mounted integral with the VSD or in a separate enclosure adjacent to the VSD if the manufacturer provides the field wiring. Coordinate installation requirements with Division 26.
  - i. A signal isolator shall be provided to isolate the control signal to and from the inverter drive.
7. The VSD shall be designed to operate within the following environmental and service conditions:
- a. Ambient service temperature - 10°C (50°F) to 40°C (104°F).
  - b. Ambient storage temperature - 20°C (68°F) to 60°C (140°F).
  - c. Humidity - non-condensing to ninety (90%) percent.
  - d. Altitude to 3300'.
  - e. Service factor - 1.0.

- f. Input voltage - three (3) phase, 460V AC  $\pm 10\%$ .
- g. Input frequency - 50/60 hertz  $\pm 2$  hertz.
- 8. The VSD shall be subject to the following parameters and tests:
  - a. All integrated circuits (TTL) and all components used for circuit board construction shall be tested to an acceptance criteria of 0.5% AQL (Accepted Quality Level).
  - b. In circuit testing of all printed circuit boards shall be conducted to insure proper mounting and correct value of all components.
  - c. All printed circuit boards shall be burned in for at least twenty-four (24) hours, at a minimum of 70°C and temperature cycled.
  - d. Final printed circuit board assemblies shall be functionally tested via computerized test equipment where all tests and acceptance criteria are preprogrammed and test results are stored as detailed quality assurance data. The Engineer and Owner may witness the factory tests. The Division 22 Subcontractor shall give the Engineer and Owner at least two (2) weeks written notice prior to start of the factory test.
  - e. All fully assembled controls shall be combine tested for performance and functionality at the manufacturer's factory with fully loaded VAV rated induction motors. The combined test data shall then be analyzed to insure adherence to quality assurance specifications.
- 9. The VSD shall be designed and built to the following standards:
  - a. ETL and/or UL.
  - b. NEMA - ICS-3-303.
  - c. IEEE STD 444 (ANSI C34.3).
  - d. IEEE STD 519-1992.
- 10. The VSD shall be provided with the following features:
  - a. One (1) door interlocked main power input disconnect to provide positive shutdown of all input power to the drive.
  - b. The complete input disconnect , overload relay package and line reactor or tuned line filter shall be mounted in the inverter cabinet or may be installed in a separate enclosure adjacent to the inverter. Coordinate installation requirements with each Division 26 Subcontractor.
  - c. Capacitor shall be sized based on the VSD design and the two (2) second ride through as required. The capacitor, which shall provide assistance to maintain the DC bus voltage for a two (2) second momentary power loss or furnish automatic restart capability, which allows restart into a rotating motor in both forward and reverse rotation.
  - d. Three (3) contactor mechanical manual by-pass circuit to manually by-pass the drive and transfer control of the motor across-the-line, running the motor at full speed with motor protected by breaker and overload relay.
  - e. Where there are at least eight (8) variable speed drives of same frame size drive, provide to the Owner one (1) set of spare parts or one (1) complete spare drive for each frame size consisting of the following unless otherwise specified in the various sections of this Specification:
    - 1) Control fuses.
    - 2) Control board.
    - 3) Drive board.
    - 4) Transistors.
    - 5) Capacitors.

### **PART 3 EXECUTION**

#### **3.1 INSTALLATION**

- A. Motor and controller installation shall be in accordance with the manufacturer's recommendations and as indicated on the Drawings. Align pulleys and install all belts at proper tension to minimize wear on belts and drives.
- B. Variable speed drive installation shall be in accordance with the manufacturer's recommendations and as indicated on the Drawings. Input power, output power, and Division 25 BMCS control wiring shall be installed in separate conduits per manufacturer's recommendations.

#### **3.2 FACTORY TESTING**

- A. All standard factory tests shall be performed in accordance with the latest version of NEMA and UL Standards.



**3.3 FIELD TESTING**

- A. Refer to Section 22 05 93 for additional testing requirements motors and controllers.

**END OF SECTION**