SECTION 262923 - VARIABLE-FREQUENCY MOTOR CONTROLLERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

See "Sustainable Design Considerations" Article in the Evaluations for a discussion of sustainable design requirements that may impact the editing of this Section.

1. GENERAL
   * + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
      1. SUMMARY

This Section is limited to separately enclosed, preassembled, combination VFCs furnished by a VFC manufacturer; it does not include panel-mounted variable-frequency drives intended to be field installed in separate enclosures by contractors or incorporated into machinery or processes as part of a packaged system. The Section Text does not include VFCs for constant-horsepower loads because they are seldom used in commercial (e.g., plumbing and HVAC) applications; however, they can be added to suit Project.

* + - * 1. Section includes separately enclosed, preassembled, combination VFCs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.
      1. DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

* + - * 1. CPT: Control power transformer.
        2. DDC: Direct digital control.
        3. EMI: Electromagnetic interference.
        4. LED: Light-emitting diode.
        5. NC: Normally closed.
        6. NO: Normally open.
        7. OCPD: Overcurrent protective device.
        8. PID: Control action, proportional plus integral plus derivative.
        9. RFI: Radio-frequency interference.
        10. VFC: Variable-frequency motor controller.
      1. SUBMITTALS
         1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.
         2. Manufacturer’s installation instructions shall be provided along with product data.
         3. Submittals shall be provided in the order in which they are specified and tabbed (for combined submittals).
         4. Product Data: For each type and rating of VFC indicated.

Include dimensions and finishes for VFCs.

Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

* + - * 1. Shop Drawings: For each VFC indicated.

Include mounting and attachment details.

Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

Include diagrams for power, signal, and control wiring.

* + - * 1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.

Retain "Coordination Drawings" paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

* + - * 1. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Required working clearances and required area above and around VFCs.

Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements.

Show support locations, type of support, and weight on each support.

Indicate field measurements.

Coordinate "Qualification Data" paragraph below with qualification requirements and as may be supplemented in "Quality Assurance" Article.

* + - * 1. Qualification Data: For testing agency.

Retain "Seismic Qualification Data" paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 260548.16 "Seismic Controls for Electrical Systems." See ASCE/SEI 7 for certification requirements for equipment and components.

* + - * 1. Seismic Qualification Data: Certificates, for each VFC, accessories, and components, from manufacturer.

Certificate of compliance.

Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.

Retain "Product Certificates" paragraph below to require submittal of product certificates from manufacturers.

* + - * 1. Product Certificates: For each VFC from manufacturer.

Retain "Harmonic Analysis Report" paragraph below if an analysis is required from VFC manufacturer. See "Harmonic Distortion" Article in the Evaluations and the Drawing Coordination Checklist for additional information.

* + - * 1. Harmonic Analysis Report: Provide Project-specific calculations and manufacturer's statement of compliance with IEEE 519.
        2. Source quality-control reports.

Retain "Field quality-control reports" paragraph below if Contractor is responsible for field quality-control testing and inspecting.

* + - * 1. Field quality-control reports.
        2. Sample Warranty: For special warranty.
      1. CLOSEOUT SUBMITTALS
         1. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals.

Retain first subparagraph below if circuit breakers are specified in VFCs; retain second if field-adjustable overload relays are specified.

Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings.

Manufacturer's written instructions for setting field-adjustable overload relays.

Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.

Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

Retain one or both subparagraphs below for projects with multiple sizes and types of VFCs, and when retaining motor-running overload protection in "Bypass Systems" Article. See Evaluations for discussion.

Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.

Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

* + - 1. MAINTENANCE MATERIAL SUBMITTALS

Revise this article to include extra materials that Owner may require and that may fail more frequently due to continual use. Coordinate extra materials with features retained in Part 2.

Coordinate quantity of fuses with Section 262813 "Fuses" for required space in spare-fuse cabinet.

Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Power Fuses: Equal to [**10**] <**Insert number**> percent of quantity installed for each size and type, but no fewer than [**three**] <**Insert number**> of each size and type.

Control Power Fuses: Equal to [**10**] <**Insert number**> percent of quantity installed for each size and type, but no fewer than [**two**] <**Insert number**> of each size and type.

Indicating Lights: [**Two**] <**Insert number**> of each type and color installed.

Auxiliary Contacts: Furnish [**one**] <**Insert number**> spare(s) for each size and type of magnetic controller installed.

Power Contacts: Furnish [**three**] <**Insert number**> spares for each size and type of magnetic contactor installed.

<**Insert extra materials**>.

* + - 1. QUALITY ASSURANCE

Retain "Testing Agency Qualifications" paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article.

* + - * 1. Testing Agency Qualifications: Accredited by NETA.

Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

* + - * 1. Equipment Qualifications For Products Other Than Those Specified:

At the time of submission provide written notice to the Director of the intent to propose an “or equal” for products other than those specified. Make the “or equal” submission in a timely manner to allow the Director sufficient time to review the proposed product, perform inspections and witness test demonstrations.

If products other than those specified are proposed for use furnish the name, address, and telephone numbers of at least 5 comparable installations that can prove the proposed products have performed satisfactorily for 3 years. Certify in writing that the Director’s Representative of the 5 comparable installations will allow inspection of their installation by the Director's Representative and the Company Field Advisor.

Make arrangements with the Director’s Representative of 2 installations (selected by the Director) for inspection of the installations by the Director's Representative. Also obtain the services of the Company Field Advisor for the proposed products to be present. Notify the Director a minimum of 3 weeks prior to the availability of the installations for the inspection, and provide at least one alternative date for each inspection.

Only references from the actual Director or Director’s Representative (Security Supervisor, Maintenance Supervisor, etc.) will be accepted. References from dealers, system installers or others, who are not the actual Director’s Representative of the proposed products, are not acceptable.

Verify the accuracy of all references submitted prior to submission and certify in writing that the accuracy of the information has been confirmed.

The product manufacturer shall have test facilities available that can demonstrate that the proposed products meet the contract requirements.

Make arrangements with the test facility for the Director's Representative to witness test demonstrations. Also obtain the services of the Company Field Advisor for the proposed product to be present at the test facility. Notify the Director a minimum of 3 weeks prior to the availability of the test facility, and provide at least one alternative date for the testing.

Provide written certification from the manufacturer that the proposed products are compatible for use with all other equipment proposed for use for this system and meet all contract requirements.

* + - * 1. Harmonic Analysis:

The adjustable speed motor controller manufacturer shall perform a harmonic current magnitude and voltage distortion analysis and provide certified calculations specific to this installation, showing that the total harmonic distortion caused by the adjustable speed motor controller will be below the specified level. The analysis shall be accordance with IEEE 519.

Use subparagraph below for new electrical system.

The results shall be based on a computer aided/modeled circuit simulation of the actual system, based upon the materials and equipment proposed to be furnished and installed.

Use subparagraph below for existing electrical system.

The results shall be based on a computer aided/model circuit from the controller to the distribution transformer supplying the controller, based upon the materials and equipment proposed to be furnished and installed, and associated portions of the existing electrical system.

Basic parameters relative to the existing system are specified herein. Additional information deemed necessary by the controller manufacturer to provide a certified harmonic analysis report shall be obtained by a field investigation of the existing system, at no additional cost to the State.

Edit number of hours to suit.

* + - * 1. Company Field Advisor: Secure the services of a Company Field Advisor from the Company providing the solid state controllers and the adjustable speed controllers for a minimum of 8 working hours for the following:

Render advice regarding installation, programming, final adjustment, and testing.

Witness final system test and then certify with an affidavit that the motor controllers are installed in accordance with the contract documents and are operating properly.

Train facility personnel on the operation and maintenance of the motor controllers (minimum of two 1 hour sessions).

Explain available service programs to facility supervisory personnel for their consideration.

* + - * 1. Service Availability: A fully equipped service organization shall be available to service the completed Work.
      1. DELIVERY, STORAGE, AND HANDLING

Retain first option in first paragraph below for controllers that are not required to have factory-installed space heaters; otherwise, retain second option.

* + - * 1. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and [**install temporary electric heating, with at least 250 W per controller**] [**connect factory-installed space heaters to temporary electrical service**].

Dimensions of VFCs, especially those with bypass systems, specialty enclosures, or various options, can vary considerably in size between manufacturers. Retain "Product Selection for Restricted Space" paragraph below with "Basis-of-Design Product" paragraph in "Manufacturers" Article if installation space for VFCs is limited; show maximum dimensions on Drawings. See "Installation Considerations" and "Large Equipment" articles in the Evaluations for additional guidance.

* + - * 1. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.
      1. WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

* + - * 1. Special Warranty: Manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

Warranty Period: [**Five**] <**Insert number**> years from date of Substantial Completion.

1. PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Deltek. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications.

* + - 1. MANUFACTURERS

* + - * 1. [Manufacturers:](http://www.specagent.com/Lookup?ulid=2177) Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

[Eaton](http://www.specagent.com/Lookup?uid=123457141441).

[Schneider Electric USA, Inc](http://www.specagent.com/Lookup?uid=123457141444).

[Siemens Industry, Inc. (Building Technologies Division)](http://www.specagent.com/Lookup?uid=123457141450).

Or equal.

* + - 1. SYSTEM DESCRIPTION

Show VFC pole quantities, voltage, accessories, size and type, short-circuit current (withstand) rating (or available short-circuit currents), and enclosure type for each controller on Drawings. See "Specifying VFCs" Article and Editing Instruction No. 9 in the Evaluations for selection considerations.

Standard and optional features vary considerably among VFC manufacturers. Not all features, accessories, and options in this article are available for every rating, with every type of enclosure, and from every listed manufacturer. Also, features and options depend on motor characteristics and operating criteria of driven equipment. Verify, with manufacturer, availability and unique characteristics. Show on Drawings the features and accessories that apply to each VFC.

* + - * 1. General Requirements for VFCs:

VFCs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

In first subparagraph below, retain UL 508A for VFCs with UL-recognized components or retain UL 508C when the packaged enclosed controller is tested. For additional details on this selection, see Editing Instruction No. 10 in the Evaluations.

Comply with NEMA ICS 7, NEMA ICS 61800-2, and [**UL 508A**] [**UL 508C**] <**Insert standard**>.

Retain first option in "Application" paragraph below for constant-torque loads such as positive-displacement pumps and reciprocating and screw compressors; retain second option for variable-torque loads such as centrifugal blowers, compressors, fans, and pumps.

* + - * 1. Application: [**Constant torque**] [**and**] [**variable torque**] <**Insert application**>.

Low-voltage VFCs are available for use with three-phase ac motors from 1/2 to 500 hp (depending on voltage rating), and in single- or three-phase input voltages from 200- to 575-V ac; however, not all listed manufacturers may offer VFCs in all these ratings and voltage ranges. Using single-phase voltages for VFCs controlling three-phase motors may require substantial derating of the VFCs; consult manufacturers for limitations and derating requirements.

* + - * 1. VFC Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

Retain one or both of first two subparagraphs below as required to support motors and driven equipment specified in other Divisions. See "Multispeed and Variable-Speed Considerations" Article in the Evaluations in Section 230513 "Common Motor Requirements for HVAC Equipment," for guidance on motor requirements and applications using VFCs. There are similar discussions in the Evaluations of the common motor requirement Sections in Divisions 11, 21, and 22.

Units suitable for operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."

Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."

Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

* + - * 1. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

Retain first option in "Output Rating" paragraph below for variable-torque drives; retain second option for constant-torque drives.

* + - * 1. Output Rating: Three phase; 10 to [**60 Hz, with voltage proportional to frequency throughout voltage range**] [**66 Hz, with torque constant as speed changes**]; maximum voltage equals input voltage.
        2. Unit Operating Requirements:

Technology advances are allowing manufacture of VFCs with greater tolerance to system anomalies and better operating performance. Most listed manufacturers offer VFCs that tolerate the greater optional variances, or they offer the higher levels of performance included in subparagraphs below. Consult manufacturers if Project system conditions fall outside the selected parameters in first three subparagraphs because corrective actions or additional modifications may be required before VFCs can be applied. In "Input AC Voltage Tolerance" Subparagraph below, voltage tolerance is more a factor of voltage limitations for industrial control devices (e.g., magnetic contactors) in an enclosed VFC and not the VFC's power converter, which can usually tolerate greater voltage variations.

Input AC Voltage Tolerance: Plus 10 and minus [**10**] [**15**] percent of VFC input voltage rating.

Input AC Voltage Unbalance: Not exceeding [**3**] [**5**] percent.

Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.

Minimum Efficiency: [**96**] [**97**] <**Insert number**> percent at 60 Hz, full load.

Minimum Displacement Primary-Side Power Factor: [**96**] [**98**] <**Insert number**> percent under any load or speed condition.

Retain "Minimum Short-Circuit Current (Withstand) Rating" Subparagraph below if all VFCs on a Project are required to have the same short-circuit current rating. Delete subparagraph if short-circuit ratings vary for individual VFCs, and indicate the ratings on Drawings.

Minimum Short-Circuit Current (Withstand) Rating: [**10**] [**22**] [**65**] [**100**] <**Insert value**> kA.

The conditions listed in ambient temperature humidity and altitude rating subparagraphs below are typical manufacturers' and industry standards for using VFC without de-rating or special enclosures and accessories. See Editing Instruction No. 2 in the Evaluations. For additional ambient compensation requirements for fuses, circuit breakers, and overload relays, see Editing Instructions No. 4, No. 5, and No. 7 in the Evaluations.

Ambient Temperature Rating: Not less than 32 deg F and not exceeding 104 deg F.

Humidity Rating: Less than 95 percent (noncondensing).

Altitude Rating: Not exceeding 3300 feet.

Retain "Vibration Withstand" Subparagraph below if VFCs are likely to be installed on vibrating equipment such as a built-up air-handling unit or skid-mounted pump assembly.

Vibration Withstand: Comply with NEMA ICS 61800-2.

Retain first option in "Overload Capability" Subparagraph below for variable-torque VFCs; retain second option for constant-torque VFCs.

Overload Capability: [**1.1**] [**1.5**] times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.

Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.

Speed Regulation: Plus or minus [**5**] [**10**] percent.

Carrier frequencies above 2.5 kHz are seldom desired for motors more than 200 hp due to the increased possibility of overheating the motor windings. For large-horsepower motors being used with VFCs, consult motor manufacturers for recommended limitations on carrier frequencies to mitigate motor winding overtemperatures.

Output Carrier Frequency: Selectable; 0.5 to [**15**] <**insert number**> kHz.

Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

* + - * 1. Inverter Logic: Microprocessor based, [**16**] [**32**] bit, isolated from all power circuits.
        2. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

Retain one of two options in "Signal" Subparagraph below if retaining "Isolated Control Interface" paragraph above. Coordinate retained option with selections made in "Control Signal Interfaces" paragraph in "Controls and Indication" Article.

Signal: [**Electrical**] [**Pneumatic**].

* + - * 1. Internal Adjustability Capabilities:

Minimum Speed: 5 to 25 percent of maximum rpm.

Maximum Speed: 80 to 100 percent of maximum rpm.

Acceleration: [**0.1 to 999.9**] <**Insert range**> seconds.

Deceleration: [**0.1 to 999.9**] <**Insert range**> seconds.

Current Limit: 30 to minimum of 150 percent of maximum rating.

<**Insert adjustment and parameters**>.

* + - * 1. Self-Protection and Reliability Features:

Coordinate Project-specific self-protection and reliability features with manufacturers, because standard and optional features vary considerably among manufacturers.

Retain one of two "Surge Suppression" subparagraphs below. Be consistent when selecting field-mounted or integral SPDs throughout Project.

Surge Suppression: Factory installed as an integral part of the VFC, complying with UL 1449 SPD, Type 1 or Type 2.

Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.

Under- and overvoltage trips.

Inverter overcurrent trips.

VFC and Motor-Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor-overload alarm and trip; settings selectable via the keypad.

Critical frequency rejection, with [**three**] <**Insert number**> selectable, adjustable deadbands.

Instantaneous line-to-line and line-to-ground overcurrent trips.

Loss-of-phase protection.

Reverse-phase protection.

Short-circuit protection.

Motor-overtemperature fault.

<**Insert protection or reliability feature**>.

"Automatic Reset/Restart" and "Power-Interruption Protection" paragraphs below are mutually exclusive in the same VFC. Retain both paragraphs if required for separate VFCs, and indicate on Drawings where each type is required.

* + - * 1. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
        2. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

Retain "Bidirectional Autospeed Search" paragraph below if retaining "Automatic Reset/Restart" paragraph above, field-selectable automatic and manual "Bypass Mode" paragraph in "Bypass Systems" Article, or both.

* + - * 1. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
        2. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
        3. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

Not all manufacturers offer all options in "Integral Input Disconnecting Means and OCPD" paragraph below. Coordinate with **manufacturers for available options. Coordinate selection of the disconnecting means and OCPD with short-circuit current (withstand) ratings required for Project. See "Application of Switches and Circuit Breakers"** Article and Editing Instructions No. 3, No. 4, No. 5, and No. 8 in the Evaluations for selection considerations.

* + - * 1. Integral Input Disconnecting Means and OCPD: [**UL 489, instantaneous-trip circuit breaker**] [**UL 489, molded-case switch, with power fuse block and current-limiting fuses**] [**UL 489, thermal-magnetic circuit breaker**] [**NEMA KS 1, nonfusible switch, with power fuse block and current-limiting fuses**] [**NEMA KS 1, fusible switch**] with pad-lockable, door-mounted handle mechanism.

Retain first "Disconnect Rating" Subparagraph below for VFCs without bypass systems; retain second for VFCs with bypass systems.

Disconnect Rating: Not less than 115 percent of VFC input current rating.

Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.

Retain "Auxiliary Contacts" Subparagraph below if retaining fusible or nonfusible switches in "Integral Input Disconnecting Means and OCPD" paragraph above and using external control power; or, use for remote indication of disconnecting means position.

Auxiliary Contacts: NO or NC, arranged to activate before switch blades open.

Retain one of or both subparagraphs below if retaining any circuit-breaker-type disconnecting means in "Integral Input Disconnecting Means and OCPD" paragraph above. Retain first subparagraph if using external control power or for remote indication of disconnecting means position. Retain second subparagraph for remote indication of tripped condition. If retaining auxiliary and alarm contacts, indicate "a" and "b" contact quantities and NO or NC contact requirements on Drawings.

Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.

[**NC**] [**NO**] alarm contact that operates only when circuit breaker has tripped.

* + - 1. PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" paragraph below with "Seismic Qualification Certificates" paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

* + - * 1. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7. The designated VFCs shall be tested and certified by an NRTL as meeting the ICC-ES AC 156 test procedure requirements.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

* + - 1. CONTROLS AND INDICATION

Coordinate local control and indication requirements with Owner or end users. Most of the indications included in "Status Lights" paragraph below can be and are accomplished by listed manufacturers through digital displays in their panel-mounted operator stations. However, many operators still prefer the ability to "pass and glance" to determine the status of operating machinery or equipment.

* + - * 1. Status Lights: Door-mounted LED indicators displaying the following conditions:

Power on.

Run.

Overvoltage.

Line fault.

Overcurrent.

External fault.

<**Insert condition**>.

* + - * 1. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.

Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.

* + - * 1. Historical Logging Information and Displays:

Retain first subparagraph below if time and date stamping is not accomplished through the DDC system for HVAC. Several listed manufacturers treat this feature as an added-cost option.

Real-time clock with current time and date.

Running log of total power versus time.

Total run time.

Fault log, maintaining last [**four**] <**Insert number**> faults with time and date stamp for each.

<**Insert information or display**>.

* + - * 1. Indicating Devices: Digital display[**and additional readout devices as required,**] mounted flush in VFC door and connected to display VFC parameters including, but not limited to:

Output frequency (Hz).

Motor speed (rpm).

Motor status (running, stop, fault).

Motor current (amperes).

Motor torque (percent).

Fault or alarming status (code).

PID feedback signal (percent).

DC-link voltage (V dc).

Set point frequency (Hz).

Motor output voltage (V ac).

<**Insert parameter**>.

Coordinate "Control Signal Interfaces," "PID Control Interface," and "Interface with DDC System for HVAC" paragraphs below with Section 230923 "Direct Digital Control (DDC) System for HVAC." Retain paragraphs to suit Project. If retaining more than one paragraph, indicate here or on Drawings where each interface type is required.

* + - * 1. Control Signal Interfaces:

Electric Input Signal Interface:

In first subparagraph below, some manufacturers offer an operator-selectable "x"- to "y"-mA dc signal input.

A minimum of [**two**] <**Insert number**> programmable analog inputs: [**0- to 10-V dc**] [**4- to 20-mA dc**] [**Operator-selectable "x"- to "y"-mA dc**] <**Insert signal parameters**>.

A minimum of [**six**] <**Insert number**> multifunction programmable digital inputs.

Retain "Pneumatic Input Signal Interface" Subparagraph below only if Project includes pneumatic controls in Division 23. Several listed manufacturers now treat this feature as an added-cost option because it is so infrequently used anymore.

Pneumatic Input Signal Interface: 3 to 15 psig.

Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the DDC system for HVAC or other control systems:

0- to 10-V dc.

4- to 20-mA dc.

Potentiometer using up/down digital inputs.

Fixed frequencies using digital inputs.

<**Insert signal input**>.

Output Signal Interface: A minimum of [**one**] <**Insert number**> programmable analog output signal(s) ([**0- to 10-V dc**] [**4- to 20-mA dc**] [**operator-selectable "x"- to "y"-mA dc**] <**Insert signal parameters**>), which can be configured for any of the following:

Output frequency (Hz).

Output current (load).

DC-link voltage (V dc).

Motor torque (percent).

Motor speed (rpm).

Set point frequency (Hz).

<**Insert indication**>.

Remote Indication Interface: A minimum of [**two**] <**Insert number**> programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

Motor running.

Set point speed reached.

Fault and warning indication (overtemperature or overcurrent).

PID high- or low-speed limits reached.

<**Insert indication**>.

Retain "PID Control Interface" paragraph below if VFC controls interface directly with local controls and not through a DDC system for HVAC.

* + - * 1. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.

Number of Loops: [**One**] [**Two**] <**Insert number**>.

Retain "Interface with DDC System for HVAC" paragraph below if VFC controls interface with the DDC system for HVAC.

* + - * 1. Interface with DDC System for HVAC: Factory-installed hardware and software shall interface with DDC system for HVAC to monitor, control, display, and record data for use in processing reports. VFC settings shall be retained within VFC's nonvolatile memory.

Retain "Hardwired Points" or "Communication Interface" Subparagraph below. Retain "Hardwired Points" Subparagraph if interface with the DDC system for HVAC is through hardwired points and minimal interface is required. Retain "Communication Interface" Subparagraph if extensive interface with the DDC system for HVAC is required and is beyond what hardwired points can provide. Requirement may exclude some manufacturers.

Hardwired Points:

Monitoring: On-off status, <**Insert monitoring point**>.

Control: On-off operation, <**Insert control point**>.

Communication Interface: Comply with [**ASHRAE 135**] <**Insert type of interface**>. Communication shall interface with DDC system for HVAC to remotely control and monitor lighting from a DDC system for HVAC operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the DDC system for HVAC.

* + - 1. LINE CONDITIONING AND FILTERING

If input current distortion due to harmonic generation in VFCs is a concern, retain "Input Line Conditioning" paragraph below, and retain "Harmonic Analysis Report" paragraph in "Informational Submittals" Article. See "Harmonic Distortion" Article in the Evaluations for additional guidance.

* + - * 1. Input Line Conditioning: Based on the manufacturer's harmonic analysis study and report, provide input filtering, as required, to limit total demand (harmonic current) distortion and total harmonic voltage demand at the defined point of common coupling to meet IEEE 519 recommendations.

Typically, if the separation between motor and VFC is less than 100 feet (30 m), the motor is designed for use with VFC, low carrier frequencies are specified, or all three, then output filtering may not be an issue. However, if distances are more than 100 feet and high carrier frequencies are being used, controller output voltage can exceed motor pulse-withstand capability. Consult motor and VFC manufacturers to determine need for, and options available for, conditioning output voltage. Options may include line inductors, dV/dT filters, output reactors, and motor termination filters. Insert requirements in "Output Filtering" paragraph below. See "Motor and VFC Compatibility" Article in the Evaluations for additional guidance.

* + - * 1. Output Filtering: <**Insert requirements**>.

If EMI/RFI generation in VFCs is a concern, consult manufacturers for options available to mitigate it. Specifying compliance with applicable standards and following proper installation methods will usually address EMI/RFI issues. Retain first "EMI/RFI Filtering" paragraph below if a specific method of mitigation is unimportant and manufacturer has delegated responsibility to incorporate whatever mitigating means are necessary to comply with specified limitations. Otherwise, retain second "EMI/RFI Filtering" paragraph below and insert specific requirements. See "Electromagnetic Compatibility" Article in the Evaluations for additional guidance.

* + - * 1. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for [**Category C2**] <**Insert category**>.
        2. EMI/RFI Filtering: <**Insert requirements**>.
      1. BYPASS SYSTEMS

Retain this article only if VFCs will require bypass systems. Applying bypass systems to VFCs requires additional consideration of system parameters and code requirements. Additionally, listed manufacturers offer different forms of bypass strategies and different operating characteristics. See "Bypass Systems" Article in the Evaluations for guidance, and coordinate with manufacturers for available selections.

* + - * 1. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

Retain one of two "Bypass Mode" paragraphs below, or retain both if required for separate VFCs, and indicate on Drawings where each type is required. First paragraph is for bypass control where the motor must be at zero speed before the bypass function is performed; second paragraph allows for bypass control whether the motor is at rest or running. If retaining second paragraph, also retain "Bidirectional Autospeed Search" paragraph in "System Description" Article.

* + - * 1. Bypass Mode: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor, and retransfer shall only be allowed with the motor at zero speed.
        2. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic-control system feedback.

Retain one of two "Bypass Controller" paragraphs below. First paragraph is frequently called a "two-contactor-style" bypass - it typically does not allow power converter maintenance while the VFC is operating in bypass, because the power converter input remains energized, unless used with an input isolating switch and barrier. Second paragraph is for a "three-contactor-style" bypass - it allows power converter testing while the motor continues to operate at full speed in bypass, because the power converter is de-energized as well as being isolated from input and output power circuits. Either controller can be operated in manual or manual/automatic mode.

* + - * 1. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller[**; with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode**].

In "Bypass Contactor" Subparagraph below, IEC-rated contactors are most often used for the bypass contactor in HVAC applications and for smaller motors, and they are usually smaller and less costly than equivalent NEMA-rated contactors. NEMA-rated contactors are most often used in industrial applications and for larger motors, where they must carry high motor inrush and full-load running currents. IEC-rated contactors are most often used in all applications for the isolating contactors, because they are only used to isolate the power converter and normally do not carry any current. Consult manufacturers for the types used for each.

Bypass Contactor: Load-break, [**IEC**] [**NEMA**]-rated contactor.

Output Isolating Contactor: Non-load-break, [**IEC**] [**NEMA**]-rated contactor.

Retain "Isolating Switch" Subparagraph below if retaining option in "Bypass Controller" paragraph above.

Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

Listed manufacturers are somewhat concerned that the input isolating contactor of the three-contactor bypass, without an isolating switch and a barrier between the power converter and the bypass, may not comply with NFPA 70 requirements for safe isolation of the power converter during energized maintenance, because the contactor is not a positive, lockable disconnecting means, and lack of a barrier can lead to accidental contact with live parts in the bypass. Consult authorities having jurisdiction if this is a concern and if retaining "Bypass Controller" paragraph below.

* + - * 1. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller[**; with input isolating switch and barrier**] arranged to isolate the power converter input and output and permit safe testing[**and troubleshooting**] of the power converter, both energized and de-energized, while motor is operating in bypass mode.

Bypass Contactor: Load-break, [**IEC**] [**NEMA**]-rated contactor.

Input and Output Isolating Contactors: Non-load-break, [**IEC**] [**NEMA**]-rated contactors.

Retain "Isolating Switch" Subparagraph below if retaining first option in last "Bypass Controller" paragraph above.

Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

First option in "Bypass Contactor Configuration" paragraph below is for full-voltage starting; second option is for reduced-voltage starting. Some listed manufacturers also offer reduced-voltage, solid-state controllers as a bypass option; consult manufacturers if this is a preference. See "Reduced-Voltage Bypass Contactors" Article in the Evaluations for additional information.

* + - * 1. Bypass Contactor Configuration: [**Full-voltage (across-the-line)**] [**Reduced-voltage (autotransformer)**] <**Insert type**> type.

NORMAL/BYPASS selector switch.

Retain first subparagraph below only if retaining field-selectable automatic and manual "Bypass Mode" paragraph above.

HAND/OFF/AUTO selector switch.

NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.

Contactor Coils: Pressure-encapsulated type[**with coil transient suppressors**].

Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.

Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.

Control Circuits: [**120**] <**Insert number**>-V ac; obtained from [**integral CPT, with primary and secondary fuses**] <**Insert source of control power**>, with [**CPT**] [**control power source**] of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.

Retain "CPT Spare Capacity" Subparagraph below if retaining "CPT" option in "Control Circuits" Subparagraph above and spare CPT capacity is required. Spare capacity is normally available in 100-VA increments. Consult manufacturers for maximum spare capacity and for available CPT sizes for different NEMA and enclosure sizes, because adding spare capacity and an oversized CPT may require using an enlarged enclosure.

CPT Spare Capacity: [**50**] [**100**] [**200**] <**Insert number**> VA.

Manufacturers typically integrate overload functions into the microprocessors of VFCs and offer overload relay options only for bypass systems. Retain one or more of "Melting-Alloy Overload Relays," "Bimetallic Overload Relays," and "Solid-State Overload Relays" subparagraphs below if specifying a bypass system. If retaining more than one, show on Drawings where each type is required. See Editing Instruction No. 6 and "Overload Protection" Article in the Evaluations for additional guidance.

Overload Relays: NEMA ICS 2.

Melting-Alloy Overload Relays:

Inverse-time-current characteristic.

[**Class 10**] [**Class 20**] [**Class 30**] tripping characteristic.

Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Bimetallic Overload Relays:

Inverse-time-current characteristic.

[**Class 10**] [**Class 20**] [**Class 30**] tripping characteristic.

Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

Retain one or both of first two subparagraphs below if applicable. See Editing Instruction No. 7 and "Overload Protection" Article in the Evaluations for guidance and warnings.

Ambient compensated.

Automatic resetting.

Solid-State Overload Relays:

Switch or dial selectable for motor-running overload protection.

Sensors in each phase.

[**Class 10**] [**Class 20**] [**Class 10/20 selectable**] tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

Retain one or both of first two subparagraphs below if applicable; these are optional, added-cost features.

Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.

Analog communication module.

Retain first subparagraph below if alarm contacts on overload relays are required for local or remote alarm indication of a tripped overload relay.

[**NC**] [**NO**] isolated overload alarm contact.

External overload, reset push button.

* + - 1. OPTIONAL FEATURES

Optional feature types and quantities vary considerably among VFC manufacturers. Consult manufacturers for availability and limitations. Features vary according to VFC and motor characteristics and the driven-equipment operating criteria. Retain applicable features in this article; insert others to suit Project. Indicate requirements for and quantities of optional features on Drawings if not included here. Manufacturers typically consider these features added-cost items. See "Optional Features" Article in the Evaluations for additional guidance, and consult manufacturers for availability of, and limitations on, other options.

Retain "Multiple-Motor Capability" paragraph below if Project requires multiple motors controlled from a single VFC and controller redundancy is unnecessary.

* + - * 1. Multiple-Motor Capability: VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications when overload protection activates.

Retain one of three subparagraphs below, or more than one if required for separate VFCs; indicate on Drawings where each type is required. Other multimotor options are available from some listed manufacturers; consult manufacturers if other combinations are required.

Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.

Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.

Retaining subparagraph below requires retaining and properly revising "Bypass Systems" Article to support this configuration. Consult manufacturers for more information.

Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.

* + - * 1. Damper control circuit with end-of-travel feedback capability.
        2. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
        3. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
        4. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from [**the firefighter's control station**] [**smoke-control fan controller**] <**Insert location**>, this password-protected input:

Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).

Retain one of first two subparagraphs below. First subparagraph is for VFCs without a bypass system; second is for VFCs with a bypass system, and the bypass is used for this function. In first subparagraph, coordinate preset speed with pressure rating of the ventilation system. Consider requiring final speed setting to be determined during commissioning, testing, and balancing of the ventilation system. Ensure that ducted systems are designed to tolerate the higher pressures generated by the full-speed or preset-speed settings.

Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.

Forces VFC to transfer to bypass mode and operate motor at full speed.

Causes display of override mode on the VFC display.

Reset VFC to normal operation on removal of override signal [**automatically**] [**manually**].

If retaining "Remote Indicating Circuit Terminals" paragraph below, consider adding Specifications for remote indicating devices.

* + - * 1. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
        2. Remote digital operator kit.
        3. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer[**and a notebook computer**].
        4. <**Insert feature**>.
      1. ENCLOSURES
         1. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.

See "Enclosures" Article in the Evaluations for discussion of enclosure types. Coordinate subparagraphs below with Drawings by identifying the designated areas on plans or by including the required enclosure types. Enclosure materials and finishes may be added to the Section Text. Availability of some enclosure types is limited by type and controller rating; special accommodations and accessories (e.g., powered/filtered ventilation) may be required for some enclosure types. Consult manufacturers for availability of, and limitations on, enclosures other than NEMA 250, Type 1. VFCs are not usually available in explosion-proof enclosures.

Dry and Clean Indoor Locations: [**Type 1**] <**Insert type**>.

Outdoor Locations: [**Type 3R**] [**Type 4X**] <**Insert type**>.

[**Kitchen**] [**Wash-Down**] Areas: [**Type 4X**] <**Insert type**>, [**stainless steel**] <**Insert material**>.

Other Wet or Damp Indoor Locations: [**Type 4**] <**Insert type**>.

Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

<**Insert enclosure requirements**>.

Retain "Plenum Rating" paragraph below when installing the VFC in plenums (e.g., in the air stream inside an air-handling unit) or in a space used for environmental air (e.g., above a suspended ceiling used for return air). Some authorities having jurisdiction require that a label verifying the rating be prominently displayed on the VFC enclosure.

* + - * 1. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."
      1. ACCESSORIES

Accessories listed in this article are limited in application by VFC and enclosure types; accessories in the first five paragraphs below apply primarily to VFCs with bypass systems. Retain applicable accessories below. Indicate requirements for and quantities of accessories on Drawings. See "Accessories" Article in the Evaluations for additional guidance; consult manufacturers for availability of, and limitations on, other accessories.

* + - * 1. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.

Push Buttons: [**Covered**] [**Lockable**] [**Shielded**] [**Unguarded**].

Pilot Lights: Push to test.

Selector Switches: [**Rotary**] <**Insert description**> type.

Stop and lockout push-button stations are no longer allowed by NFPA 70 as a means of isolating controllers or motors for personnel safety during maintenance; however, they are still required by some end users and Owners. Retain "Stop and Lockout Push-Button Station" Subparagraph below only if required by the end user or Owner.

Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

* + - * 1. [**NC**] [**NO**] [**Reversible NC/NO**] bypass contactor auxiliary contact(s).
        2. Control Relays: Auxiliary and adjustable [**pneumatic**] [**solid-state**] time-delay relays.

Features in "Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays" paragraph below provide one method of protecting against input circuit anomalies while in the bypass mode. They are available in individual relays or combined into a single multipurpose relay, and they would only be required if retaining "Bypass Systems" Article. Because features below may not be available from all listed manufacturers, other methods of providing redundant control of motor loads served may be required; consult manufacturers for availability. Consider specifying phase-failure relays for single-phasing protection when fuses are retained with the bypass feature, if solid-state overload relays are unspecified.

* + - * 1. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

* + - * 1. Supplemental Digital Meters:

Elapsed-time meter.

Kilowatt meter.

Kilowatt-hour meter.

* + - * 1. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, [**Type 4**] [**Type 4X**] [**Type 12**] <**Insert type**> enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
        2. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, [**Type 3R**] [**Type 4X**] [**Type 12**] <**Insert type**> enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
        3. Cooling Fan and Exhaust System: For NEMA 250, [**Type 1**] [**Type 12**] <**Insert enclosure type**>; UL 508 component recognized: Supply fan, with [**composite**] [**stainless-steel**] <**Insert material**> intake and exhaust grills [**and filters**]; [**120**] <**Insert number**>-V ac; obtained from [**integral CPT**] <**Insert source of control power**>.
        4. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.

Indicate quantities of spare control-wiring terminal blocks on Drawings.

* + - * 1. Spare control-wiring terminal blocks[**; unwired**][**; wired**].
        2. <**Insert accessory**>.
      1. SOURCE QUALITY CONTROL

NEMA ICS 61800-2 includes acceptance testing by manufacturer of VFCs completely assembled and wired, before shipment from the factory.

* + - * 1. Testing: Test and inspect VFCs according to requirements in [**NEMA ICS 61800-2**] <**Insert standard**>.

Test each VFC while connected to [**its specified motor**] [**a motor that is comparable to that for which the VFC is rated**].

Verification of Performance: Rate VFCs according to operation of functions and features specified.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

* + - * 1. VFCs will be considered defective if they do not pass tests and inspections.
        2. Prepare test and inspection reports.

1. EXECUTION
   * + 1. EXAMINATION
          1. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, <**insert Project-specific conditions,**> and other conditions affecting performance of the Work.
          2. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
          3. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
          4. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
          5. Proceed with installation only after unsatisfactory conditions have been corrected.
       2. INSTALLATION
          1. Wall-Mounting Controllers: Install with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor, unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall.

Retain "Floor-Mounting Controllers" paragraph below for equipment supported on slabs-on-grade. If installing VFCs on concrete bases, ensure that their disconnect operating handles are higher than 79 inches (2000 mm) above finished floor.

* + - * 1. Floor-Mounting Controllers: Install VFCs on 4-inch nominal thickness concrete base.

Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.

For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

Install anchor bolts to elevations required for proper attachment to supported equipment.

Retain "Roof-Mounting Controllers" paragraph below for equipment supported on roofs.

* + - * 1. Roof-Mounting Controllers: Install VFC on roofs with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished roof surface unless otherwise indicated, and by bolting units to curbs or mounting on freestanding, lightweight, structural-steel channels bolted to curbs. Seal roof penetrations after raceways are installed.

Retain "Seismic Bracing" paragraph below if seismic controls are Project requirement. Coordinate with Drawings and Sections specifying vibration and seismic controls.

* + - * 1. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

Retain first four paragraphs below, as appropriate, to coincide with retained VFC features and attributes.

* + - * 1. Install fuses in each fusible-switch VFC.
        2. Install fuses in control circuits if not factory installed.
        3. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors are installed.
        4. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
        5. Comply with NECA 1.
      1. CONTROL WIRING INSTALLATION

Retain this article if applicable or if remote control or indication is required.

* + - * 1. Install wiring between VFCs and remote devices[**and facility's central-control system**].
        2. Bundle, train, and support wiring in enclosures.
        3. Connect selector switches and other automatic-control devices where applicable.

Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.

Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protectors.

* + - 1. IDENTIFICATION
         1. Identify VFCs, components, and control wiring.

Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.

Label each VFC with engraved nameplate.

Label each enclosure-mounted control and pilot device.

If specific operational procedures are required in emergency situations, specify below. Show specific information to be included in framed instructions on Drawings; retain "Operating Instructions" paragraph below if required.

* + - * 1. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.
      1. FIELD QUALITY CONTROL

Retain "Testing Agency" paragraph to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" paragraph, retain "Field quality-control reports" paragraph in "Informational Submittals" Article.

* + - * 1. Testing Agency: [**Director’s Representative will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" paragraph below to require a factory-authorized service representative to perform inspections, tests, and adjustments. Due to the complexity of VFCs, it is advisable to require manufacturer's services for installations other than simple systems.

* + - * 1. Manufacturer's Field Service: Engage a Company Service Advisor to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" paragraph below to require Contractor to perform tests and inspections.

* + - * 1. Perform tests and inspections[**with the assistance of a Company Service Advisor**].

Retain "Acceptance Testing Preparation" and "Tests and Inspections" paragraphs below to describe tests and inspections to be performed.

* + - * 1. Acceptance Testing Preparation:

Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.

Test continuity of each circuit.

* + - * 1. Tests and Inspections:

Inspect VFC, wiring, components, connections, and equipment installation.[**Test and adjust controllers, components, and equipment.**]

Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.

Test continuity of each circuit.

In first subparagraph below, the 10 percent voltage variation is a functional issue. Where ASHRAE 90.1 is Project's applicable energy code, further restrictions in voltage drop are required.

Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify [**Architect**] [**Construction Manager**] [**Director’s Representative**] before starting the motor(s).

Test each motor for proper phase rotation.

Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

NETA Acceptance Testing Specification allows for three methods of testing and inspecting bolted electrical connections for high resistance; the infrared (thermographic) method is the most thorough and costly. Retain "Initial Infrared Scanning" Subparagraph below if this method is preferred.

Perform the following infrared (thermographic) scan tests and inspections, and prepare reports:

Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.

Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Substantial Completion.

Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

* + - * 1. VFCs will be considered defective if they do not pass tests and inspections.

Retain paragraph below if tests and inspections are performed by Contractor or manufacturer's field-service representative engaged by Contractor.

* + - * 1. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.
      1. STARTUP SERVICE
         1. [**Engage a Company Service Advisor** **to perform**] [**Perform**] startup service.

Complete installation and startup checks according to manufacturer's written instructions.

<**Insert startup steps if any**>.

* + - 1. ADJUSTING

Retain applicable paragraphs below to correspond to selections made in Part 2.

* + - * 1. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

First two paragraphs below pertain primarily to VFCs with bypass systems. Retain if retaining "Bypass Systems" Article.

* + - * 1. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
        2. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed 8 times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify [**Architect**] [**Construction Manager**] [**Director’s Representative**] before increasing settings.
        3. Set the taps on reduced-voltage autotransformer controllers.

Retain option in first paragraph below unless settings are included on Drawings.

* + - * 1. Set field-adjustable circuit-breaker trip ranges.
        2. Set field-adjustable pressure switches.
      1. PROTECTION

Retain this article if retaining "Delivery, Storage, and Handling" Article and if retaining space heaters in "Accessories" Article.

* + - * 1. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.
        2. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.
      1. DEMONSTRATION
         1. [**Engage a Company Service Advisor** **to train**] [**Train**] Director’s Representative's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

END OF SECTION 262923