PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls and variable frequency drives.

B. Refer to Related Division 23 Sections:

1.3 DEFINITIONS

A. DDC: Direct digital control.

B. I/O: Input/output.

C. LonWorks: A control network technology platform for designing and implementing interoperable control devices and networks.

D. MS/TP: Master slave/token passing.

E. PC: Personal computer.

F. PID: Proportional plus integral plus derivative.

G. RTD: Resistance temperature detector.

1.4 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:
   1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.
   2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
   3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
   4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
   5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
   6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
   7. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
   8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
      a. Water Temperature: Plus or minus 1 deg F (0.5 deg C).
      b. Water Flow: Plus or minus 5 percent of full scale.
      c. Water Pressure: Plus or minus 2 percent of full scale.

d. Space Temperature: Plus or minus 1 deg F (0.5 deg C).
e. Ducted Air Temperature: Plus or minus 1 deg F (0.5 deg C).
f. Outside Air Temperature: Plus or minus 2 deg F (1.0 deg C).
g. Dew Point Temperature: Plus or minus 3 deg F (1.5 deg C).
h. Temperature Differential: Plus or minus 0.25 deg F (0.15 deg C).
i. Relative Humidity: Plus or minus 5 percent.
j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
l. Airflow (Terminal): Plus or minus 10 percent of full scale.
m. Air Pressure (Space): Plus or minus 0.01-inch wg (2.5 Pa).
n. Air Pressure (Ducts): Plus or minus 0.1-inch wg (25 Pa).

1.5 SEQUENCE OF OPERATION – REFER TO PROJECT DRAWINGS

1.6 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
   1. DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.
   2. Control System Software: Include technical data for operating system software, operator interface, color graphics, and other third-party applications.
   3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
   2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
   3. Wiring Diagrams: Power, signal, and control wiring.
   4. Details of control panel faces, including controls, instruments, and labeling.
   5. Written description of sequence of operation.
   6. Schedule of dampers including size, leakage, and flow characteristics.
   7. Schedule of valves including flow characteristics.
   8. DDC System Hardware:
      a. Wiring diagrams for control units with termination numbers.
      b. Schematic diagrams and floor plans for field sensors and control hardware.
      c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
   9. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
   10. Controlled Systems:

a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
c. Written description of sequence of operation including schematic diagram.
d. Points list.

C. Software and Firmware Operational Documentation: Include the following:
1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
3. Device address list.
4. Printout of software application and graphic screens.
5. Software license required by and installed for DDC workstations and control systems.

D. Software Upgrade Kit: Provide for Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.

E. Qualification Data: Installer and manufacturer shall have provided similar service for at least five (5) years and shall have service staff based within 200 miles of the facility.

F. Field quality-control test reports.

G. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:
1. Maintenance instructions and lists of spare parts for each type of control device and compressed-air station.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

1.7 QUALITY ASSURANCE

A. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this Project.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

B. System Software: Update to latest version of software at Project completion.

1.9 COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.

B. Coordinate supply of conditioned electrical branch circuits for control units and existing operator workstation.

C. Coordinate equipment with Division 26 Section "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.

D. Coordinate equipment with Division 26 Section "Panelboards" to achieve compatibility with starter coils and annunciation devices.

E. Coordinate equipment with Division 26 Section "Motor-Control Centers" to achieve compatibility with motor starters and annunciation devices.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.2 CONTROL SYSTEM

A. Manufacturers: Subject to compliance with requirements, provide the product by the following:
   1. Honeywell Spyder BACnet Controller.

B. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on token-passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics. Software system shall be compatible with existing SPYDER controls, including existing front end computer. Update graphics and provide necessary field programming.

2.3 DDC EQUIPMENT

A. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.
   1. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.
   2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
      a. Global communications.
      b. Discrete/digital, analog, and pulse I/O.

c. Monitoring, controlling, or addressing data points.
d. Software applications, scheduling, and alarm processing.
e. Testing and developing control algorithms without disrupting field hardware and controlled environment.

3. Standard Application Programs:
   a. Electric Control Programs: Demand limiting, duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, on-off control with differential sequencing, staggered start, antishort cycling, PID control, DDC with fine tuning, and trend logging.
   b. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.
   c. Programming Application Features: Include trend point; alarm processing and messaging; weekly, monthly, and annual scheduling; energy calculations; run-time totalization; and security access.
   d. Remote communications.
   e. Maintenance management.
   f. Units of Measure: Inch-pound and SI (metric).
4. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.

B. Local Control Units: Modular, comprising processor board with electronically programmable, nonvolatile, read-only memory; and backup power source.
1. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.
2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
   a. Global communications.
   b. Discrete/digital, analog, and pulse I/O.
   c. Monitoring, controlling, or addressing data points.
3. Local operator interface provides for download from or upload to operator workstation.

C. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
1. Binary Inputs: Allow monitoring of on-off signals without external power.
2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
3. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation.
5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA.
6. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
7. Universal I/Os: Provide software selectable binary or analog outputs.

D. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:
1. Output ripple of 5.0 mV maximum peak to peak.
2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.
3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.

E. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:
   1. Minimum dielectric strength of 1000 V.
   2. Maximum response time of 10 nanoseconds.
   3. Minimum transverse-mode noise attenuation of 65 dB.
   4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.4 UNITARY CONTROLLERS

A. Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.
   1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or card connected with ribbon cable; memory with bios; and 24-hour battery backup.
   2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. Perform automatic system diagnostics; monitor system and report failures.
   3. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
   4. Enclosure: Dustproof rated for operation at 32 to 120 deg F (0 to 50 deg C).
   5. Enclosure: Waterproof rated for operation at 40 to 150 deg F (5 to 65 deg C).

2.5 ALARM PANELS

A. Unitized cabinet with suitable brackets for wall or floor mounting. Fabricate of 0.06-inch-(1.5-mm-) thick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish.

B. Indicating light for each alarm point, single horn, acknowledge switch, and test switch, mounted on hinged cover.
   1. Alarm Condition: Indicating light flashes and horn sounds.
   2. Acknowledge Switch: Horn is silent and indicating light is steady.
   3. Second Alarm: Horn sounds and indicating light is steady.
   4. Alarm Condition Cleared: System is reset and indicating light is extinguished.
   5. Contacts in alarm panel allow remote monitoring by independent alarm company.

2.6 ANALOG CONTROLLERS

A. Step Controllers: 6- or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.

B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 10 to plus 70 deg F (minus 23 to plus 21 deg C), and single- or double-pole contacts.

C. Electronic Controllers: Wheatstone-bridge-amplifier type, in steel enclosure with provision for remote-resistance readjustment. Identify adjustments on controllers, including proportional band and authority.
   1. Single controllers can be integral with control motor if provided with accessible control readjustment potentiometer.

D. Fan-Speed Controllers: Solid-state model providing field-adjustable proportional control of motor speed from maximum to minimum of 55 percent and on-off action below minimum fan speed. Controller shall briefly apply full voltage, when motor is started, to rapidly bring motor up to minimum speed. Equip with filtered circuit to eliminate radio interference.

2.7 ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Thermistor Temperature Sensors, RTDs, and Transmitters:
   1. Manufacturers:
      a. BEC Controls Corporation.
      b. Ebtron, Inc.
      c. Heat-Timer Corporation.
      d. I.T.M. Instruments Inc.
      e. MAMAC Systems, Inc.
      f. RDF Corporation.
   2. Accuracy: Plus or minus 0.5 deg F at calibration point.
   3. Wire: Twisted, shielded-pair cable.
   4. Insertion Elements in Ducts: Single point, 8 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (0.84 sq. m).
   5. Averaging Elements in Ducts: Use where prone to temperature stratification or where ducts are larger than 9 sq. ft. (1 sq. m).
   6. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches (64 mm).
   7. Room Sensor Cover Construction: Manufacturer's standard locking covers.
   8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
   9. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.

C. Humidity Sensors: Bulk polymer sensor element.
   1. Manufacturers:
      a. General Eastern Instruments.
      b. TCS/Basys Controls.
      c. Vaisala.
   2. Accuracy: 5 percent full range with linear output.
   3. Room Sensor Range: 20 to 80 percent relative humidity.
   4. Room Sensor Cover Construction: Manufacturer's standard locking covers.
   5. Duct Sensor: 20 to 80 percent relative humidity range with element guard and mounting plate.
   6. Outside-Air Sensor: 20 to 80 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of 32 to 120 deg F.
   7. Duct and Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.

D. Pressure Transmitters/Transducers:
   1. Manufacturers:
      a. BEC Controls Corporation.
      b. General Eastern Instruments.
      c. MAMAC Systems, Inc.
      d. ROTRONIC Instrument Corp.
      e. TCS/Basys Controls.

f. Vaisala.

2. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
   a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
   b. Output: 4 to 20 mA.
   c. Building Static-Pressure Range: 0- to 0.25-inch wg (0 to 62 Pa).
   d. Duct Static-Pressure Range: 0- to 5-inch wg (0 to 1240 Pa).
3. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig (1034-kPa) operating pressure; linear output 4 to 20 mA.
4. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig (1034-kPa) operating pressure and tested to 300-psig (2070-kPa); linear output 4 to 20 mA.
5. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
6. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.

E. Room Sensor Cover Construction: Manufacturer's standard locking covers.

F. Room sensor accessories include the following:
   1. Insulating Bases: For sensors located on exterior walls.

2.8 STATUS SENSORS

A. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.

2.9 FLOW MEASURING STATIONS

A. Airflow measurement devices for supply and return fans shall be provided with the AHU.

B. Provide thermal dispersion airflow measurement stations at each outside air intake hood for each AHU. Thermal dispersion airflow measurement stations shall be Ebtron or approved equal, be capable of measuring airflows less than 400 fpm, and be provided with transmitter.

2.10 THERMOSTATS

A. Public spaces shall have a temperature sensor, but no visible temperature display or means of setpoint adjustment.

B. Thermostats shall have temperature sensor, durable push buttons for setpoint adjustment, and digital display of temperature.

C. Thermostats shall not have any buttons that have no function.

D. The range of user setpoint adjustment shall be adjustable through the BMS.

E. In general, mount thermostats at 48” A.F.F to center of thermostat.

F. Electric, Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic- reset switch that trips if temperature sensed across any 12 inches (300 mm) of bulb length is equal to or below set point.

1. Bulb Length: Minimum 20 feet (6 m).
2. Quantity: One thermostat for every 20 sq. ft. (2 sq. m) of coil surface.

2.11 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
   1. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
   2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.

B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
   1. Manufacturers:
      a. Belimo Aircontrols (USA), Inc.
   2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
   3. Dampers: Size for running torque calculated as follows:
      a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. (86.8 kg-cm/sq. m) of damper.
      b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. (62 kg-cm/sq. m) of damper.
      c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft (49.6 kg-cm/sq. m) of damper.
      d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. (37.2 kg-cm/sq. m) of damper.
      e. Dampers with 2- to 3-Inch wg (500 to 750 Pa) of Pressure Drop or Face Velocities of 1000 to 2500 fpm (5 to 13 m/s): Increase running torque by 1.5.
      f. Dampers with 3- to 4-Inch wg (750 to 1000 Pa) of Pressure Drop or Face Velocities of 2500 to 3000 fpm (13 to 15 m/s): Increase running torque by 2.0.
   4. Coupling: V-bolt and V-shaped, toothed cradle.
   5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
   6. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
   7. Power Requirements (Two-Position Spring Return): 24 or 120 230-V ac.
   8. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
   9. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
   10. Temperature Rating: Minus 22 to plus 122 deg F.
   11. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F (Minus 30 to plus 121 deg C).
   12. Run Time: 30 seconds.

2.12 CONTROL VALVES

A. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location. Heating water valves shall be ANSI Class 125. Chilled water valves shall be ANSI Class 250.

B. Valves 2 inches and smaller shall be bronze body with threaded or flare connections.

C. Valves 2 ½ inches and larger shall be bronze or cast iron body with flanged connections.

D. Valves controlling water shall have brass or bronze seats. Valves controlling steam shall have stainless steel seats.

E. Flow characteristics:
   1. Three way valves shall have a linear relation or equal percentage relation of flow versus value position.
   2. Two-way valves position versus flow relation shall be linear for steam and equal percentage for water flow control.

F. Maximum pressure drop:
   1. Two position steam control, 20 percent of inlet gauge pressure.
   2. Modulating Steam Control, 80 percent of inlet gauge pressure (acoustic velocity limitation).
   3. Modulating water flow control, greater of 10 feet of water or the pressure drop through the apparatus.
   4. Two position water valves shall be line size.

G. Valve actuators shall be electric.
   1. Size actuator with sufficient reserve power to provide smooth modulation and close completely.
   2. Where required, provide spring return for normally open or normally closed valves.

2.13 DAMPERS

A. Dampers: AMCA-rated, parallel or opposed-blade design; 0.108-inch- (2.8-mm-) minimum thick, galvanized-steel or 0.125-inch- (3.2-mm-) minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch- (1.6-mm-) thick galvanized steel with maximum blade width of 8 inches (200 mm) and length of 48 inches (1220 mm).
   1. Secure blades to 1/2-inch- (13-mm-) diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
   2. Operating Temperature Range: From minus 40 to plus 200 deg F (minus 40 to plus 93 deg C).
   3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
   4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. (50 L/s per sq. m) of damper area, at differential pressure of 4-inch wg (1000 Pa) when damper is held by torque of 50 in. x lbf (5.6 N x m); when tested according to AMCA 500D.

2.14 CONTROL CABLE

A. Install control wiring, without splices between terminal points, color-coded. Install in neat workmanlike manner, securely fastened. Install in accordance with National Electrical Code and Division 16. Install all control wiring in mechanical spaces and any other exposed areas in electrical conduit. Control wiring in return plenum ceiling cavity shall be plenum rated wire.

B. Install circuits over 25-volt with colored coded wire. Wire gauge shall be in accordance with National Electrical Code.

C. Control wiring for analog functions shall be 18 AWG minimum with 600 volt insulation, twisted and shielded, 2 or 3 wire to match analog function hardware.

D. Wiring to wall-mounted thermostats shall be hidden. Surface mounted Wiremold for wiring to thermostats is only acceptable in mechanical or shell spaces.

E. Sensor Wiring: Sensor wiring shall be 20 AWG minimum twisted and shielded, 2 or 3 wire to match analog function hardware.

F. Network wiring shall be as recommended by BMS manufacturer, but minimum of 20 AWG.

2.15 VARIABLE FREQUENCY DRIVES

A. Available Manufacturers: Provide product by one of the manufacturer listed:
   1. Danfoss Inc.; Danfoss Electronic Drives Div.
   2. Toshiba.
   3. ABB.
   4. Approved Equal.

B. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
   1. Provide unit suitable for operation of premium-efficiency motor as defined by NEMA MG 1.

C. 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.

D. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.

E. Unit Operating Requirements:
   1. Input ac voltage tolerance, plus or minus 10 percent.
   2. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
   3. Minimum Efficiency: 96 percent at 60 Hz, full load.
   4. Minimum Displacement Primary-Side Power Factor: 96 percent.
   5. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
   6. Starting Torque: 100 percent of rated torque or as indicated.
   7. Speed Regulation: Plus or minus 1 percent.

F. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
   1. Electrical Signal: 4 to 20 mA at 24 V.

G. Internal Adjustability Capabilities:
   1. Minimum Speed: 5 to 25 percent of maximum rpm.
   2. Maximum Speed: 80 to 100 percent of maximum rpm.
   3. Acceleration: 2 to a minimum of 22 seconds.

4. Deceleration: 2 to a minimum of 22 seconds.
5. Current Limit: 50 to a minimum of 110 percent of maximum rating.

H. Self-Protection and Reliability Features:
1. Input transient protection by means of surge suppressors.
2. Under- and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
3. Motor Overload Relay: Adjustable and capable of NEMA ICS 2, Class 10 performance.
4. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
5. Instantaneous line-to-line and line-to-ground overcurrent trips.
6. Loss-of-phase protection.
7. Reverse-phase protection.
8. Short-circuit protection.
9. Motor overtemperature fault.

I. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.

J. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped.

K. 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.

L. 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.

M. Status Lights: Door-mounted LED indicators shall indicate the following conditions:
1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

N. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual speed control potentiometer and elapsed time meter.

O. Indicating Devices: Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (VDC).

9. Set-point frequency (Hz).
10. Motor output voltage (V).

P. Control Signal Interface:
1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BMS or other control systems:
   a. 0 to 10-V dc.
   b. 0-20 or 4-20 mA.
   c. Potentiometer using up/down digital inputs.
   d. Fixed frequencies using digital inputs.
   e. RS485.
   f. Keypad display for local hand operation.
3. Output Signal Interface:
   a. A minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
      1) Output frequency (Hz).
      2) Output current (load).
      3) DC-link voltage (VDC).
      4) Motor torque (percent).
      5) Motor speed (rpm).
      6) Set-point frequency (Hz).
4. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
   a. Motor running.
   b. Set-point speed reached.
   c. Fault and warning indication (overtemperature or overcurrent).
   d. PID high- or low-speed limits reached.

Q. Communications: Provide an RS485 interface allowing VFD to be used with an external system within a multidrop LAN or BACNET configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFD to retain these settings within the nonvolatile memory.

R. Manual Bypass: Magnetic contactor arranged to safely transfer motor between controller output and bypass controller circuit when motor is at zero speed. Controller-off-bypass selector switch sets mode, and indicator lights give indication of mode selected. Unit shall be capable of stable operation (starting, stopping, and running), with motor completely disconnected from controller (no load). Three motor controllers shall be used.

S. Bypass Controller: NEMA ICS 2, full-voltage, nonreversing enclosed controller with across-the-line starting capability in manual-bypass mode. Provide motor overload protection under both modes of operation with control logic that allows common start-stop capability in either mode.

T. Integral Disconnecting Means: NEMA KS 1, fusible switch with lockable handle.

U. Isolating Switch: Non-load-break switch arranged to isolate VFD and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode.

V. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.

W. Harmonic Filtering
1. The VFD shall incorporate a 5% AC input line reactor or a D.C. line choke (equivalent to a 3% AC line reactor) plus a 3% AC input line reactor.
2. All chokes and reactors shall be factory wired and contained within the VFD enclosure.
3. The VFD manufacturer is responsible for meeting the defined IEEE 519-1992 harmonic distortion limits as specified in this specification.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that power supply is available to control units and operator workstation.

B. Verify that duct-, pipe-, and equipment-mounted devices are installed before proceeding with installation.

3.2 INSTALLATION

A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Verify location of thermostats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above the floor.
1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

D. Install temperature sensors with no setpoint adjustment in the following locations: Setpoint shall be adjustable at the Operator Worksation.
1. Entrances.
2. Public areas.
3. Where indicated.

E. Install automatic dampers according to Division 23 Section "Air Duct Accessories."

F. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

G. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC Piping and Equipment."

H. Install hydronic instrument wells, valves, and other accessories according to Division 23 Section "Hydronic Piping."

I. Install steam and condensate instrument wells, valves, and other accessories according to Division 23 Section "Steam and Condensate Heating Piping."

J. Install duct volume-control dampers according to Division 23 Sections specifying air ducts.

K. Install electronic and fiber-optic cables according to Division 27 Section "Communications Horizontal Cabling."

3.3 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems."

B. Install building wire and cable according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

C. Install signal and communication cable according to Division 27 Section "Communications Horizontal Cabling."
   1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
   2. Install exposed cable in raceway.
   3. Install concealed cable in raceway.
   4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
   5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
   6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
   7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing to Engineer for review.

B. Perform the following field tests and inspections and prepare test reports:
   1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
   2. Test and adjust controls and safeties.
   3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   4. Pressure test control air piping at 30 psig (207 kPa) or 1.5 times the operating pressure for 24 hours, with maximum 5-psig (35-kPa) loss.
   5. Pressure test high-pressure control air piping at 150 psig (1034 kPa) and low-pressure control air piping at 30 psig (207 kPa) for 2 hours, with maximum 1-psig (7-kPa) loss.
   6. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
   7. Test each point through its full operating range to verify that safety and operating control set points are as required.
   8. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.

9. Test each system for compliance with sequence of operation.
10. Test software and hardware interlocks.

C. DDC Verification:
1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check instrument tubing for proper fittings, slope, material, and support.
5. Check installation of air supply for each instrument.
6. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
8. Check temperature instruments and material and length of sensing elements.
9. Check control valves. Verify that they are in correct direction.
10. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
11. Check DDC system as follows:
    a. Verify that DDC controller power supply is from emergency power supply, if applicable.
    b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
    c. Verify that spare I/O capacity has been provided.
    d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

E. Submit printout of “live” data of all input and output points.

3.5 ADJUSTING

A. Calibrating and Adjusting:
1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analog instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:
    a. Check analog inputs at 0, 50, and 100 percent of span.
    b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
    c. Check digital inputs using jumper wire.
    d. Check digital outputs using ohmmeter to test for contact making or breaking.
    e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
5. Flow:
    a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
    b. Manually operate flow switches to verify that they make or break contact.
6. Pressure:

a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

7. Temperature:
   a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
   b. Calibrate temperature switches to make or break contacts.
8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.
11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to four (4) visits to Project during other than normal occupancy hours for this purpose.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Provide twenty (20) hours of training. The training shall occur on at least four (4) different occasions and attendance and topics covered shall be documented and submitted. Refer to Division 01 Section "Demonstration and Training."

3.7 APPLICATIONS

A. Select features of each VFD to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; and duty cycle of motor, controller, and load.

B. Select horsepower rating of controllers to suit motor controlled.

3.8 IDENTIFICATION

A. Identify VFDs, components, and control wiring according to Division 26 Section "Identification for Electrical Systems."

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.9 CONTROL WIRING INSTALLATION

A. Install wiring between VFDs and remote devices according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

B. Bundle, train, and support wiring in enclosures.

C. Connect hand-off-automatic switch and other automatic-control devices where applicable.
   1. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
   2. Connect selector switches with control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.10 FIELD QUALITY CONTROL

A. Prepare for acceptance tests as follows:
   1. Test insulation resistance for each enclosed controller element, bus, component, connecting supply, feeder, and control circuit.
   2. Test continuity of each circuit.

B. Perform the following field tests and inspections and prepare test reports:
   1. Perform each electrical test and visual and mechanical inspection, except optional tests, stated in NETA ATS. Certify compliance with test parameters.
   2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

3.11 ADJUSTING

A. Set field-adjustable switches and circuit-breaker trip ranges.

END OF SECTION