

SECTION 23 09 23
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 GENERAL

1.01 GENERAL

- A. This section is a supplement to Section 23 09 00, Instrumentation and Control Devices for HVAC.
- B. The requirements of this section shall be provided in addition to those listed in Section 23 09 00, Instrumentation and Control Devices for HVAC.

1.02 ABBREVIATIONS

- A. Abbreviations that may be used in this section:
 - 1. BIOS: Basic Input Output System.
 - 2. DDC: Direct Digital Control.
 - 3. IBM: International Business Machines, Inc.
 - 4. LCD: Liquid Crystal Display.
 - 5. PC: Personal Computer.
 - 6. PID: Process Instrumentation Diagram.
 - 7. PI: Pressure Indicator.

1.03 DEFINITIONS

- A. ASCII: ANSI X3.4, Information Systems—Coded Character Sets—7-Bit American National Standard Code for Information Interchange (7-Bit ASCII).
- B. BACnet: ASHRAE 135, BACnet, Data Communication Protocol for Building Automation and Control Networks.
- C. Distributed Control: System whereby control processing is decentralized and independent of central computer. Control system is built up of standalone controllers. Single controller failure shall not impact more than one system.
- D. Ethernet: ISO/IEC 8802-3. The most common high performance peer-to-peer LAN protocol.
- E. Integration:
 - 1. Ability of control system components from different manufacturers to connect together and provide coordinated control via real-time data exchange through common communications data exchange protocol.
 - 2. Integration shall extend to operator's workstation software, which shall support user interaction with control system components.

3. Methods of integration include industry standard protocols, such as: BACnet, LonMark/LonTalk, OLE for Process Control (OPC), or integrator interfaces between manufacturer's systems.
- F. Interoperability: Ability of equipment to communicate mutually.
- G. Input/Output (I/O): Connections between computer and sensors and actuators.
- H. Human-Machine Interface (HMI): Method by which operator communicates with HVAC Control System. Allows operator to command, monitor, and program control system.
- I. Internet Protocol (IP): Network layer protocol originally created by Defense Advanced Research Project Agency to facilitate data communication between U.S. Defense Department and defense contractors, including universities and manufacturers.
- J. Local Area Network (LAN): Network in which devices can communicate directly without going through intervening routers. LANs commonly used by DDC system Suppliers include Ethernet (ISO 8802-3), ARCNET, Echelon LonTalk, and EIA 485.
- K. Master-Slave/Token-Passing (MS/TP): One of the data link layers created specifically for use with BACnet messages.
- L. Network:
1. System of distributed control units that are linked together on communication highway.
 2. Allows sharing of point information between control units.
 3. Provides central monitoring and control of entire system from any distributed control unit location.
 4. Primary networks provide peer-to-peer communications.
 5. Secondary networks provide either peer-to-peer, master-slave, or supervised token-passing communications.
- M. Peripheral: Input/Output equipment used to communicate with computer and make copies of system outputs. Peripherals include CRT, printer, tape deck, diskette.
- N. PID (Proportional, Integral, Derivative) Control Loop: Mathematical calculation used to evaluate control input and determine control output value required to maintain input value at set point. Shall have operator adjustable maximum rate of change, P and D gains, and loop response time delay. Loop shall be self-integrating, so no integral constant is required and not be subject to integral windup.

- O. Transmission Control Protocol (TCP): Connection-oriented protocol used to convey multiple related messages (e.g., file transfers, Web pages, etc.).

1.04 QUALITY ASSURANCE

A. Compatibility:

1. System shall have documented history of compatibility by design for minimum of 15 years.
2. Future compatibility shall be supported for no less than 10 years.
3. Compatibility shall be defined as:
 - a. Ability to upgrade existing microelectronic controllers to current level of technology and extend new microelectronic controllers on previously installed network.
 - b. Ability for any existing microelectronic controller microprocessor to be connected and directly communicate with new microelectronic controllers without bridges, routers, or protocol converters.

1.05 SYSTEM PERFORMANCE

A. System shall conform to the following performance standards:

1. Graphic Display:
 - a. Minimum of 20 dynamic points.
 - b. Current data displayed within 20 seconds of request.
2. Graphic Refresh: System shall update dynamic points with current data within 30 seconds.
3. Object Command:
 - a. Maximum time between command of binary object by operator and reaction by device shall be 10 seconds.
 - b. Analog objects shall start to adjust within 10 seconds.
4. Object Scan: Changes of state and change of analog values shall be transmitted over high-speed network such that any data used or displayed at controller or workstation will be current, within prior 60 seconds.
5. Alarm Response Time: Maximum time from when object goes into alarm to when it is annunciated at workstation shall not exceed 45 seconds.
6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every 5 seconds. Select execution times consistent with mechanical process under control.
7. Performance: Programmable Controllers shall be able to execute DDC PID control loops at selectable frequency from at least once every 5 seconds. Controller shall scan and update process value and output generated by this calculation at this same frequency.

8. Multiple Alarm Annunciation: Workstations on network shall receive alarms within 5 seconds of each other.
9. Reporting Accuracy: Table 1 lists minimum acceptable reporting accuracies for values reported by specified system.

Table 1 Reporting Accuracy	
Measured Variable	Reported Accuracy
Space temperature	$\pm 0.5^{\circ}\text{C}$ [$\pm 1^{\circ}\text{F}$]
Ducted air	$\pm 1.0^{\circ}\text{C}$ [$\pm 2^{\circ}\text{F}$]
Outside air	$\pm 1.0^{\circ}\text{C}$ [$\pm 2^{\circ}\text{F}$]
Delta-T	$\pm 0.15^{\circ}\text{C}$ [$\pm 0.25^{\circ}\text{F}$]
Relative humidity	$\pm 5\%$ RH
Air flow (terminal)	$\pm 10\%$ of reading ¹
Air flow (measuring stations)	$\pm 5\%$ of reading
Air Pressure (ducts)	± 25 Pa [± 0.1 " WC]
Electrical Power	5% of reading ²
¹ (10%-100% of scale) (cannot read accurately below 10%).	
² Not including utility supplied meters.	

1.06 EXTRA MATERIALS

- A. Furnish, tag, and box for shipment and storage the following special tools:

Item	Quantity
Special tools required to maintain or dismantle	One complete set for each different size unit

PART 2 PRODUCTS

2.01 STANDALONE DDC CONTROL SYSTEM

- A. Standalone Custom Controllers:

1. General:
 - a. Physical Characteristics:
 - 1) Environment: Controller hardware shall be suitable for anticipated ambient conditions.

- 2) Controller shall be mounted in locking enclosure. Refer to Section 23 09 13, HVAC Controls, Field Components, and Instruments, Article HVAC Control Panels (HCP), for enclosure details.
 - 3) Controller used outdoors or in wet ambient conditions shall be mounted within waterproof enclosure and rated for operation at minus 40 degrees C to 65 degrees C (minus 40 degrees F to 150 degrees F).
 - 4) Controller used in conditioned ambient shall be mounted in dust-proof enclosure and shall be rated for operation at 0 degree C to 50 degrees C (32 degrees F to 120 degrees F).
 - 5) Clock:
 - a) Real time clock that shall remain active during power failure for up to 7 days under normal operating conditions.
 - b) When controller is used with higher level system, time clock shall be automatically synchronized with system controller.
- b. Functional Characteristics:
- 1) Microprocessor based true no-host system; no PC or "host" computer required to perform control functions or communications, capable of standalone operation, providing control functions without being connected to a network.
 - 2) Software:
 - a) Software for controller setup, programming, and editing of database.
 - b) In English language.
 - c) IBM PC compatible.
 - d) PI and PID control loops.
 - e) Programming subroutine blocks available to be used in any combination for program modifications.
 - f) As a minimum, routines shall include:
 - (1) Time- or event-based scheduling.
 - (2) Offline, fill-in-the-blank programming of controller.
 - (3) Operating and programming error messages and diagnostics.
 - (4) Database save and restore.
 - (5) Adaptive optimum start/stop.
 - (6) Run time totalization.
 - (7) Alarm detection and dial out.
 - (8) Historical Trending: Trend data shall be fully compatible with Microsoft Access and Excel.

- 3) Documentation:
 - a) Provide to Contracting Officer, before completion of Project:
 - (1) Electronic copy of programming tool software.
 - (2) Electronic copy of control logic program used in controller.
 - (3) User's manual for software operation.
 - (4) Include appropriate cable for interconnection between PC serial port and controller.
- 4) Electrical:
 - a) Power:
 - (1) On/Off switch inside cabinet.
 - (2) Controller Power: 24V, 50/60 Hz.
 - (3) On-board isolation transformer or dedicated transformer, rated at minimum of 125 percent of maximum power consumption, and shall be fused or current limiting type.
 - (4) Battery Backup: Local controller must provide backup of all memory for period of 7 days under normal operating conditions if commercial power to controller is interrupted.
 - b) Connections:
 - (1) Plug-in terminal blocks, in accordance with requirements of Section 23 09 13, HVAC Controls, Field Components, and Instruments, Article HVAC Control Panels (HCP).
 - (2) Logic card containing active electrical components shall be easily removable from wiring base without use of tools.
 - (3) Provide quick disconnect interconnection with electrical wiring.
 - c) Immunity to Power and Noise:
 - (1) Controller shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform orderly shutdown below 80 percent nominal voltage.
 - (2) Operation shall be protected against electrical noise of 5 Hz to 120 Hz and from keyed radios up to 5W at 1 meter (3 feet).
 - (3) Provide filters, as required to comply with applicable FCC regulations.
 - d) Power Loss/Restart:
 - (1) Tolerant of power failures.
 - (2) Memory shall be nonvolatile, or unit shall hold memory up to 30 days minimum on backup batteries.

- (3) When power failure has occurred and power is restored, controller shall restart automatically and without operator intervention.
 - (4) Restart Procedures:
 - (a) Come online.
 - (b) Update monitored functions.
 - (c) Implement special facility startup strategies as required.
 - (5) Resume operation based on current time and status.
- c. Performance Characteristics:
 - 1) Provide adequate number of controllers to provide performance specified in Article System Performance and as shown.
 - 2) Set points, controller operating system, and programming shall be resident in EEPROM, within controller.
 - 3) Capable of executing DDC loops and custom control routines.
 - 4) DDC loop control programming with editable proportional, integral, and derivative control parameters.
 - 5) DDC loops shall have editable high and low output limits as well as editable failure output values.
 - 6) Software control reaction time shall be programmable to be no slower than 5 seconds.
 - 7) DDC loops shall be programmable to operate at user defined intervals with maximum frequency of 1 second.
 - 8) Sufficient memory to support its operating system, database, and programming requirements.
 - 9) Diagnostics:
 - a) Controller shall contain the following diagnostic information:
 - (1) LEDs indicating status of main board, communications Transmit and Receive, and Binary Output ON/OFF.
 - (2) Information regarding failure of analog or change of state of any binary point. Controller must then capture an image of all points at value or state at time of event/alarm. This data must be able to be viewed from a set of screens that are labeled with alarm point, date and time of occurrence, and cause of failure.
 - (3) Self test procedure for checking communications and verifying functionality of memory and database.
 - (4) Upon detection of communication loss, retransmission shall be attempted.

- (5) Continuing failure shall cause trouble signal to be annunciated at HCP.
- 10) External Communication:
 - a) Allow service tool editing of programming while controller is in total standalone operation.
 - b) Include RS232 port for connection to portable operator interface device for commissioning, adjustment, diagnosis, upload, download, and editing of data.
 - c) Provide port for connection to LAN.
- 11) Input/Output:
 - a) Controller shall be configurable using modular Input/Output points to allow for system customization and expansion.
 - b) Each controller shall monitor analog inputs and analog outputs and perform minimum 10-bit A-to-D and 8-bit D-to-A conversion.
 - c) Local controller shall receive signals from industry standard sensors and input devices and directly control actuators and control devices.
 - d) Controller shall have capability to monitor and control the following types of inputs and outputs:
 - (1) Analog Inputs:
 - (a) Current: 4 mA to 20 mA.
 - (b) Voltage: 0V dc to 10V dc.
 - (c) Thermistor.
 - (d) 1,000 Ohm RTD.
 - (2) Binary Inputs:
 - (a) Isolated dry contact closure.
 - (b) Pulse.
 - (3) Analog Outputs:
 - (a) Current: 4 mA to 20 mA.
 - (b) Voltage: 0V dc to 10V dc.
 - (4) Binary Outputs: 24V ac, Triac switch.
 - e) Output points must be available with manual software and hardware overrides with feedback indication that an output is presently overridden.
 - f) Port Isolation:
 - (1) Individually, electrically isolated to protect against transients, spikes, and power surges.
 - (2) Optically isolated from each other, controller circuit board, and from power wiring.
 - (3) Optical isolation either as integral component to controller or as a separate interface device between controller and field wiring.

- g) Quantity of I/O Points: As required to provide equipment function as described in sequences of operation.
- 12) Expansion Capability:
 - a) Capable of accepting expansion modules for addition of:
 - (1) Memory.
 - (2) Input/Output points.
- 13) Trending:
 - a) Minimum of eight user selectable points shall be able to be logged, with a minimum of 24 Samples per log.
 - b) Start and stop times for each trend log shall be definable or continuous.
- 14) User Interface:
 - a) Local keypad and display shall be provided for each controller for interrogating and editing data.
 - b) Keypad and display shall comply with Paragraph Human Machine Interface (HMI).

B. Human Machine Interface (HMI):

- 1. LCD Display Terminal:
 - a. Physical Characteristics:
 - 1) Each DDC Controller shall include LCD display operator interface allowing user to monitor point status, view alarms, and control output points.
 - 2) Factory installed on controller, with option for remote mounting at least 250 feet from controller.
 - 3) Capable of accepting user defined, alpha-numeric passcodes, providing discrete user defined levels of security.
 - 4) Able to display current state of any input/output point connected to controller.
 - 5) Able to modify current state of any output point connected to controller, given appropriate security level.
 - 6) Capable of displaying controller status, faults, and diagnostics including:
 - a) Communications errors.
 - b) Controller software versions.
 - c) Input/output point alarms.
 - d) Controller operating mode.
 - 7) Keypad shall have the following:
 - a) Minimum four-line by 20-character backlit LCD display.
 - b) Keypad for interrogating and editing data.
 - c) System security password.
 - d) Set point limits.

- b. Functional Characteristics:
 - 1) Operator interface shall allow display, setup, and adjustment of:
 - a) Heating and cooling occupied and unoccupied set points.
 - b) Viewing alarms.
 - c) Monitoring temperatures, operating modes, ON/OFF statuses, and failure conditions.
 - d) Units of temperature.
 - 2) Remote Communications:
 - a) Provide modem to allow dial-in for complete EIA/TIA 232F access for system monitoring, control, and programming.
 - b) Possible to retrieve and save system panel's database and to download that database from remote location over standard telephone lines.
 - c) Enable auto-dial out of alarms including equipment failures and temperatures out-of-range for automatic annunciation and logging at remote location.
- c. Performance Characteristics: None.

2.02 NETWORK COMMUNICATION

A. Physical Characteristics:

- 1. Operator Workstations and Building Controllers shall be installed on a primary high-speed peer-to-peer network.
- 2. Custom Application Controllers and Application Specific Controllers may be installed on either primary high-speed peer-to-peer network, or Secondary network.
- 3. Provide all communication media, connectors, repeaters, hubs, and routers necessary for network.
- 4. Building Controllers shall have communications port for connections with operator interfaces using BACnet Data Link/Physical layer protocol.

B. Functional Characteristics:

- 1. Control products for Networked DDC Control System shall comprise an interoperable network.
- 2. Provide device on network with minimum 28,000 baud modem that will allow remote operator interface using BACnet Data Link/Physical layer protocol. Modem shall allow for communication with controllers on this network as described below.

3. Communications services over network shall result in operator interface and value passing that is transparent to network architecture as follows:
 - a. Connection of operator interface device to any one controller on network shall allow operator to interface with other controllers as if that interface were directly connected to other controllers.
 - b. Data, status information, reports, system software, custom programs for controllers shall be available for viewing and editing from any controller on network.
 - c. Database values (i.e., points, software variable, custom program variables) of any one controller shall be readable by any other controller on network.
 - d. This value passing shall be automatically performed by controller when reference to point name not located in that controller is entered into controller's database.
 - e. Operator/installer shall not be required to set up any communications services to perform network value passing.
4. Time clocks in controllers shall be automatically synchronized daily.

C. Performance Characteristics: None.

2.03 NETWORK HUMAN-MACHINE INTERFACE

A. Physical Characteristics:

1. Operator Interface:
 - a. Furnish PC based operator workstation.
 - b. Workstation shall be able to access all information in system.
 - c. Workstation shall reside on same high-speed network as building controllers and shall also be able to dial into system.
2. Hardware:
 - a. Each operator workstation shall consist of the following:
 - 1) Personal Computer:
 - a) Furnish one IBM compatible PC.
 - b) Features:
 - (1) Monitor: 17-inch, minimum, SVGA.
 - (2) CPU: 13th Gen Intel Core i7-13700, minimum, and operate at a minimum of 2.1 GHz.
 - (3) RAM: 256 Megabytes, minimum.
 - (4) Hard Drive: 500 GB capacity, minimum, with minimum access time of 12 milliseconds.
 - (5) Mouse: Two buttons.
 - c) Furnish required serial, parallel, and network communication ports, and cables for proper system operation.
 - 2) Ethernet: Gigabit Ethernet Port.

- 3) BACnet:
 - a) Workstation shall use Read (Initiate) and Write (Execute) Services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE 135, to communicate with BACnet objects in network.
 - b) Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.

B. Functional Characteristics:

1. Communications: Workstation information access shall use BACnet Protocol.
2. System Software:
 - a. Operating System:
 - 1) Commercially available, concurrent multitasking.
 - 2) Support use of other common software applications that operate under DOS or Microsoft Windows.
 - 3) Acceptable operating systems are Windows 10 or later versions of Windows.
 - b. System Graphics:
 - 1) Operator workstation software shall be graphically oriented.
 - 2) System shall allow display of up to 10-graphic screens at once for comparison and monitoring of system status.
 - 3) Provide method for operator to easily move between graphic displays and change size and location of graphic displays on screen.
 - 4) Able to be modified while online.
 - 5) Operator with proper password level shall be able to add, delete, or change dynamic points on graphic.
 - 6) Dynamic points shall include analog and binary values, dynamic text, static text, video, and animation files.
 - 7) Ability to show animation of equipment.
 - c. Custom Graphics:
 - 1) Created with use of commonly available graphics packages, such as PC Paint.
 - 2) Graphics generation package shall create and modify graphics that are saved in industry standard formats such as PCX, BMP, GIF, and JPEG.
 - 3) Graphics generation package shall also provide capability of capturing or converting graphics from other programs such as Designer, or AutoCAD.
 - d. Graphics Library:
 - 1) Complete library of standard HVAC equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators.

- 2) Include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork.
- 3) File format compatible with graphics generation package program.
- e. Engineering Units:
 - 1) Allow for selection of desired engineering units (i.e., inch pound or SI) in system.
 - 2) Unit selection shall be able to be customized by locality to select desired units for each measurement.
 - 3) Engineering units on this project shall be Standard Inch Pound.
3. System Applications. Each workstation shall provide operator interface and offline storage of system information. Provide the following applications at each workstation:
 - a. Automatic System Database Save and Restore:
 - 1) Store on hard disk copy of current database of each building controller.
 - 2) Database shall be updated whenever change is made in any panel in system.
 - 3) Storage of data shall be automatic and not require operator intervention.
 - 4) In the event of database loss in building management panel, first workstation to detect loss shall automatically restore database for that panel.
 - b. Manual Database Save and Restore:
 - 1) System operator with proper password clearance shall be able to archive database from any system panel and store on magnetic media.
 - 2) Operator shall also be able to clear panel database and manually initiate download of specified database to any panel in system.
 - c. System Configuration:
 - 1) Workstation software shall provide graphical method of configuring system.
 - 2) User with proper security shall be able to add new devices and assign modems to devices.
 - 3) This shall allow for future system changes or additions.
 - d. Online Help:
 - 1) Context sensitive to assist operator in operation and editing of system.
 - 2) Available for all applications and shall provide relevant data for that particular screen.
 - 3) Additional help information shall be available through use of hypertext.

- e. Security:
 - 1) Each operator shall be required to log on to system with username and password in order to view, edit, add, or delete data. System security shall be selectable for each operator.
 - 2) System supervisor shall have ability to set passwords and security levels for other operators.
 - 3) Each operator password shall be able to restrict operators' access for viewing and/or changing each system application, full screen editor, and object.
 - 4) Each operator shall automatically be logged off system if no keyboard or mouse activity is detected.
 - 5) Auto logoff time shall be set per operator password.
 - 6) System security data shall be stored in encrypted format.
- f. System Diagnostics:
 - 1) System shall automatically monitor operation of workstations, printers, modems, network connections, building management panels, and controllers.
 - 2) Failure of any device shall be annunciated to operator.
- g. Alarm Processing:
 - 1) Any object in system shall be configurable to alarm in and out of normal state.
 - 2) Operator shall be able to configure alarm limits, warning limits, states, and reactions for each object in system.
 - 3) Alarm Reactions:
 - a) Operator shall be able to determine what actions, if any, are to be taken, by object (or point), during alarm.
 - b) Actions shall include logging, printing, starting programs, displaying messages, dialing out to remote stations, paging, providing audible annunciation, or displaying specific system graphics.
 - c) Each of these actions shall be configurable by workstation and time of day.
 - d) Object in alarm that has not been acknowledged within operator specified time period shall be rerouted to alternate operator specified alarm receipt device.
 - 4) Binary Alarms:
 - a) Each binary object shall be set to alarm based on operator specified state.
 - b) Capability to disable alarming when associated equipment is turned off or is being serviced.
 - 5) Analog Alarms:
 - a) Each analog object shall have both high and low alarm limits and warning limits.
 - b) Alarming must be able to be automatically and manually disabled.

- h. Trend Logs:
 - 1) Operator shall be able to define custom trend log for any data in system.
 - 2) This definition shall include interval, start-time, and stop-time. Trend intervals of 1, 5, 15, 30, and 60 minutes as well as once a shift (8 hours), once a day, once a week, and once a month shall be selectable.
 - 3) Trends shall start based on the hour. Each trend shall accommodate up to 64 system objects.
 - 4) System operator with proper password shall be able to determine how many samples are stored in each trend.
 - 5) Trend Data:
 - a) Sampled and stored on building controller panel and archived on hard disk.
 - b) Able to be viewed and printed from operator interface software.
 - c) Storable in tab delimited ASCII format for use by other industry standard word processing and spreadsheet packages.
- i. Alarm and Event Log:
 - 1) Operator shall be able to view logged system alarms and events from any location in system.
 - 2) Events shall be listed chronologically.
 - 3) Operator with proper security level may acknowledge and clear alarms.
 - 4) All that have not been cleared by operator shall be archived to hard disk on workstation.
- j. Object and Property Status and Control:
 - 1) Provide method for operator with proper password protection to view, and edit if applicable, status of any object and property in system.
 - 2) Statuses shall be available by menu, on graphics, or through custom programs.
- k. Clock Synchronization:
 - 1) Real time clocks in building control panels and workstations shall be synchronized on command of operator.
 - 2) System shall also be able to automatically synchronize system clocks daily from any operator-designated device in system.
 - 3) System shall automatically adjust for daylight savings and standard time, if applicable.
- 4. Reports and Logs:
 - a. Reporting package shall allow operator to select, modify, or create reports.
 - b. Each report shall be definable as to data content, format, interval, and date.

- c. Report data shall be archived on hard disk for historical reporting.
 - d. Ability for operator to obtain real time logs of designated lists of objects.
 - e. Reports and logs shall be stored on PC hard disk in format that is readily accessible by other standard software applications, including spreadsheets and word processing.
 - f. Reports and logs shall be readily printed to system printer.
 - g. Operator shall be able to designate reports that shall be printed or stored to disk at selectable intervals.
 - h. Custom Reports:
 - 1) Capable for operator to easily define any system data into daily, weekly, monthly, or annual report.
 - 2) Time and date stamped and shall contain report title and name of facility.
 - i. Standard Reports: The following standard system reports shall be provided for this Project. Reports shall be readily customized to Project by Contracting Officer.
 - 1) Electrical Meter Report:
 - a) Monthly report showing daily electrical consumption and peak electrical demand for each building meter.
 - b) Annual (12 months) summary report showing monthly electrical consumption and peak demand for each meter.
 - 2) Weather Data Report:
 - a) Monthly report showing daily minimum, maximum, and average outdoor air temperature, and number of heating and cooling degree-days for each day.
 - b) Annual (12 months) report showing minimum, maximum, and average outdoor air temperature for month, and number of heating and cooling degree days for each month.
 - 3) Tenant Override Reports:
 - a) Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC and lighting services.
 - b) Annual (12 months) report that shows override usage on monthly basis.
5. Workstation Applications Editor:
- a. General:
 - 1) Each PC workstation shall support full screen editing of system applications.
 - 2) Editor for each application at PC workstation.
 - 3) Applications shall be downloaded and executed at appropriate controller panels.
 - 4) Full screen editor for each type controller and application that shall allow operator with proper password to view and

- change configuration, name, control parameters, and system set points.
- b. Scheduling:
 - 1) Editor for scheduling application shall be provided at each workstation.
 - 2) Monthly calendar for each schedule.
 - 3) Exception schedules and holidays shall be shown clearly on calendar.
 - 4) Capable of allowing several related objects to follow a schedule.
 - 5) Advance and delay time for each object shall be adjustable from this master schedule.
 - 6) Operator with proper password level shall be able to modify schedule.
 - 7) Schedules shall be able to be easily copied between objects and/or dates.
 - c. Equipment Coordination:
 - 1) Full screen editor shall allow equipment to be grouped for proper operation as specified in sequence of operations.
 - 2) Include coordination of VAV boxes with their associated Air Handling Equipment.
 - d. Custom Application Programming:
 - 1) Provide tools to create, modify, and debug custom application programming.
 - 2) Operator shall be able to create, edit, and download custom programs at same time that other system applications are operating.
 - 3) System shall be fully operable while custom routines are edited, compiled, and downloaded.
 - 4) Programming language shall have the following features:
 - a) English language oriented and based on syntax of programming languages such as BASIC. It shall allow for free form or fill in the blank programming. Alternatively, programming language can be graphically based using function blocks as long as blocks are available that directly provide functions listed below, and that custom or compound function blocks can be created.
 - b) Full screen character editor/programming environment. Editor shall be cursor/mouse driven and allow user to insert, add, modify, and delete code from custom programming. It shall also incorporate word processing features such as cut/paste and find/replace.
 - c) Allow independently executing program modules to be developed. Each module shall be able to independently enable and disable other modules.

- d) Editor/programming environment shall have debugging/simulation capability that allows user to step through program and to observe intermediate values and results. Debugger shall also provide error messages for syntax and execution errors.
 - e) Support conditional statements (if/then/else/else-if) using compound Boolean (and, or, and not) and/or relations (equal, less than, greater than, not equal) comparisons.
 - f) Support floating point arithmetic using the following operators: +, -, /, x, square root, and xy.
 - g) The following mathematical functions shall also be provided: natural log, log, absolute value, and minimum/maximum value from a list of values.
 - h) Predefined variables that represent clock time, day of week, and date. Variables that provide interval timing shall also be available. Language shall allow for computations using these values.
 - i) Ability to predefined variables representing status and results of System Software, and shall be able to enable, disable, and change values of BACnet objects in system.
6. Portable Operator's Terminal:
- a. Provide one capable of accessing system data.
 - b. Ability to connect to any point on system network or directly to any controller for programming, setup, and troubleshooting.
 - c. BACnet:
 - 1) Shall use Read (Initiate) and Write (Execute) Services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE 135, to communicate with BACnet objects in network.
 - 2) Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
 - d. IBM compatible PC, including software and hardware required. PC shall contain at minimum:
 - 1) 13th Gen Intel Core i7-13700 Processor.
 - 2) 256 MB RAM.
 - 3) 500 GB Hard Drive.

C. Performance Characteristics: None.

2.04 NETWORKED DDC CONTROLLERS

A. Controller Software:

1. Physical Characteristics:
 - a. General:
 - 1) Provide applications software for building and energy management.
 - 2) Software applications shall reside and run in system controllers.
 - 3) Editing of applications shall occur at operator workstation.
2. Functional Characteristics:
 - a. System Security:
 - 1) User access shall be secured using individual security passwords and usernames.
 - 2) Passwords shall restrict user to only objects, applications, and system functions as assigned by system manager.
 - 3) User logon/logoff attempts shall be recorded.
 - 4) System shall protect itself from unauthorized use by automatically logging off following last keystroke. Delay time shall be user definable.
 - b. Scheduling:
 - 1) General:
 - a) Provide capability to schedule each object or group of objects in system.
 - b) Each schedule shall include capability for start, stop, optimal start, optimal stop, and night economizer actions.
 - c) Each schedule may consist of up to 10 events.
 - d) When group of objects are scheduled together, provide capability to define advances and delays for each member.
 - 2) Weekly Schedule: Separate schedules for each day of the week.
 - 3) Exception Schedule:
 - a) Ability for operator to designate any day of the year as an exception schedule.
 - b) Shall override standard schedule for that day.
 - c) May be defined up to a year in advance.
 - d) Once executed, it will be discarded and replaced by standard schedule for that day of the week.
 - 4) Holiday Schedule:
 - a) Capability for operator to define up to 99 special or holiday schedules.
 - b) May be placed on scheduling calendar and repeated each year.

- c) Operator shall be able to define length of each holiday period.
- c. Alarm Reporting:
 - 1) Operator shall be able to determine action to be taken in event of alarm.
 - 2) Alarms shall be routed to appropriate workstations based on time and other conditions.
 - 3) Alarm shall be able to start programs, be logged in event log, printed, display custom messages or graphics.
- d. Remote Communications:
 - 1) Ability to dial out in event of alarm.
 - 2) Receivers shall include PC Workstations and alpha-numeric pagers.
 - 3) Alarm message shall include name of calling location, device that generated alarm, and alarm message itself.
 - 4) Operator shall be able to remotely access and operate system using dial-up communications in same format and method used on Site under Paragraph Operator Interface.
- e. Maintenance Management: System shall monitor equipment status and generate maintenance messages based upon user designated run time, starts, and/or calendar date limits.
- f. PID (Proportional-Integral-Derivative) Control:
 - 1) Algorithm with direct or reverse action, and anti-wind-up.
 - 2) Algorithm shall calculate time-varying analog value used to position output or stage series of outputs.
 - 3) Controlled variable, set point, and PID gains shall be user selectable.
 - 4) Set point shall optionally be chosen to be reset schedule.
- g. Staggered Start: Shall prevent controlled equipment from simultaneously restarting after power outage. Order that equipment (or groups of equipment) is started, along with time delay between starts shall be user selectable.
- h. System Calculations:
 - 1) Software to allow instantaneous power (e.g., kW), flow rates in gpm to be accumulated and converted to energy usage data.
 - 2) Algorithm shall calculate the following:
 - a) Sliding-window kW demand value.
 - b) Energy usage and weather data (heating and cooling degree days).
 - c) Items shall all be available for daily, previous day, monthly and previous month.
 - 3) Anti-Short Cycling: Binary output points shall be protected from short cycling. This feature shall allow minimum on-time and off-time to be selected.
- 3. Performance Characteristics: None.

B. Building Controllers:

1. Physical Characteristics:

a. Environment:

- 1) Controller hardware shall be suitable for anticipated ambient conditions.
- 2) Controller used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosure and shall be rated for operation at minus 40 degrees C to 65 degrees C (minus 40 degrees F to 150 degrees F).
- 3) Controller used in conditioned ambient shall be mounted in dust-proof enclosure and shall be rated for operation at 0 degree C to 50 degrees C (32 degrees F to 120 degrees F).

b. Keypad:

- 1) Local keypad and display shall be provided for each controller.
- 2) Provided for interrogating and editing data.
- 3) Optional system security password shall be available to prevent unauthorized use of keypad and display.
- 4) If manufacturer does not provide keypad display, provide portable operator terminal.

2. Functional Characteristics:

a. Sufficient memory to support its operating system, database, and programming requirements.

b. Data shall be shared between networked Building Controllers.

c. Operating system of Controller shall manage input and output communications signals to allow distributed controllers to share real and virtual point information and allow central monitoring and alarms.

d. Controllers that perform scheduling shall have real time clock.

e. Continually check status of its processor and memory circuits. If abnormal operation is detected, controller shall:

- 1) Assume predetermined failure mode.
- 2) Generate alarm notification.

f. BACnet:

- 1) Building Controller shall communicate with other BACnet objects on primary network using Read (Execute and Initiate) and Write (Execute and Initiate) Property services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE 135.
- 2) Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.

g. Communications:

- 1) Each Building Controller shall reside on primary high-speed peer to peer network.

- 2) Each Building Controller shall also perform routing if connected to secondary network of Custom Application and Application Specific Controllers.
- 3) Building Controller shall provide service communications port for connection to Portable Operators Terminal.
- h. Serviceability: Provide diagnostic LEDs for power, communications, and processor. Wiring connections shall be made to field removable, modular terminal strips or to termination card connected by ribbon cable.
- i. Memory: Building Controller shall maintain BIOS and programming information in event of power loss for at least 72 hours.
- j. Immunity to Power and Noise:
 - 1) Controller shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform orderly shutdown below 80 percent nominal voltage.
 - 2) Operation shall be protected against electrical noise of 5 Hz to 120 Hz and from keyed radios up to 5 watts at 1 meter (3 feet).
- k. Transformer: Power supply for Controller shall be rated at minimum of 125 percent of maximum power consumption and shall be fused or current limiting type.
- 3. Performance Characteristics:
 - a. Provide adequate number of Building Controllers to provide performance specified in Article System Performance.
 - b. Manage global strategies described in Paragraph Controller Software.
 - c. Microprocessor based, capable of stand-alone operation, and shall continue to provide control functions without being connected to network.

C. Custom Application Controllers:

- 1. Physical Characteristics:
 - a. Communications:
 - 1) Each controller shall reside on secondary network.
 - 2) Controller shall provide service communications port for connection to Portable Operator's Terminal.
 - b. Environment: Controller hardware shall be suitable for anticipated ambient conditions.
 - 1) Controller used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosure and shall be rated for operation at minus 40 degrees C to 65 degrees C (minus 40 degrees F to 150 degrees F).

- 2) Controller used in conditioned ambient shall be mounted in dust-proof enclosure and shall be rated for operation at 0 degree C to 50 degrees C (32 degrees F to 120 degrees F).
- c. Keypad:
 - 1) Local keypad and display shall be provided for each controller.
 - 2) Provided for interrogating and editing data.
 - 3) Optional system security password shall be available to prevent unauthorized use of keypad and display.
 - 4) If manufacturer does not provide keypad display, provide portable operator terminal.
2. Functional Characteristics:
 - a. Sufficient memory to support its operating system, database, and programming requirements.
 - b. Data shall be shared between networked controllers.
 - c. Operating system of controller shall manage input and output communications signals to allow distributed controllers to share real and virtual point information and allow central monitoring and alarms.
 - d. Controllers that perform scheduling shall have real-time clock.
 - e. Continually check status of its processor and memory circuits. If abnormal operation is detected, controller shall:
 - 1) Assume predetermined failure mode.
 - 2) Generate alarm notification.
 - f. BACnet:
 - 1) Controller shall communicate with other BACnet objects on primary network using Read (Execute and Initiate) and Write (Execute and Initiate) Property services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE 135.
 - 2) Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
 - g. Serviceability: Provide diagnostic LEDs for power, communications, and processor. Wiring connections shall be made to field removable, modular terminal strips or to termination card connected by ribbon cable.
 - h. Memory: Controller shall maintain BIOS and programming information in event of power loss for at least 72 hours.
 - i. Immunity to Power and Noise:
 - 1) Controller shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform orderly shutdown below 80 percent nominal voltage.
 - 2) Operation shall be protected against electrical noise of 5 Hz to 120 Hz and from keyed radios up to 5 watts at 1 meter (3 feet).

- j. Transformer: Power supply for controller shall be rated at minimum of 125 percent of maximum power consumption and shall be fused or current limiting type.
- 3. Performance Characteristics:
 - a. Provide adequate number of Custom Application controllers to provide performance specified in Article System Performance.
 - b. Shall manage local strategies described in Paragraph Controller Software.
 - c. Microprocessor based, capable of standalone operation, and shall continue to provide control functions without being connected to network.

D. Application Specific Controllers:

- 1. Physical Characteristics:
 - a. Communications:
 - 1) Each controller shall reside on secondary network.
 - 2) Controller shall provide service communications port for connection to Portable Operators Terminal. Connection shall be extended to space temperature sensor where shown.
 - 3) Environment: Controller hardware shall be suitable for anticipated ambient conditions.
 - 4) Controller used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosure and shall be rated for operation at minus 40 degrees C to 65 degrees C (minus 40 degrees F to 150 degrees F).
 - 5) Controller used in conditioned ambient shall be mounted in dust-proof enclosure and shall be rated for operation at 0 degree C to 50 degrees C (32 degrees F to 120 degrees F).
- 2. Functional Characteristics:
 - a. Contain sufficient I/O capacity to control target system.
 - b. BACnet:
 - 1) Controller shall communicate with other BACnet objects on primary network using Read (Execute and Initiate) and Write (Execute and Initiate) Property services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE 135.
 - 2) Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
 - c. Serviceability: Provide diagnostic LEDs for power, communications, and processor. Wiring connections shall be made to field removable, modular terminal strips or to termination card connected by ribbon cable.
 - d. Memory: Controller shall use nonvolatile memory and maintain BIOS and programming information in event of power loss.

- e. Immunity to Power and Noise:
 - 1) Controller shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform orderly shutdown below 80 percent nominal voltage.
 - 2) Operation shall be protected against electrical noise of 5 Hz to 120 Hz and from keyed radios up to 5 watts at 1 meter (3 feet).
 - f. Transformer: Power supply for controller shall be rated at minimum of 125 percent of maximum power consumption and shall be fused or current limiting type.
3. Performance Characteristics:
- a. Performance:
 - 1) Provide number of application specific controllers to provide performance specified in Article System Performance.
 - 2) Microprocessor based, capable of standalone operation and shall continue to provide control functions without being connected to network.

E. Controller Input/Output Interface:

- 1. Physical Characteristics: None.
- 2. Functional Characteristics:
 - a. Hard-wired inputs and outputs may tie into system through building, custom, or application specific controllers.
 - b. Protected such that shorting of point to itself, another point, or ground will cause no damage to controller.
 - c. Protected from voltage up to 24V of any duration, such that contact with this voltage will cause no damage to controller.
 - d. Binary Inputs:
 - 1) Shall allow monitoring of ON/OFF signals from remote devices.
 - 2) Shall provide wetting current of at least 12 mA to be compatible with commonly available control devices.
 - e. Pulse Accumulation Input Points: Conform to requirements of Binary Input points and accept up to two pulses per second for pulse accumulation and shall be protected against effects of contact bounce and noise.
 - f. Analog Inputs:
 - 1) Allow monitoring of low voltage (0V dc to 10V dc), current (4 mA to 20 mA), or resistance signals (thermistor, RTD).
 - 2) Compatible with and field configurable to commonly available sensing devices.

- g. Binary Outputs:
 - 1) Provide for ON/OFF operation or pulsed low voltage signal for pulse width modulation control.
 - 2) Selectable for either normally-open or normally-closed operation.
 - h. Analog Outputs:
 - 1) Shall provide a modulating signal for control of end devices.
 - 2) Shall provide either 0V dc to 10V dc or 4 mA to 20 mA signal as required to provide proper control of output device.
3. Performance Characteristics: None.

PART 3 EXECUTION

3.01 GENERAL

- A. Refer to Section 23 09 00, Instrumentation and Control Devices for HVAC, for requirements.

END OF SECTION