ADDENDUM NUMBER 3

Giles County Public Schools Macy McClaugherty Elementary/Middle School Renovations Pearisburg, Virginia ZMM ARCHITECTS ENGINEERS

A/E Commission No. 2022088

November 2, 2023

This addendum contains 1 pages and the listed attachments. These form a part of the bidding documents and modify the Project Manual and Drawings. Acknowledge receipt of this addendum on the bid form. Failure to acknowledge the receipt of this addendum may disqualify the bid.

SPECIFICATIONS:

Section 250923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

1. Add section in its entirety as attached to this addendum.

END OF ADDENDUM NUMBER 3

Addendum Total No. of Pages: 1

Attachments to Addendum No. 3:

Section 250923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

SECTION 250923

DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

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.
- B. Related Requirements:
 - 1. Section 200553 "Identification for General Mechanical Piping and Equipment" for identification requirements for mechanical components.
 - 2. Section 250993 "Sequence of Operations for HVAC DDC" for control sequences.
 - 3. Section 260519 "Power Conductors and Cables" for balanced twisted pair communications cable.
 - 4. Section 260533 "Raceways and Boxes" for raceways for low-voltage control cable.
 - 5. Section 260553 "Identification for Electrical" for identification requirements for electrical components.

1.2 SUMMARY

- A. Provide a complete Direct Digital Control (DDC) Building Control System (BCS), suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and shown.
 - 1. All controllers, control interface hardware, services, installation, wiring, warranty, training, etc., shall be included and shall be new. Contractor is allowed to reuse tubing and conduit only.
 - 2. The BCS Contractor shall furnish all labor, materials, equipment, and service necessary for a complete and operating BCS. All labor, materials, tools, equipment, software, software licenses, software configurations and database entries, interfaces, wiring, installation, labeling, calibration, documentation, submittals, testing, training services, permits and licenses, transportation, administration, supervision, management, insurance, temporary protection, cleaning, cutting and patching, warranties, services, and items, even though these may not be specifically mentioned shall be included for a complete, fully functional temperature control system. This will include connecting any mechanical equipment furnished with a control interface device and contacting the equipment suppliers and/or manufacturers for information for the proper interface to the equipment being furnished.
 - 3. These apparatuses shall consist of, but not limited to, all necessary controllers, thermostats, sensing devices, valves, automatic dampers, damper motors, actuators, (except controllers, automatic dampers, valves, damper motors furnished with the HVAC

equipment), and with the necessary accessories for the complete control of all equipment specified.

- 4. The BCS Contractor shall provide remote login information to the Engineer of Record (EOR) to facilitate in reviewing system operation and compliance with these documents. Coordinate the remote login access requirements with the EOR and make security, restriction or level changes as requested.
- B. The system shall provide a graphical, web-based, operator interface that allows for instant access to any system through a standard browser. All hardware and software shall be modular in design to provide future expansion of both input/output points and processing/control functions.
- C. Communication: All System Application Controllers shall communicate via ETHERNET and shall reside on the owner's existing ETHERNET IT wide Area Network, operating at a minimum speed of 10/100 Mb/sec.
- D. Provide a system meeting the requirements of this Section and with the following characteristics:
 - 1. Except for Gateways, the control system shall be an open implementation of BACnet technology using ASHRAE 135 and Fox as the communications protocols. The system shall use standard ASHRAE 135 Objects and Properties and the Niagara Framework. The system shall use standard ASHRAE 135 Services and the Niagara Framework exclusively for communication over the network. Gateways to packaged units shall communicate with other DDC hardware using ASHRAE 135 or the Fox protocol exclusively and may communicate with packaged equipment using other protocols. The control system shall be installed such that any two ASHRAE 135 devices on the Internetwork can communicate using standard ASHRAE 135 Services.
 - 2. Install and configure control hardware to provide ASHRAE 135 Objects and Properties or Niagara Framework Objects as indicated and as needed to meet the requirements of this specification.
 - 3. Use Niagara Framework hardware and software exclusively for scheduling, trending, and communication. Use Niagara Framework or standard BACnet Objects and services for alarming. Use the Fox protocol for all communication between Niagara Framework Supervisory Gateways; use the ASHRAE 135 protocol for all other building communication. Niagara Framework Supervisory Gateway shall serve web pages as specified.
 - 4. Use Niagara Framework Version 4.0 or later.
 - 5. System architecture shall fully support a multi-vendor environment and be able to integrate third party systems via existing vendor protocols including, as a minimum, LonTalk, BACnet and MODBUS.
 - 6. System architecture shall provide secure Web access using any of the current versions of Microsoft Internet Explorer, Mozilla Firefox, or Google Chrome browsers from any computer on the owner's LAN.
 - 7. All control devices furnished with this Section shall be programmable directly from the Niagara 4 Workbench embedded toolset upon completion of this project. The use of configurable or programmable controllers that require additional software tools for post-installation maintenance shall not be acceptable.
 - 8. Any control vendor that shall provide additional BMS server software shall be unacceptable. Only systems that utilize the Niagara 4 Framework shall satisfy the requirements of this section.

- 9. The BMS server shall host all graphic files for the control system. Where applicable all graphics and navigation schemes for this project shall match those that are on the existing campus NiagaraAX or Niagara 4 Framework server.
- E. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the approved manufacturer's local field office. The approved manufacturer's local field office shall have a minimum of 3 years of installation experience with the manufacturer and shall provide documentation in the bid and submittal package verifying longevity of the installing company's relationship with the manufacturer when requested. Supervision, hardware and software engineering, calibration and checkout of the system shall be by the employees of the approved manufacturer's local field office and shall not be subcontracted. The control contractor shall have an in place support facility within 100 miles of the site with factory certified technicians and engineers, spare parts inventory and all necessary test and diagnostic equipment for the installed system, and the control contractor shall have 24 hours/day, 7 days/week emergency service available.
- F. Ownership: The Owner shall retain licenses to software for this project.
 - 1. The Owner shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition off this contractor. Such license shall grant use of all programs and application software to the Owner as defined by the manufacturer's license agreement, but shall protect the manufacturer's rights to disclosure of Trade Secrets contained within such software.
 - 2. The licensing agreement shall not preclude the use of the software by individuals under contract to the owner for commissioning, servicing or altering the system in the future. Use of the software by individuals under contract to the owner shall be restricted to use on the owner's computers and only for the purpose of commissioning, servicing, or altering the installed system.
 - 3. All project developed software, files and documentation shall become the property of the Owner. These include but are not limited to:
 - a. Server and workstation software
 - b. Application programming tools
 - c. Configuration tools
 - d. Network diagnostic tools
 - e. Addressing tools
 - f. Application files
 - g. Configuration files
 - h. Graphic files
 - i. Report files
 - j. Graphic symbol libraries
 - k. All documentation
- G. At substantial completion, all software provided shall be updated to the latest version.

1.3 QUALIFICATIONS OF BIDDER

- A. All bidders must be building automation contractors in the business of installing direct digital control building automation systems for a minimum of 10 years.
- B. All bidders must have an office within 100 miles of the project.
- C. All bidders must have a trained staff of application engineers, who have been certified by the manufacturer in the configuration, programming and service of the automation system.
- D. The following bidder is Base Bid:
 - 1. Alerton Controls, Hoffman Building Technologies, (540) 725 8701, (BASIS OF DESIGN)
 - 2. Automated Logic, Premier Energy Systems, (304) 252 1918
 - 3. ASI Controls, RDS, Inc., (304) 757 3314

1.4 DEFINITIONS

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.
- B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.
- C. ASC: Application Specific Controller.
- D. ASHRAE: American Society of Heating, Refrigeration, and Air Conditioning Engineers.
- E. BACnet Specific Definitions:
 - 1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
 - 2. BACnet Advanced Application Controller (B-AAC): A hardware device BTL Listed as a B-AAC. A control device which contains BIBBs in support of scheduling and alarming but otherwise has limited resources relative to a B-BC. It may be intended for specific applications and supports some degree of programmability.
 - 3. BACnet Advanced Operator Workstation (B-AWS): Monitoring and Control (M&C) Software BTL Listed as an Advanced Operator Workstation and includes the ability to manage scheduling, alarming and trending in an open manner. The B-AWS is the advanced operator's window into a BACnet system. It is primarily used to monitor the performance of a system and to modify parameters that affect the operation of a system.
 - 4. BACnet Application Specific Controller (B-ASC): A hardware device BTL Listed as a B-ASC. A controller with limited resources relative to a B-AAC. It is intended for use in a specific application and supports limited programmability.
 - 5. BACnet Building Controller (B-BC): A hardware device BTL Listed as a B-BC. A general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks including control and monitoring via direct digital control (DDC) of specific systems and data storage for trend information, time schedules, and

alarm data. Like the other BTL Listed controller types (B-AAC, B-ASC etc.) a B-BC device is required to support the server ("B") side of the ReadProperty and WriteProperty services, but unlike the other controller types it is also required to support the client ("A") side of these services. Communication between controllers requires that one of them support the client side and the other support the server side, so a B-BC is often used when communication between controllers is needed.

- 6. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
- 7. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
- 8. BACnet Operator Display (B-OD): A hardware device BTL Listed as a B-OD. A basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. The B-OD profile could be used for wall-mounted LCD devices, displays affixed to BACnet devices; hand-held terminals or other very simple user interfaces.
- 9. BACnet Operator Workstation (B-OWS): Monitoring and Control (M&C) Software BTL Listed as a B-OWS. An operator interface with limited capabilities relative to a B-AWS. The B-OWS is used for monitoring and basic control of a system, but differs from a B-AWS in that it does not support configuration activities, nor does it provide advanced troubleshooting capabilities.
- 10. BACnet Smart Actuator (B-SA): A hardware device BTL Listed as a B-SA. A simple control output device with limited resources; it is intended for specific applications.
- 11. BACnet Smart Sensor (B-SS): A hardware device BTL Listed as a B-SS. A simple sensing device with very limited resources.
- 12. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
- 13. BACnet Testing Laboratories (BTL) Listed: A device that has been certified by BACnet Testing Laboratory. Devices may be certified to a specific device profile, in which case the certification indicates that the device supports the required capabilities for that profile, or may be certified as "other".
- 14. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.
- F. BCN: Building Control Network. The network used by the Building Control System. Typically the BCN is a BACnet ASHRAE 135 network installed by the building control system contractor.
- G. BCS: Building Control System. A control system for building electrical and mechanical systems, typically HVAC (including central plants) and lighting. A BCS generally uses Direct Digital Control (DDC) Hardware and generally does NOT include its own local front end.
- H. Binary: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.
- I. BPOC: Building Point of Connection. The BPOC is part of the CCS IP network and acts as the point of connection between the CCS IP Network and the building control IP network. The BPOC is an IT device such as a switch, IP router, or firewall, typically managed by the Owner's

IT staff. (Note that the building control IP network may consist of a single IP device, or that integration may require installation of a building control network IP device.)

- J. CCS: Countywide Control System.
- K. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.
- L. COV: Changes of value.
- M. DDC: Direct Digital Control.
- N. Digital: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Binary" is sometimes used interchangeably with "Digital" to indicate a two-state signal.
- O. Fox Protocol: The protocol used for communication between components in the Niagara Framework. By default, Fox uses TCP port 1911.
- P. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- Q. GUI: Graphical User Interface.
- R. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.
- S. JACE: Java Application Control Engine. See Niagara Framework Supervisory Gateway.
- T. LAN: Local Area Network.
- U. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- V. Modbus TCP/IP: An open protocol for exchange of process data.
- W. Monitoring and Control (M&C) Software: The CCS 'front end' software which performs supervisory functions such as alarm handling, scheduling and data logging and provides a user interface for monitoring the system and configuring these functions.
- X. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- Y. MTBF: Mean time between failures.

- Z. Network Server Controller (NSC): Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.
- AA. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- BB. Niagara Framework: A set of hardware and software specifications for building and utility control owned by Tridium Inc. and licensed to multiple vendors. The Framework consists of front end (M&C) software, web-based clients, field level control hardware, and engineering tools. While the Niagara Framework is not adopted by a recognized standards body and does not use an open licensing model, it is sufficiently well-supported by multiple HVAC vendors to be considered a de-facto Open Standard.
- CC. Niagara Framework Supervisory Gateway: DDC Hardware component of the Niagara Framework. A typical Niagara architecture has Niagara specific supervisory gateways at the IP level and other (non-Niagara specific) controllers on field networks (MS/TP, etc.) beneath the Niagara supervisory gateways. The Niagara specific controllers function as a gateway between the Niagara framework protocol (Fox) and the field network beneath. These supervisory gateways may also be used as general purpose controllers and also have the capability to provide a web-browser based user interface. Note that different vendors refer to this component by different names. The most common name is "JACE"; other names include "EC-BOS", "FX-40", and "UNC".
- DD. Override: To change the value of a point outside of the normal sequence of operation where this change has priority over the sequence. An override can be accomplished in one of two ways: the point itself may be Commandable and written to with a priority or there may be a separate point on the controller for the express purpose of implementing the override. Typically this override is from the Countywide Control System (CCS) Monitoring and Control (M&C) Software. Note that this definition is not standard throughout industry.
- EE. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- FF. Point, Calculated: A value within the M&C Software that is not a network point but has been calculated by logic within the software based on the value of network points or other calculated points. Calculated points are sometimes called virtual points or internal points.
- GG. Point, Network: A value that the M&C Software reads from or writes to a field control network.
- HH. Polling: A requested transmission of data between devices, rather than an unrequested transmission such as Change-Of-Value (COV) or Binding where data is automatically transmitted under certain conditions.
- II. RAM: Random Access Memory.
- JJ. Repeater: A device that connects two control network segments and retransmits all information received on one side onto the other.
- KK. RF: Radio frequency.

- LL. Router: Device connecting two or more networks at network layer.
- MM. SDCU: Standalone Digital Control Unit.
- NN. Server: Computer used to maintain system configuration, historical and programming database.
- OO. SLC: Supervisory Logic Controller. A controller implementing a combination of supervisory logic (global control strategies or optimization strategies), scheduling, alarming, event management, trending, web services or network management. Note this is defined by use; many supervisory controllers have the capability to also directly control equipment.
- PP. Supervisory Gateway: A device that is both a supervisory controller and a gateway, such as a Niagara Framework Supervisory Gateway.
- QQ. TCP/IP: Transport control protocol/Internet protocol.
- RR. UPS: Uninterruptible power supply.
- SS. USB: Universal Serial Bus.
- TT. VAV: Variable air volume.
- UU. WLED: White light emitting diode.
- VV. Workstation: Any device (i.e. desktop, portable computer, mobile device, or other interface apparatus) from which an authorized user can interface with web-based DDC system.

1.5 SYSTEM UNITS AND ACCURACY

A. Use English (inch-pound) units for displays, print-outs and calculations. Perform calculations with an accuracy of at least three significant figures. For displays and printouts present values to at least three significant figures.

1.6 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at project site or at a site requested by Owner.

1.7 SUBMITTALS

- A. All shop drawings shall be prepared in Revit or AutoCAD software. In addition to the drawings, the Contractor shall furnish a USB drive containing the identical information. Drawings shall be B size or larger.
- B. Shop drawings shall include a riser diagram depicting locations of all controllers with associated network wiring. Also included shall be individual schematics of each mechanical system showing all connected points with reference to their associated controller. Typicals will be allowed where appropriate.

- C. Shop drawings shall include an estimate of the IP network bandwidth usage by the BCS.
- D. Submittal data shall contain manufacturer's data on all hardware and software products required by the specification, including copies of all manufacturer catalog cuts and specification sheets to indicate conformance to product requirements. Valve, damper and air flow station schedules shall indicate size, configuration, capacity and location of all equipment.
- E. Software submittals shall contain narrative descriptions of sequences of operation, program listings, point lists, and a complete description of the graphics, reports, alarms and configuration to be furnished with the workstation software. Information shall be bound or in a three ring binder with an index and tabs. Diagrams shall be on 11" by 17" foldouts. If color has been used to differentiate information, the printed copies shall be in color.
- F. Submit submittal data and shop drawings to the Engineer for review prior to ordering or fabrication of the equipment. The Contractor, prior to submitting, shall check all documents for accuracy.
- G. The Engineer will make corrections, if required, and return to the Contractor. The Contractor will then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the Engineer and the submittals are fully approved.
- H. The following is a list of post construction submittals that shall be updated to reflect any changes during construction and re-submitted as "As-Built".
 - 1. System architecture drawing.
 - 2. Layout drawing for each control panel
 - 3. Wiring diagram for individual components
 - 4. System flow diagram for each controlled system
 - 5. Instrumentation list for each controlled system
 - 6. Sequence of control
 - 7. Binding map
 - 8. Operation and Maintenance Manuals
- I. Information common to the systems in the building shall be provided.
 - 1. System architecture diagram for components within the building annotated with specific location information.
 - 2. As-built drawing for each control panel.
 - 3. As-built wiring design diagram for all components.
 - 4. Installation design details for each I/O device.
 - 5. As-built system flow diagram for each system.
 - 6. Sequence of control for each system.
 - 7. Binding map for the building.
 - 8. Product data sheet for each component.
 - 9. Installation data sheet for each component.
 - 10. Submit two copies for each building.
- J. Software shall be provided:

- 1. Submit a copy of all software installed on the server.
- 2. Submit all licensing information for all software installed on the server.
- 3. Submit a copy of all software used to execute the project even if the software was not installed on the server.
- 4. Submit all licensing information for all of the software used to execute the project.
- 5. All software revisions shall be as installed at the time of the system acceptance.
- 6. Firmware Files
- 7. Submit a copy of all firmware files that were downloaded to or pre-installed on any devices installed as part of this project.
- 8. This does not apply to firmware that is permanently burned on a chip at the factory and can only be replaced by replacing the chip.
- 9. Submit a copy of all application files that were created during the execution of the project.
- 10. Submit a copy of all graphic page files created during the execution of the project.
- K. Operation and Maintenance (O&M) Manuals: Provide BCS Operation and Maintenance manuals which include the following, as a minimum:
 - 1. Procedures for the BCS system start-up, operation and shut-down.
 - 2. Final As-Built drawings.
 - 3. Routine maintenance checklist, arranged in a columnar format: The first column listing all installed devices, the second column stating the maintenance activity or stating that no maintenance required, the third column stating the frequency of the maintenance activity, and the fourth column providing any additional comments or reference.
 - 4. Qualified service organization list including points of contact with phone numbers.
 - 5. Start-Up and Start-Up Testing Report.
 - 6. Performance Verification Test (PVT) Procedures and Reports.

1.8 QUALITY ASSURANCE

- A. Each point in the system shall be tested for both hardware and software functionality. In addition, each mechanical and electrical system under control of the BCS will be tested against the appropriate sequence of operation specified. A written report will be submitted to the owner indicating that the installed system functions in accordance with the plans and specifications.
- B. The BCS Contractor shall provide a technician for 4 days manpower and engineering services required to program and troubleshoot the points from all systems in the building to be connected to the BCS.
- C. A performance verification test shall also be completed for the operator interaction with the system. Test elements shall be written to require the verification of all operator interaction tasks including, but not limited to the following.
 - 1. Graphics navigation.
 - 2. Trend data collection and presentation.
 - 3. Alarm handling, acknowledgement and routing.
 - 4. Time schedule editing.
 - 5. Application parameter adjustment.
 - 6. Manual control.

- 7. Report execution.
- 8. Automatic backups.
- 9. Web Client access.
- D. A Startup Testing Report and a Performance Verification Testing Report shall be provided upon test completion.

1.9 WARRANTY

- A. All components, system software, and parts furnished and installed by the BCS contractor shall be guaranteed against defects in materials and workmanship for two years from date of Substantial Completion. Labor to repair, reprogram, or replace these components shall be furnished by the BCS contractor at no charge during normal working hours during the warranty period. Materials furnished but not installed by the BCS contractor shall be covered to the extent of the product only. Installation labor shall be the responsibility of the trade contractor performing the installation. All corrective software modifications made during warranty periods shall be updated on all user documentation and on user and manufacturer archived software disks. The Contractor shall respond to the owner's request for warranty service within 24 standard working hours.
- B. Install and program software upgrades that become available within five years of date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.

PART 2 - PRODUCTS

2.1 DDC SYSTEM DESCRIPTION

- A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.
 - 1. DDC system shall consist of a high-speed, peer-to-peer network of distributed DDC controllers, other network devices, operator interfaces, and software.
 - 2. 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.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 WEB ACCESS

A. DDC system shall be Web-Based.

- 1. Web-Based Access to DDC System:
 - a. DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed using a Web browser over DDC system network, using Owner's LAN, and remotely over Internet through Owner's LAN.
 - b. Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
 - c. Web access shall be password protected and shall provide varying levels of access.
- 2. The web browser graphical user interface (GUI) shall provide a completely interactive user interface and shall provide a HTML5 experience that supports the following features as a minimum:
 - a. Trending.
 - b. Scheduling.
 - c. Electrical demand limiting.
 - d. Duty Cycling.
 - e. Downloading Memory to field devices.
 - f. Real time 'live' Graphic Programs.
 - g. Tree Navigation.
 - h. Parameter change of properties.
 - i. Set point adjustments.
 - j. Alarm / event information.
 - k. Configuration of operators.
 - l. Execution of global commands.
 - m. Add, delete, and modify graphics and displayed data.
- 3. BCS Server Database: The BCS server software shall utilize a Java Database Connectivity (JDBC) compatible database such as: MS SQL 8.0, Oracle 8i or IBM DB2. BCS systems written to Non -Standard and/or Proprietary databases are NOT acceptable.

2.3 WEB BROWSER GRAPHICAL USER INTERFACE

- A. Web Browser Navigation: The Thin Client web browser GUI shall provide a comprehensive user interface. Using a collection of web pages, it shall be constructed to "feel" like a single application, and provide a complete and intuitive mouse/menu driven operator interface. It shall be possible to navigate through the system using a web browser to accomplish requirements of this specification. The Web Browser GUI shall (as a minimum) provide for navigation, and for display of animated graphics, schedules, alarms/events, live graphic programs, active graphic set point controls, configuration menus for operator access, reports and reporting actions for events.
- B. Login: On launching the web browser and selecting the appropriate domain name or IP address, the operator shall be presented with a login page that will require a login name and strong password. Navigation in the system shall be dependent on the operator's role-based application control privileges.

- C. Navigation: Navigation through the GUI shall be accomplished by clicking on the appropriate level of a navigation tree (consisting of an expandable and collapsible tree control like Microsoft's Explorer program) and/or by selecting dynamic links to other system graphics. Both the navigation tree and action pane shall be displayed simultaneously, enabling the operator to select a specific system or equipment and view the corresponding graphic. A navigation tree shall as a minimum provide the following views: Geographic, Network, Groups and Configuration.
 - 1. Geographic View shall display a logical geographic hierarchy of the system including: cities, sites, buildings, building systems, floors, equipment and objects.
 - 2. Groups View shall display Scheduled Groups and custom reports.
 - 3. Configuration View shall display all the configuration categories (Operators, Schedule, Event, Reporting and Roles).
- D. Action Pane: The Action Pane shall provide several functional views for each subsystem specified. A functional view shall be accessed by clicking on the corresponding button:
 - 1. Graphics: Using graphical format suitable for display in a web browser, graphics shall include aerial building/campus views, color building 3D floorplans, equipment drawings, active graphic set point controls, web content and other valid HTML elements. The data on each graphic page shall automatically refresh.
 - 2. Dashboards: User customizable data using drag and drop HTML5 elements. Shall include Web Charts, Gauges, and other custom developed widgets for web browser. User shall have ability to save custom dashboards.
 - 3. Search: User shall have multiple options for searching data based upon Tags. Associated equipment, real time data, Properties, and Trends shall be available in result.
 - 4. Properties: Shall include graphic controls and text for the following: Locking or overriding objects, demand strategies, and any other valid data required for setup. Changes made to the properties pages shall require the operator to depress an 'accept/cancel' button.
 - 5. Schedules: Shall be used to create, modify/edit and view schedules based on the systems hierarchy (using the navigation tree).
 - 6. Alarms: Shall be used to view alarm information geographically (using the navigation tree), acknowledge alarms, sort alarms by category, actions and verify reporting actions.
 - 7. Charting: Shall be used to display associated trend and historical data, modify colors, date range, axis and scaling. User shall have ability to create HTML charts through web browser without utilizing chart builder. User shall be able to drag and drop single or multiple data points, including schedules, and apply status colors for analysis.
 - 8. Logic Live Graphic Programs: Shall be used to display' live' graphic programs of the control algorithm, (micro block programming) for the mechanical/electrical system selected in the navigation tree.
 - 9. Other actions such as Print, Help, Command, and Logout shall be available via a dropdown window.
- E. Color Graphics: The Web Browser GUI shall make extensive use of color in the graphic pane to communicate information related to set points and comfort. Animated gifs or .jpg, vector scalable, active set point graphic controls shall be used to enhance usability. Graphics tools used to create Web Browser graphics shall be non-proprietary and conform to the following basic criteria:

- 1. Display Size: The GUI workstation software shall graphically display in a minimum of 1024 by 768 pixels 24-bit True Color.
- 2. General Graphic: General area maps shall show locations of controlled buildings in relation to local landmarks.
- 3. 3D Floor Plans in 2D format: Floor plan graphics shall show heating and cooling zones throughout the buildings with areas served by a device (zones) being highlighted by mouseover. Provide a visual display of temperature relative to their respective set points. The colors shall be updated dynamically as a zone's actual comfort condition changes.
- 4. Mechanical Components: Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. Selected I/O points being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units. Animation shall be used for rotation or moving mechanical components to enhance usability.
- 5. Minimum System Color Graphics: Color graphics shall be selected and displayed via a web browser for the following:
 - a. Each piece of equipment monitored or controlled including each terminal unit.
 - b. Each building.
 - c. Each floor and zone controlled.
- F. Hierarchical Schedules: Utilizing the Navigation Tree and/or a custom graphical interface displayed in the web browser GUI, an operator (with proper access credentials) shall be able to define a Normal, Holiday or Override schedule for an individual piece of equipment or room, or choose to apply a hierarchical schedule to the entire system, site or floor area. For example, Independence Day ' Holiday' for every level in the system would be created by clicking at the top of the geographic hierarchy defined in the Navigation Tree. No further operator intervention would be required and every control module in the system with would be automatically downloaded with the ' Independence Day' Holiday. All schedules that affect the system/area/equipment highlighted in the Navigation Tree shall be shown in a summary schedule table and graph.
 - 1. Schedules: Schedules shall comply with the BACnet standards, (Schedule Object, Calendar Object, Weekly Schedule property and Exception Schedule property) and shall allow events to be scheduled based on:
 - a. Types of schedule shall be Normal, Holiday or Override.
 - b. A specific date.
 - c. A range of dates.
 - d. Any combination of Month of Year (1-12, any), Week of Month (1-5, last, any), Day of Week (M-Sun, Any).
 - e. Wildcard (example, allow combinations like second Tuesday of every month).
 - 2. Schedule Categories: The system shall allow operators to define and edit scheduling categories (different types of "things" to be scheduled; for example, lighting, HVAC occupancy, etc.). The categories shall include: name, description, icon (to display in the hierarchy tree when icon option is selected) and type of value to be scheduled.
 - 3. Schedule Groups: In addition to hierarchical scheduling, operators shall be able to define functional Schedule Groups, comprised of an arbitrary group of areas/rooms/equipment scattered throughout the facility and site. For example, the operator shall be able to define an 'individual tenant' group who may occupy different areas within a building or

buildings. Schedules applied to the ' tenant group' shall automatically be downloaded to control modules affecting spaces occupied by the ' tenant group'.

- 4. Intelligent Scheduling: The control system shall be intelligent enough to automatically turn on any supporting equipment needed to control the environment in an occupied space. If the operator schedules an individual room in a VAV system for occupancy, for example, the control logic shall automatically turn on the VAV air handling unit, chiller, boiler and/or any other equipment required to maintain the specified comfort and environmental conditions within the room.
- 5. Partial Day Exceptions: Schedule events shall be able to accommodate a time range specified by the operator (ex: board meeting from 6 pm to 9 pm overrides Normal schedule for conference room).
- 6. Schedule Summary Graph: The schedule summary graph shall clearly show Normal versus Holiday versus Override Schedules and the net operating schedule that results from all contributing schedules. Note: In case of priority conflict between schedules at the different geographic hierarchy, the schedule for the more detailed geographic level shall apply.
- G. Alarms: Alarms associated with a specific system, area, or equipment selected in the Navigation Tree, shall be displayed in the Action Pane by selecting an ' Alarms' view. Alarms, and reporting actions shall have the following capabilities:
 - 1. Alarms View: Each Alarm shall display an Alarms Category (using a different icon for each alarm category), date/time of occurrence, current status, alarm report and a bold URL link to the associated graphic for the selected system, area or equipment. The URL link shall indicate the system location, address and other pertinent information. An operator shall easily be able to sort events, edit event templates and categories, acknowledge or force a return to normal in the Events View as specified in this section.
 - 2. Alarm Categories: The operator shall be able to create, edit or delete alarm categories such as HVAC, Maintenance, Fire, or Generator. An icon shall be associated with each alarm category, enabling the operator to easily sort through multiple events displayed.
 - 3. Alarm Templates: Alarm template shall define different types of alarms and their associated properties. As a minimum, properties shall include a reference name, verbose description, severity of alarm, acknowledgement requirements, and high/low limit and out of range information.
 - 4. Alarm Areas: Alarm Areas enable an operator to assign specific Alarm Categories to specific Alarm Reporting Actions. For example, it shall be possible for an operator to assign all HVAC Maintenance Alarm on the 1st floor of a building to email the technician responsible for maintenance. The Navigation Tree shall be used to setup Alarm Areas in the Graphic Pane.
 - 5. Alarm Time/Date Stamp: All events shall be generated at the DDC control module level and comprise the Time/Date Stamp using the standalone control module time and date.
 - 6. Alarm Configuration: Operators shall be able to define the type of Alarm generated per object. A 'network' view of the Navigation Tree shall expose all objects and their respective Alarm Configuration. Configuration shall include assignment of Alarm, type of Acknowledgement and notification for return to normal or fault status.
 - 7. Alarm Summary Counter: The view of Alarm in the Graphic Pane shall provide a numeric counter, indicating how many Alarms are active (in alarm), require acknowledgement and total number of Alarms in the BAS Server database.
 - 8. Alarm Auto-Deletion: Alarms that are acknowledged and closed shall be auto-deleted from the database and archived to a text file after an operator defined period.

- 9. Alarm Reporting Actions: Alarm Reporting Actions specified shall be automatically launched (under certain conditions) after an Alarm is received by the BAS server software. Operators shall be able to easily define these Reporting Actions using the Navigation Tree and Graphic Pane through the web browser GUI. Reporting Actions shall be as follows:
 - a. Print: Alarm information shall be printed to the BAS server's PC or a networked printer.
 - b. Email: Email shall be sent via any POP3-compatible e-mail server (most Internet Service Providers use POP3). Email messages may be copied to several email accounts. Note: Email reporting action shall also be used to support alphanumeric paging services, where email servers support pagers.
 - c. File Write: The ASCII File write reporting action shall enable the operator to append operator defined alarm information to any alarm through a text file. The alarm information that is written to the file shall be completely definable by the operator. The operator may enter text or attach other data point information (such as AHU discharge temperature and fan condition upon a high room temperature alarm).
 - d. Write Property: The write property reporting action updates a property value in a hardware module.
 - e. SNMP: The Simple Network Management Protocol (SNMP) reporting action sends an SNMP trap to a network in response to receiving an alarm.
 - f. Run External Program: The Run External Program reporting action launches specified program in response to an event.
- H. Trends: As system is engineered, all points shall be enabled to trend. Trends shall both be displayed and user configurable through the Web Browser GUI. Trends shall comprise analog, digital or calculated points simultaneously. A trend log's properties shall be editable using the Navigation Tree and Graphic Pane.
 - 1. Viewing Trends: The operator shall have the ability to view trends by using the Navigation Tree and/or a custom graphical interface and selecting a Trends button in the Graphic Pane. The system shall allow y- and x-axis maximum ranges to be specified and shall be able to simultaneously graphically display multiple trends per graph.
 - 2. Local Trends: Trend data shall be collected locally by Multi-Equipment/Single Equipment general-purpose controllers, and where installed periodically uploaded to the BAS server if historical trending is enabled for the object. Trend data, including run time hours and start time date shall be retained in non-volatile module memory. Systems that rely on a gateway/router to run trends are NOT acceptable.
 - 3. Resolution. Sample intervals shall be as small as one second. Each trended point will have the ability to be trended at a different trend interval. When multiple points are selected for displays that have different trend intervals, the system will automatically scale the axis.
 - 4. Dynamic Update. Trends shall be able to dynamically update at operator-defined intervals.
 - 5. Zoom/Pan. It shall be possible to zoom-in on a particular section of a trend for more detailed examination and ' pan through' historical data by simply scrolling the mouse.
 - 6. Numeric Value Display. It shall be possible to pick any sample on a trend and have the numerical value displayed.

- 7. Copy/Paste. The operator shall have the ability to pan through a historical trend and copy the data viewed to the clipboard using standard keystrokes (i.e. CTRL+C, CTRL+V).
- I. Security Access: Systems that are accessed from the web browser GUI to BAS server shall require a Login Name and Strong Password. Access to different areas of the BAS system shall be defined in terms of Role-Based Access Control privileges as specified:
 - 1. Roles: Roles shall reflect the actual roles of different types of operators. Each role shall comprise a set of ' easily understood English language' privileges. Roles shall be defined in terms of View, Edit and Function Privileges.
 - a. View Privileges shall comprise: Navigation, Network, and Configuration Trees, Operators, Roles and Privileges, Alarm/Event Template and Reporting Action.
 - b. Edit Privileges shall comprise: Set point, Tuning and Logic, Manual Override, and Point Assignment Parameters.
 - c. Function Privileges shall comprise: Alarm/Event Acknowledgement, Control Module Memory Download, Upload, Schedules, Schedule Groups, Manual Commands, Print and Alarm/Event Maintenance.
 - 2. Geographic Assignment of Roles: Roles shall be geographically assigned using a similar expandable/collapsible navigation tree. For example, it shall be possible to assign two HVAC Technicians with similar competencies (and the same operator defined HVAC Role) to different areas of the system.

2.4 GRAPHICAL PROGRAMMING

- A. The system software shall include a Graphic Programming Language (GPL) for all DDC control algorithms resident in all control modules. Any system that does not use a drag and drop method of graphical icon programming shall not be accepted. All systems shall use a GPL method used to create a sequence of operations by assembling graphic microblocks that represent each of the commands or functions necessary to complete a control sequence. Microblocks represent common logical control devices used in conventional control systems, such as relays, switches, high signal selectors etc., in addition to the more complex DDC and energy management strategies such as PID loops and optimum start. Each microblock shall be interactive and contain the programming necessary to execute the function of the device it represents.
- B. Graphic programming shall be performed while on screen and using a mouse; each microblock shall be selected from a microblock library and assembled with other microblocks necessary to complete the specified sequence. Microblocks are then interconnected on screen using graphic "wires," each forming a logical connection. Once assembled, each logical grouping of microblocks and their interconnecting wires then forms a graphic function block which may be used to control any piece of equipment with a similar point configuration and sequence of operation.
- C. Graphic Sequence: The clarity of the graphic sequence shall be such that the operator has the ability to verify that system programming meets the specifications, without having to learn or interpret a manufacturer's unique programming language. The graphic programming shall be

self-documenting and provide the operator with an understandable and exact representation of each sequence of operation.

- D. GPL Capabilities: The following is a minimum definition of the capabilities of the Graphic Programming software:
 - 1. Function Block (FB): Shall be a collection of points, microblocks and wires which have been connected together for the specific purpose of controlling a piece of HVAC equipment or a single mechanical system.
 - 2. Logical I/O: Input/Output points shall interface with the control modules in order to read various signals and/or values or to transmit signal or values to controlled devices.
 - 3. Microblocks: Shall be software devices that are represented graphically and may be connected together to perform a specified sequence. A library of microblocks shall be submitted with the control contractors bid.
 - 4. Wires: Shall be Graphical elements used to form logical connections between microblocks and between logical I/O.
 - 5. Reference Labels: Labels shall be similar to wires in that they are used to form logical connections between two points. Labels shall form a connection by reference instead of a visual connection, i.e. two points labeled 'A' on a drawing are logically connected even though there is no wire between them.
 - 6. Parameter: A parameter shall be a value that may be tied to the input of a microblock.
 - 7. Properties: Dialog boxes shall appear after a microblock has been inserted which has editable parameters associated with it. Default parameter dialog boxes shall contain various editable and non-editable fields and shall contain 'push buttons' for the purpose of selecting default parameter settings.
 - 8. Icon: An icon shall be graphic representation of a software program. Each graphic microblock has an icon associated with it that graphically describes its function.
 - 9. Menu-bar Icon: Shall be an icon that is displayed on the menu bar on the GPL screen, which represents its associated graphic microblock.
 - 10. Live Graphical Programs: The Graphic Programming software shall support a ' live' mode, where all input/output data, calculated data and set points shall be displayed in a ' live' real-time mode.

2.5 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer to design DDC system to satisfy requirements indicated.
 - 1. System Performance Objectives:
 - a. DDC system shall manage HVAC systems.
 - b. DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
 - c. DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
 - d. DDC system shall operate while unattended by an operator and through operator interaction.
 - e. DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.

- B. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1. Flame-Spread Index: 25 or less.
 - 2. Smoke-Developed Index: 50 or less.
- C. DDC System Speed:
 - 1. Response Time of Connected I/O:
 - a. AI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - b. BI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - c. AO points connected to DDC system shall begin to respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
 - d. BO point values connected to DDC system shall respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
 - 2. Display of Connected I/O:
 - a. Analog point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
 - b. Binary point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
 - c. Alarms of analog and digital points connected to DDC system shall be displayed within 30 seconds of activation or change of state.
 - d. Graphic display refresh shall update within eight seconds.
 - e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.
- D. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.
- E. DDC System Data Storage:
 - 1. Include capability to archive not less than 48 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.
 - 2. Local Storage: Provide server with data storage indicated.

- F. DDC Data Access:
 - 1. When logged into the system, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
 - 2. System(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.
- G. Future Expandability:
 - 1. DDC system size shall be expandable to an ultimate capacity of at least three times total I/O points indicated.
 - 2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
 - 3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.
- H. Environmental Conditions for Controllers, Gateways, and Routers:
 - 1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.
 - a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.
 - 2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: Type 2.
 - b. Outdoors, Unprotected: Type 4.
 - c. Indoors, Heated with Filtered Ventilation: Type 1.
 - d. Indoors, Heated with Non-Filtered Ventilation: Type 2.
 - e. Indoors, Heated and Air Conditioned: Type 1.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 4.
 - 2) Air-Moving Equipment Rooms: Type 1.
 - g. Localized Areas Exposed to Washdown: Type 4.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.

- j. Hazardous Locations: Explosion-proof rating for condition.
- I. Electric Power Quality:
 - 1. Power-Line Surges:
 - a. Protect DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
 - b. Do not use fuses for surge protection.
 - 2. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.
- J. Continuity of Operation after Electric Power Interruption:
 - 1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.6 SYSTEM ARCHITECTURE

- A. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system utilizing Open protocols in one open, interoperable system.
- B. The software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system.
- C. All components and controllers supplied under this contract shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.
- D. The supplied system shall incorporate the ability to access all data using HTML5 enabled browsers without requiring proprietary operator interface and configuration programs or browser plug-ins. An Open Database Connectivity (ODBC) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on the Operating System Server located in the Facilities Office on the LAN. Systems requiring proprietary database and user interface programs shall not be acceptable.
- E. A hierarchical topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network. Systems employing a "flat" single tiered architecture shall not be acceptable.
 - 1. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 5 seconds for network connected user interfaces.

2. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.

2.7 DDC SYSTEM OPERATOR INTERFACES

- A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:
 - 1. Desktop and portable workstation with hardwired connection through LAN port.
 - 2. Mobile device and application with secured wireless connection through LAN router or cellular data service.
 - 3. Remote connection through web access.
- B. Access to system, regardless of operator means used, shall be transparent to operator.
- C. Network Ports: For hardwired connection of desktop or portable workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:
 - 1. Each mechanical equipment room.
 - 2. Each different roof level with roof-mounted air-handling units or rooftop units.
 - 3. Fire-alarm system command center.
- D. Desktop Workstations:
 - 1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
 - 2. Able to communicate with any device located on any DDC system LAN.
- E. Mobile Devices/Portable Workstations:
 - 1. Connect to system through a wireless router connected to LAN and/or cellular data service.
- F. Critical Alarm Reporting:
 - 1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
 - 2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
 - 3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.
- G. Simultaneous Operator Use: Capable of accommodating up to five simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.8 NETWORKS

- A. Acceptable networks for connecting workstations, mobile devices, and network controllers include the following:
 - 1. ATA 878.1, ARCNET.
 - 2. IP.
 - 3. IEEE 8802-3, Ethernet.
- B. Acceptable networks for connecting programmable application controllers include the following:
 - 1. ATA 878.1, ARCNET.
 - 2. IP.
 - 3. IEEE 8802-3, Ethernet.
- C. Acceptable networks for connecting application-specific controllers include the following:
 - 1. ATA 878.1, ARCNET.
 - 2. EIA-485A.
 - 3. IP.
 - 4. IEEE 8802-3, Ethernet.

2.9 ASHRAE 135 GATEWAYS

- A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, variable-speed drives.
- B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.
- C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.
- D. Gateway Minimum Requirements:
 - 1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
 - 2. Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.
 - 3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
 - 4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.

- 5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
- 6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.10 ASHRAE 135 PROTOCOL ANALYZER

- A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.
- B. Analyzer shall include the following minimum capabilities:
 - 1. Capture and store to a file data traffic on all network levels.
 - 2. Measure bandwidth usage.
 - 3. Filtering options with ability to ignore select traffic.

2.11 DDC EQUIPMENT

- A. Control Units: Modular, comprising processor board with programmable, nonvolatile, randomaccess 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: In addition to LAN/WAN architecture support, the same workstation software must be capable of managing systems via the County Network as a standard component of the software. The remote system architecture

shall consist of two levels providing control, alarm detection, reporting and information management for the remote facility. Level 1 shall contain the Remote Site Control Unit (RSCU), communicating to the remotely located operator workstation through the use of the County Network. Level 2 shall consist of one or more field buses controlled by the RSCU.

- 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.
- 5. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
- 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 or diagnostic terminal unit.
 - 4. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
- 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 with three-position (on-off-auto) override switches and status lights.
 - 5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA) with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer.
 - 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.

2.12 DDC CONTROLLERS

- A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.
- B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.
- C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.
- D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.
- E. Environment Requirements:
 - 1. Controller hardware shall be suitable for the anticipated ambient conditions.
 - 2. Controllers located in conditioned space shall be rated for operation at 32 to 120 deg F
 - 3. Controllers located outdoors shall be rated for operation at 40 to 150 deg F
- F. Power and Noise Immunity:
 - 1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
 - 2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches of enclosure.
- G. DDC Controller Spare Processing Capacity:
 - 1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated.
 - 2. Memory shall support DDC controller's operating system and database and shall include the following:

- a. Monitoring and control.
- b. Energy management, operation and optimization applications.
- c. Alarm management.
- d. Historical trend data of all connected I/O points.
- e. Maintenance applications.
- f. Operator interfaces.
- g. Monitoring of manual overrides.
- H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller.

2.13 NETWORK CONTROLLERS

- A. General Network Controller Requirements:
 - 1. Include adequate number of controllers to achieve performance indicated.
 - 2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
 - 3. Controller shall have enough memory to support its operating system, database, and programming requirements.
 - 4. Data shall be shared between networked controllers and other network devices.
 - 5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
 - 6. Controllers that perform scheduling shall have a real-time clock.
 - 7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
 - 8. Controllers shall be fully programmable.
- B. Communication:
 - 1. Network controllers shall communicate with other devices on DDC system Level one network.
 - 2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.
- C. Operator Interface:
 - 1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation.
- D. Serviceability:
 - 1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
 - 2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 - 3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.14 PROGRAMMABLE APPLICATION CONTROLLERS

- A. General Programmable Application Controller Requirements:
 - 1. Include adequate number of controllers to achieve performance indicated.
 - 2. Controller shall have enough memory to support its operating system, database, and programming requirements.
 - 3. Data shall be shared between networked controllers and other network devices.
 - 4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
 - 5. Controllers that perform scheduling shall have a real-time clock.
 - 6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
 - 7. Controllers shall be fully programmable.
- B. Communication:
 - 1. Programmable application controllers shall communicate with other devices on network.
- C. Operator Interface:
 - 1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation.
- D. Serviceability:
 - 1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
 - 2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 - 3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.15 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 72 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 scheduling with real-time clock. Perform automatic system diagnostics; monitor system and report failures.

- 3. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
- 4. Enclosure: Waterproof rated for operation at 40 to 150 deg F.

2.16 ALARM PANELS

- A. Unitized cabinet with suitable brackets for wall or floor mounting. Fabricate of 0.06-inchthick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish. Provide common keying for all panels.
- 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.

2.17 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, 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.
- E. Receiver Controllers: Single- or multiple-input models with control-point adjustment, direct or reverse acting with mechanical set-point adjustment with locking device, proportional band adjustment, authority adjustment, and proportional control mode.

- 1. Remote-control-point adjustment shall be plus or minus 20 percent of sensor span, input signal of 3 to 13 psig.
- 2. Proportional band shall extend from 2 to 20 percent for 5 psig.
- 3. Authority shall be 20 to 200 percent.
- 4. Air-supply pressure of 18 psig, input signal of 3 to 15 psig, and output signal of zero to supply pressure.
- 5. Gages: 2-1/2 inches in diameter, 2.5 percent wide-scale accuracy, and range to match transmitter input or output pressure.

2.18 TIME CLOCKS

- A. Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
- B. Solid-state, programmable time control with 8 separate programs each with up to 100 on-off operations; 1-second resolution; lithium battery backup; keyboard interface and manual override; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; system fault alarm; and communications package allowing networking of time controls and programming from PC.

2.19 ENCLOSURES

- A. General Enclosure Requirements:
 - 1. House each controller and associated control accessories in an enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
 - 2. Do not house more than one controller in a single enclosure.
 - 3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
 - 4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
 - 5. Individual wall-mounted single-door enclosures shall not exceed 36 inches wide and 48 inches high.
 - 6. Individual wall-mounted double-door enclosures shall not exceed 60 inches wide and 36 inches high.
 - 7. Freestanding enclosures shall not exceed 48 inches wide and 72 inches high.
 - 8. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
 - 9. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door.
- B. Internal Arrangement:

- 1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
- 2. Arrange layout to group similar products together.
- 3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
- 4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
- 5. Terminate field cable and wire using heavy-duty terminal blocks.
- 6. Include spare terminals, equal to not less than 20 percent of used terminals.
- 7. Include spade lugs for stranded cable and wire.
- 8. Install a maximum of two wires on each side of a terminal.
- 9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
- 10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
- 11. Mount products within enclosure on removable internal panel(s).
- 12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch- high lettering.
- 13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
- 14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
- 15. Size enclosure internal panel to include at least 25 percent spare area on face of panel.
- C. Environmental Requirements:
 - 1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
 - 2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.
 - 3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
 - 4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
 - 5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
 - 6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

2.20 RELAYS

- A. General-Purpose Relays:
 - 1. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
 - 2. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
 - 3. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
 - 4. Construct the contacts of either silver cadmium oxide or gold.
 - 5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
 - 6. Relays shall have LED indication and a manual reset and push-to-test button.
 - 7. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
 - 8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
 - 9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
 - 10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.
- B. Multifunction Time-Delay Relays:
 - 1. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
 - 2. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.
 - 3. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
 - 4. Construct the contacts of either silver cadmium oxide or gold.
 - 5. Enclose the relay in a dust-tight cover.
 - 6. Include knob and dial scale for setting delay time.
 - 7. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
 - d. Repeatability: Within 2 percent.
 - e. Recycle Time: 45 ms.
 - f. Minimum Pulse Width Control: 50 ms.
 - g. Power Consumption: 5 VA or less at 120-V ac.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
 - 8. Equip relays with coil transient suppression to limit transients to non-damaging levels.

- 9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
- 10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.
- C. Latching Relays:
 - 1. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
 - 2. Relays shall be either DPDT or three-pole double throw, depending on the control application.
 - 3. Use a plug-in-style relay with a multibladed plug.
 - 4. Construct the contacts of either silver cadmium oxide or gold.
 - 5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
 - 6. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
 - 7. Equip relays with coil transient suppression to limit transients to non-damaging levels.
 - 8. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
 - 9. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.
- D. Current Sensing Relay:
 - 1. Monitors ac current.
 - 2. Independent adjustable controls for pickup and dropout current.
 - 3. Energized when supply voltage is present and current is above pickup setting.
 - 4. De-energizes when monitored current is below dropout current.
 - 5. Dropout current is adjustable from 50 to 95 percent of pickup current.
 - 6. Include a current transformer, if required for application.
 - 7. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.
- E. Combination On-Off Status Sensor and On-Off Relay:
 - 1. Description:
 - a. On-off control and status indication in a single device.
 - b. LED status indication of activated relay and current trigger.
 - c. Closed-Open-Auto override switch located on the load side of the relay.
 - 2. Performance:

- a. Ambient Temperature: Minus 30 to 140 deg F.
- b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.
- 3. Status Indication:
 - a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
 - b. Current Sensor Range: As required by application.
 - c. Current Set Point: Fixed or adjustable as required by application
 - d. Current Sensor Output:
 - 1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
 - 2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
 - 3) Analog, zero- to 5- or 10-V dc.
 - 4) Analog, 4 to 20 mA, loop powered.
- 4. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.
- 5. Enclosure: NEMA 250, Type 1 enclosure.

2.21 ELECTRONIC SENSORS

- A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.
- B. Thermistor Temperature Sensors and Transmitters:
 - 1. Accuracy: Plus or minus 0.5 deg F at calibration point.
 - 2. Wire: Twisted, shielded-pair cable.
 - 3. 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.
 - 4. Averaging Elements in Ducts: 18 inches long, rigid; use where prone to temperature stratification or where ducts are larger than 10 sq. ft.
 - 5. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
 - 6. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
- C. RTDs and Transmitters:
 - 1. Accuracy: Plus or minus 0.2 percent at calibration point.
 - 2. Wire: Twisted, shielded-pair cable.
 - 3. 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.
 - 4. Averaging Elements in Ducts: 18 inches; use where prone to temperature stratification or where ducts are larger than 9 sq. ft.; length as required.
 - 5. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches.

- 6. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
- 7. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
- D. Humidity Sensors: Bulk polymer sensor element.
 - 1. Accuracy: 2 percent full range with linear output.
 - 2. Room Sensor Range: 20 to 80 percent relative humidity.
 - 3. Duct Sensor: 20 to 80 percent relative humidity range with element guard and mounting plate.
 - 4. Outside-Air Sensor: 20 to 80 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of minus 22 to plus 185 deg F.
 - 5. Duct and Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.
- E. Pressure Transmitters/Transducers:
 - 1. 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.
 - d. Duct Static-Pressure Range: 0- to 5-inch wg.
 - 2. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure; linear output 4 to 20 mA.
 - 3. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure and tested to 300-psig; linear output 4 to 20 mA.
 - 4. Differential-Pressure Switch (Air): Snap acting, with pilot-duty rating and with suitable scale range and differential.
 - 5. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.
- F. Room sensor accessories include the following:
 - 1. Insulating Bases: For sensors located on exterior walls.
 - 2. Guards: Locking; heavy-duty, transparent plastic; mounted on separate base.
 - 3. Adjusting Key: As required for calibration and cover screws.

2.22 STATUS SENSORS

- A. Status Inputs for Fans: Differential-pressure switch with pilot-duty rating and with adjustable range of 0- to 5-inch wg.
- B. Status Inputs for Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig, piped across pump.

- C. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or splitcore transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.
- D. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.
- E. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.
- F. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.
- G. Electronic Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

2.23 GAS DETECTION EQUIPMENT

- A. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of 23 to 130 deg F and calibrated for 0 to 2 percent, with continuous or averaged reading, 4- to 20-mA output;, for wall mounting.
- B. Oxygen Sensor and Transmitter: Single detectors using solid-state zircon cell sensing; suitable over a temperature range of minus 32 to plus 1100 deg F and calibrated for 0 to 5 percent, with continuous or averaged reading, 4- to 20-mA output; for wall mounting.
- C. Occupancy Sensor: Passive infrared, with time delay, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment; for flush mounting.

2.24 FLOW MEASURING STATIONS

- A. Duct Airflow Station: Combination of air straightener and multiport, self-averaging pitot tube station.
 - 1. Casing: Galvanized-steel frame.
 - 2. Flow Straightener: Aluminum honeycomb, 3/4-inch parallel cell, 3 inches deep.
 - 3. Sensing Manifold: Copper manifold with bullet-nosed static pressure sensors positioned on equal area basis.

2.25 THERMOSTATS

- A. Space thermostat.
 - 1. Automatic switching from heating to cooling.
 - 2. Preferential rate control to minimize overshoot and deviation from set point.
 - 3. Digital temperature display in deg. F.
 - 4. Sliding warmer-cooler temperature selector, with +/- 2 deg. F (adj.) range.

- 5. Occupancy override button.
- B. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.
 - 1. Bulbs in water lines with separate wells of same material as bulb.
 - 2. Bulbs in air ducts with flanges and shields.
 - 3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit; adequately supported.
 - 4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
 - 5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
 - 6. Modulating Thermostats: Construct so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.
- C. Fire-Protection Thermostats: Listed and labeled by an NRTL acceptable to authorities having jurisdiction; with fixed or adjustable settings to operate at not less than 75 deg F above normal maximum operating temperature, and the following:
 - 1. Reset: Manual.
 - 2. Reset: Automatic, with control circuit arranged to require manual reset at central control panel; with pilot light and reset switch on panel labeled to indicate operation.
- D. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.
- E. Airstream Thermostats: Two-pipe, fully proportional, single-temperature type; with adjustable set point in middle of range, adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.
- 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 of bulb length is equal to or below set point.
 - 1. Bulb Length: Minimum 20 feet.
 - 2. Quantity: One thermostat for every 20 sq. ft. of coil surface.
- G. Electric, High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic- reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or above set point.
 - 1. Bulb Length: Minimum 20 feet.
 - 2. Quantity: One thermostat for every 20 sq. ft. of coil surface.

2.26 HUMIDISTATS

A. Electronic Room Humidistats: Wall-mounting, proportioning type with adjustable throttling range, 20 to 90 percent operating range, and cover matching room thermostat cover.

B. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.

2.27 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 Section 200513 "Common Motor and Frequency Drive Requirements for General Mechanical 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.
 - 3. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
 - 4. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
 - 5. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
 - 6. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.
- B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
 - 1. Dampers: Size for running torque calculated as follows:
 - a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
 - b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
 - c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft of damper.
 - d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
 - e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.
 - f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.
 - 2. Coupling: V-bolt and V-shaped, toothed cradle.
 - 3. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
 - 4. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
 - 5. Power Requirements (Two-Position Spring Return): 120-V ac.
 - 6. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
 - 7. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
 - 8. Temperature Rating: Minus 22 to plus 122 deg F.
 - 9. Run Time: 12 seconds open, 5 seconds closed.

2.28 PRESSURE INDEPENDENT CONTROL VALVES

- A. Pressure Independent Control Valves shall be provided where indicated on plans. Provide one of the following products:
 - 1. Flow-Control Industries Delta P Valve.
 - 2. Belimo PICCV.
 - 3. Griswold PIC-V.
 - 4. Bell & Gossett Ultra Setter.
- B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.
 - 1. Operators shall be sized to close against a differential pressure equal to the design pump head plus 10 percent.
- C. Sizing Criteria:
 - 1. Determine the design GPM of the actual coil that is selected be used (may be different than the coil and GPM on the design coil schedule).
 - 2. Select the PICV valve with a GPM rating higher than the GPM required.
 - 3. If more than one valve fits the GPM rating, then pick the valve that matches or is closest to the line size of the circuit piping.
 - 4. If the maximum GPM of the valve exceeds the design GPM required, then adjust the Flow Limiter setting on the valve to the GPM required.
 - 5. Traditional flow coefficient and pressure drop sizing is not applicable to pressure independent control valves.

2.29 DAMPERS

- A. Dampers: AMCA-rated, opposed-blade design; 0.108-inch- minimum thick, galvanized-steel or 0.125-inch- minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch- thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.
 - 1. Secure blades to 1/2-inch- diameter, zinc-plated axles using zinc-plated hardware, with oil-impregnated sintered bronze 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.
 - 3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.

2.30 METERS

- A. All meters shall have BACnet output connections for interface with BAS.
- B. Water (Domestic and Geothermal): Electromagnetic, insertion-type.
 - 1. Dwyer Series IEF

- 2. ONICON model F-3500 Series.
- 3. Smart Measurement model ALMAG-IS.
- C. Natural Gas: Thermal mass, insertion-type.
 - 1. Fox Thermal model FT-1.
 - 2. ONICON model F-5500 Series.
 - 3. SIERRA model 620S BT Boiler-Trak.
- D. Building Power and Energy: Full data set, Main Distribution Panel installation, for use with Rogowski Coil CT's.
 - 1. GE EPM 6010.
 - 2. Mod-Tronic Acuvim II Series.
 - 3. Setra Power Squad 24.
 - 4. VERIS Industries model E50C2A

2.31 CONTROLLER SOFTWARE

- A. General Controller Software Requirements:
 - 1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
 - 2. I/O points shall be identified by up to 30-character point name and up to 16-character point descriptor. Same names shall be used at operator workstations.
 - 3. Control functions shall be executed within controllers using DDC algorithms.
 - 4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.
- B. Security:
 - 1. Operator access shall be secured using individual security passwords and user names.
 - 2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
 - 3. Operator log-on and log-off attempts shall be recorded.
 - 4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.
- C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:
 - 1. Weekly Schedule:
 - a. Include separate schedules for each day of week.
 - b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
 - c. Each schedule may consist of up to 10 events.

- d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.
- 2. Exception Schedules:
 - a. Include ability for operator to designate any day of the year as an exception schedule.
 - b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.
- 3. Holiday Schedules:
 - a. Include capability for operator to define up to 99 special or holiday schedules.
 - b. Schedules may be placed on scheduling calendar and will be repeated each year.
 - c. Operator shall be able to define length of each holiday period.
- D. System Coordination:
 - 1. Include standard application for proper coordination of equipment.
 - 2. Application shall include operator with a method of grouping together equipment based on function and location.
 - 3. Group may then be used for scheduling and other applications.
- E. Binary Alarms:
 - 1. Each binary point shall be set to alarm based on operator-specified state.
 - 2. Include capability to automatically and manually disable alarming.
- F. Analog Alarms:
 - 1. Each analog object shall have both high and low alarm limits.
 - 2. Alarming shall be able to be automatically and manually disabled.
- G. Alarm Reporting:
 - 1. Operator shall be able to determine action to be taken in event of an alarm.
 - 2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
 - 3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.
- H. Remote Communication:
 - 1. System shall have ability to dial out in the event of an alarm.
- I. Electric Power Demand Limiting:

- 1. Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.
- 2. Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.
- 3. Demand reduction shall be accomplished by the following means:
 - a. Reset air-handling unit supply temperature set points.
 - b. Reset space temperature set points.
 - c. De-energize equipment based on priority.
- 4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.
- 5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
- 6. Include means operator to make the following changes online:
 - a. Addition and deletion of loads controlled.
 - b. Changes in demand intervals.
 - c. Changes in demand limit for meter(s).
 - d. Maximum shutoff time for equipment.
 - e. Minimum shutoff time for equipment.
 - f. Select rotational or sequential shedding and restoring.
 - g. Shed and restore priority.
- 7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:
 - a. Total electric consumption.
 - b. Peak demand.
 - c. Date and time of peak demand.
 - d. Daily peak demand.
- J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.
- K. Sequencing: Include application software based on sequences of operation indicated to properly sequence applicable HVAC equipment.
- L. Control Loops:
 - 1. Support any of the following control loops, as applicable to control required:
 - a. Two-position (on/off, open/close, slow/fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.

- d. Proportional plus integral plus derivative (PID) control.
 - 1) Include PID algorithms with direct or reverse action and anti-windup.
 - 2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
 - 3) Controlled variable, set point, and PID gains shall be operator-selectable.
- e. Adaptive (automatic tuning).
- M. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.
- N. Energy Calculations:
 - 1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
 - 2. Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
 - 3. Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.
- O. Anti-Short Cycling:
 - 1. BO points shall be protected from short cycling.
 - 2. Feature shall allow minimum on-time and off-time to be selected.
- P. On and Off Control with Differential:
 - 1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
 - 2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.
- Q. Run-Time Totalization:
 - 1. Include software to totalize run-times for all BI and BO points.
 - 2. A high run-time alarm shall be assigned, if required, by operator.

2.32 ELECTRICAL POWER DEVICES

- A. Transformers:
 - 1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
 - 2. Transformer shall be at least 40 VA.
 - 3. Transformer shall have both primary and secondary fuses.

- B. DC Power Supply:
 - 1. Plug-in style suitable for mating with a standard eight-pin octal socket. Include the power supply with a mating mounting socket.
 - 2. Enclose circuitry in a housing.
 - 3. Include both line and load regulation to ensure a stable output. To protect both the power supply and the load, power supply shall have an automatic current limiting circuit.
 - 4. Performance:
 - a. Output voltage nominally 25-V dc within 5 percent.
 - b. Output current up to 100 mA.
 - c. Input voltage nominally 120-V ac, 60 Hz.
 - d. Load regulation within 0.5 percent from zero- to 100-mA load.
 - e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
 - f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

2.33 CONTROL POWER WIRING AND RACEWAYS

- A. Comply with requirements in Section 260519 "Conductors and Cables" electrical power conductors and cables.
- B. Comply with requirements in Section 260533 "Raceways and Boxes" for electrical power raceways and boxes.

2.34 SOURCE QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:
 - 1. DDC controllers.
 - 2. Gateways.
 - 3. Routers.
- B. Product(s) and material(s) will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
 - 1. Verify compatibility with and suitability of substrates.

- B. Examine roughing-in for products to verify actual locations of connections before installation.
 - 1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
 - 2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

- A. Communication Interface to Equipment with Integral Controls:
 - 1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.
 - 2. Equipment to Be Connected:
 - a. Air-handling units specified in Section 238146 "Water-Source Unitary Heat Pumps."
 - b. Dedicated outdoor air systems specified in Section 237433 "Dedicated Outdoor-Air Units."
 - c. Variable refrigerant systems specified in Section 238129 "Variable Refrigerant Systems."
- B. Communication Interface to Other Building Systems:
 - 1. DDC system shall have a communication interface with systems having a communication interface.
 - 2. Systems to Be Connected:
 - a. Power monitoring specified in Division 26.
 - b. Fire-alarm system.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install products to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Support products, piping wiring and raceways.
- D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.

- E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- F. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."
- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."
- H. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.
- I. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.
- J. Connect and configure equipment and software to achieve sequence of operation specified.
- K. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation.
 - 1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.
- L. Install guards on thermostats in the following locations:
 - 1. Gymnasium.
 - 2. Dining.
 - 3. Other locations as directed by Owner.
- M. Install automatic dampers according to Section 233300 "Air Duct Accessories."
- N. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.
- O. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

3.4 GATEWAY INSTALLATION

- A. Install gateways if required for DDC system communication interface requirements indicated.
 - 1. Install gateway(s) required to suit indicated requirements.
- B. Test gateway to verify that communication interface functions properly.

3.5 ROUTER INSTALLATION

- A. Install routers if required for DDC system communication interface requirements indicated.
 - 1. Install router(s) required to suit indicated requirements.
- B. Test router to verify that communication interface functions properly.

3.6 CONTROLLER INSTALLATION

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply.
- C. Install controller with latest version of applicable software and configure to execute requirements indicated.
- D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.
- E. Installation of Network Controllers:
 - 1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Top of controller shall be within 84 inches of finished floor.
- F. Installation of Programmable Application Controllers:
 - 1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Top of controller shall be within 84 inches of finished floor.
- G. Application-Specific Controllers:
 - 1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.7 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
 - 1. Gateways.
 - 2. Routers.
 - 3. Controllers.
 - 4. Electrical power devices.

- 5. Relays.
- 6. Accessories.
- 7. Instruments.
- 8. Actuators
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
 - 1. For NEMA 250, Type 1 Enclosures: Use painted steel or galvanized-steel strut and hardware.
 - 2. For NEMA 250, Type 4 or Type 4X Enclosures and Enclosures Located Outdoors: Use stainless-steel strut and hardware.
 - 3. Install plastic caps on exposed cut edges of strut.
- C. Install floor-mounted enclosures located in mechanical equipment rooms on concrete housekeeping pads. Attach enclosure legs using galvanized- or stainless-steel anchors.
- D. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

3.8 ELECTRIC POWER CONNECTIONS

- A. Connect electrical power to DDC system products requiring electrical power connections.
- B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.
- C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.
- D. Comply with requirements in Section 260519 "Conductors and Cables" for electrical power conductors and cables.
- E. Comply with requirements in Section 260533 "Raceways and Boxes" for electrical power raceways and boxes.

3.9 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Electrical Identification" for identification products and installation.
- B. Identify each of the following components. Comply with requirements in Section 200553 "Identification for General Mechanical Piping and Equipment" for identification products and installation.
 - 1. Gateway.
 - 2. DDC controller.

- 3. Enclosure.
- 4. Control damper.
- 5. Control valve.
- 6. Accessory.
- C. Install unique instrument identification on face of each instrument connected to a DDC controller.
- D. Where product is installed above accessible tile ceiling, also install matching identification on face of ceiling grid located directly below.
- E. Where product is installed above an inaccessible ceiling, also install identification on face of access door directly below.
- F. Warning Labels and Signs:
 - 1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
 - 2. Shall be located in highly visible location near power service entry points.

3.10 NETWORK INSTALLATION

- A. Install balanced twisted pair or optical fiber cable when connecting between the following network devices:
 - 1. Operator workstations.
 - 2. Operator workstations and network controllers.
 - 3. Network controllers.
- B. Install balanced twisted pair or copper cable (as required by equipment) when connecting between the following:
 - 1. Gateways.
 - 2. Gateways and network controllers or programmable application controllers.
 - 3. Routers.
 - 4. Routers and network controllers or programmable application controllers.
 - 5. Network controllers and programmable application controllers.
 - 6. Programmable application controllers.
 - 7. Programmable application controllers and application-specific controllers.
 - 8. Application-specific controllers.
- C. Install cable in continuous raceway.
 - 1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.11 NETWORK NAMING AND NUMBERING

- A. Coordinate with Owner and provide unique naming and addressing for networks and devices.
- B. ASHRAE 135 Networks:
 - 1. MAC Address:
 - a. Every network device shall have an assigned and documented MAC address unique to its network.
 - b. Ethernet Networks: Document MAC address assigned at its creation.
 - c. ARCNET or MS/TP networks: Assign from 00 to 64.
 - 2. Network Numbering:
 - a. Assign unique numbers to each new network.
 - b. Provide ability for changing network number through device switches or operator interface.
 - c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.
 - 3. Device Object Identifier Property Number:
 - a. Assign unique device object identifier property numbers or device instances for each device network.
 - b. Provide for future modification of device instance number by device switches or operator interface.
 - c. LAN shall support up to 4,194,302 unique devices.
 - 4. Device Object Name Property Text:
 - a. Device object name property field shall support 32 minimum printable characters.
 - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.
 - Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
 - 2) Example 2: Device object name for a VAV terminal unit controller serving room 102 could be "VAV unit 102".
 - 5. Object Name Property Text for Other Than Device Objects:
 - a. Object name property field shall support 32 minimum printable characters.
 - b. Assign object name properties with plain-English names descriptive of application.
 - 1) Example 1: "Zone 1 Temperature."
 - 2) Example 2 "Fan Start and Stop."
 - 6. Object Identifier Property Number for Other Than Device Objects:

- a. Assign object identifier property numbers according to Drawings indicated.
- b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.

3.12 ELECTRICAL WIRING AND CONNECTION INSTALLATION

- A. Install raceways, boxes, and cabinets according to Section 260533 "Raceways and Boxes."
- B. Install building wire and cable according to Section 260519 "Conductors and Cables."
 - 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.
- C. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.
- D. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.13 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.
- B. Perform the following tests and inspections:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Testing:
 - 1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
 - 2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification

documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.

- 3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
- 4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
- 5. Test Equipment: Use an optical fiber time domain reflectometer for testing of length and optical connectivity.
- 6. Test Results: Record test results and submit copy of test results for Project record.

3.14 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests, leak tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
- D. Control Damper Checkout:
 - 1. Verify that control dampers are installed correctly for flow direction.
 - 2. Verify that proper blade alignment, either parallel or opposed, has been provided.
 - 3. Verify that damper frame attachment is properly secured and sealed.
 - 4. Verify that damper actuator and linkage attachment is secure.
 - 5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
 - 6. Verify that damper blade travel is unobstructed.
- E. Control Valve Checkout:
 - 1. Verify that control valves are installed correctly for flow direction.
 - 2. Verify that valve body attachment is properly secured and sealed.
 - 3. Verify that valve actuator and linkage attachment is secure.
 - 4. Verify that actuator wiring is complete, enclosed and connected to correct power source.
 - 5. Verify that valve ball, disc or plug travel is unobstructed.
 - 6. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.
- F. Instrument Checkout:
 - 1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.

- 2. Verify that attachment is properly secured and sealed.
- 3. Verify that conduit connections are properly secured and sealed.
- 4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
- 5. Inspect instrument tag against approved submittal.
- 6. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
- 7. For temperature instruments:
 - a. Verify sensing element type and proper material.
 - b. Verify length and insertion.

3.15 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
- C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
- F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
- G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- I. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- J. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 - 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

- K. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact making or breaking.
- L. Control Dampers:
 - 1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed and 100 percent open at proper air pressure.
 - 3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 4. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- M. Control Valves:
 - 1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed and 100 percent open at proper air pressures.
 - 3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 4. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- N. Meters: Check sensors at zero, 50, and 100 percent of Project design values.
- O. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.
- P. Switches: Calibrate switches to make or break contact at set points indicated.
- Q. Transmitters:
 - 1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
 - 2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.16 DDC SYSTEM CONTROLLER CHECKOUT

- A. Verify power supply.
 - 1. Verify voltage, phase and hertz.
 - 2. Verify that protection from power surges is installed and functioning.
 - 3. Verify that ground fault protection is installed.
 - 4. If applicable, verify if connected to UPS unit.

- 5. If applicable, verify if connected to a backup power source.
- 6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.
- B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.
- C. Verify that spare I/O capacity is provided.

3.17 DDC CONTROLLER I/O CONTROL LOOP TESTS

- A. Testing:
 - 1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
 - 2. Test every I/O point throughout its full operating range.
 - 3. Test every control loop to verify operation is stable and accurate.
 - 4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
 - 5. Test and adjust every control loop for proper operation according to sequence of operation.
 - 6. Test software and hardware interlocks for proper operation. Correct deficiencies.
 - 7. Operate each analog point at the following:
 - a. Upper quarter of range.
 - b. Lower quarter of range.
 - c. At midpoint of range.
 - 8. Exercise each binary point.
 - 9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
 - 10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desire results.

3.18 DDC SYSTEM VALIDATION TESTS

- A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.
- B. After approval of Test Plan, execute all tests and procedures indicated in plan.
- C. After testing is complete, submit completed test checklist.
- D. Pretest Checklist: Submit the following list with items checked off once verified:

- 1. Detailed explanation for any items that are not completed or verified.
- 2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
- 3. HVAC equipment motors operate below full-load amperage ratings.
- 4. Required DDC system components, wiring, and accessories are installed.
- 5. Installed DDC system architecture matches approved Drawings.
- 6. Control electric power circuits operate at proper voltage and are free from faults.
- 7. Required surge protection is installed.
- 8. DDC system network communications function properly, including uploading and downloading programming changes.
- 9. Using BACnet protocol analyzer, verify that communications are error free.
- 10. Each controller's programming is backed up.
- 11. Equipment, products, wiring cable and conduits are properly labeled.
- 12. All I/O points are programmed into controllers.
- 13. Testing, adjusting and balancing work affecting controls is complete.
- 14. Dampers and actuators zero and span adjustments are set properly.
- 15. Each control damper and actuator goes to failed position on loss of power.
- 16. Valves and actuators zero and span adjustments are set properly.
- 17. Each control valve and actuator goes to failed position on loss of power.
- 18. Meter, sensor and transmitter readings are accurate and calibrated.
- 19. Control loops are tuned for smooth and stable operation.
- 20. View trend data where applicable.
- 21. Each controller works properly in standalone mode.
- 22. Safety controls and devices function properly.
- 23. Interfaces with fire-alarm system function properly.
- 24. Electrical interlocks function properly.
- 25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
- 26. Record Drawings are completed.
- E. Test Plan:
 - 1. Prepare and submit a validation test plan including test procedures for performance validation tests.
 - 2. Test plan shall address all specified functions of DDC system and sequences of operation.
 - 3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
 - 4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
 - 5. Include a test checklist to be used to check and initial that each test has been successfully completed.
 - 6. Submit test plan documentation 20 business days before start of tests.
- F. Validation Test:
 - 1. Verify operating performance of each I/O point in DDC system.
 - a. Verify analog I/O points at operating value.
 - b. Make adjustments to out-of-tolerance I/O points.

- 1) Identify I/O points for future reference.
- 2) Simulate abnormal conditions to demonstrate proper function of safety devices.
- 3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
- 2. Simulate conditions to demonstrate proper sequence of control.
- 3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
- 4. After 24 Hours following Initial Validation Test:
 - a. Re-check I/O points that required corrections during initial test.
 - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
- 5. After 24 Hours of Second Validation Test:
 - a. Re-check I/O points that required corrections during second test.
 - b. Continue validation testing until I/O point is normal on two consecutive tests.
- 6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
- 7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.
- G. DDC System Response Time Test:
 - 1. Simulate HLC.
 - a. Heavy load shall be an occurrence of 50 percent of total connected binary COV, one-half of which represent an "alarm" condition, and 50 percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.
 - 2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
 - 3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
 - 4. Purpose of test is to demonstrate DDC system, as follows:
 - a. Reaction to COV and alarm conditions during HLC.
 - b. Ability to update DDC system database during HLC.
 - 5. Passing test is contingent on the following:
 - a. Alarm reporting at printer beginning no more than two seconds after the initiation (time zero) of HLC.
 - b. All alarms, both binary and analog, are reported and printed; none are lost.
 - c. Compliance with response times specified.

- 6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.
- H. DDC System Network Bandwidth Test:
 - 1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
 - 2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

3.19 DDC SYSTEM WIRELESS NETWORK VERIFICATION

- A. DDC system Installer shall design wireless DDC system networks to comply with performance requirements indicated.
- B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.
- C. Testing and verification of all wireless devices shall include, but not be limited to, the following:
 - 1. Speed.
 - 2. Online status.
 - 3. Signal strength.

3.20 FINAL REVIEW

- A. Submit written request to Architect and Construction Manager when DDC system is ready for final review. Written request shall state the following:
 - 1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
 - 2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
 - 3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
 - 4. DDC system is complete and ready for final review.
- B. Review by Architect and Construction Manager shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.
- C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third

and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.

E. Prepare and submit closeout submittals when no deficiencies are reported.

3.21 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 dampers without positioners, following the manufacturer's recommended procedure, so that damper is 100 percent open and closed.
 - 9. Stroke and adjust control dampers with positioners, following manufacturer's recommended procedure, so that 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 three visits to Project during other than normal occupancy hours for this purpose.

3.22 MAINTENANCE SERVICE

A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include <u>24</u> months' full maintenance by DDC system manufacturer's authorized service representative. Include quarterly preventive maintenance, repair or replacement of worn or defective components, cleaning, calibration and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.23 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for <u>two</u> years.
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least 30 days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.24 DEMONSTRATION

- A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.
- B. Extent of Training:
 - 1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
 - 2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
 - 3. Minimum Training Requirements:
 - a. Provide not less than five days of training total.
 - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
- C. Training Schedule:

- 1. Schedule training with Owner 20 business days before expected Substantial Completion.
- 2. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with 30-minute break between sessions. Morning and afternoon sessions shall be separated by 60-minute lunch period. Training, including breaks and excluding lunch period, shall not exceed eight hours per day.
- 3. Provide staggered training schedule as requested by Owner.
- D. Training Attendee List and Sign-in Sheet:
 - 1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
 - 2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
 - 3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.
 - 4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
 - 5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.
- E. Training Attendee Headcount:
 - 1. Plan in advance of training for five attendees.
 - 2. Make allowance for Owner to add up to two attendees at time of training.
 - 3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.
- F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:
 - 1. High school education and degree.
 - 2. Intermediate user knowledge of computers and office applications.
 - 3. Intermediate knowledge of HVAC systems.
 - 4. Intermediate knowledge of DDC systems.
 - 5. Basic knowledge of DDC system and products installed.
- G. Attendee Training Manuals:
 - 1. Provide each attendee with a color hard copy of all training materials and visual presentations.
 - 2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
 - 3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.

- H. Instructor Requirements:
 - 1. One or multiple qualified instructors, as required, to provide training.
 - 2. Instructors shall have not less than five years of providing instructional training on not less than five past projects with similar DDC system scope and complexity to DDC system installed.
- I. Organization of Training Sessions:
 - 1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
 - a. Daily operators.
 - b. Advanced operators.
 - c. System managers and administrators.
 - 2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.
- J. Training Outline:
 - 1. Submit training outline for Owner review at least 10 business day before scheduling training.
 - 2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.
- K. On-Site Training:
 - 1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.
 - 2. Instructor shall provide training materials, projector and other audiovisual equipment used in training.
 - 3. Provide as much of training located on-site as deemed feasible and practical by Owner.
 - 4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration and service requirements.
 - 5. Operator workstation provided with DDC system shall be used in training.
- L. Training Content for Daily Operators:
 - 1. Basic operation of system.
 - 2. Understanding DDC system architecture and configuration.
 - 3. Understanding each unique product type installed including performance and service requirements for each.
 - 4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.

- 5. Operating operator workstations, printers and other peripherals.
- 6. Logging on and off system.
- 7. Accessing graphics, reports and alarms.
- 8. Adjusting and changing set points and time schedules.
- 9. Recognizing DDC system malfunctions.
- 10. Understanding content of operation and maintenance manuals including control drawings.
- 11. Understanding physical location and placement of DDC controllers and I/O hardware.
- 12. Accessing data from DDC controllers.
- 13. Operating portable operator workstations.
- 14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
- 15. Running each specified report and log.
- 16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
- 17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
- 18. Executing digital and analog commands in graphic mode.
- 19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
- 20. Demonstrating DDC system performance through trend logs and command tracing.
- 21. Demonstrating scan, update, and alarm responsiveness.
- 22. Demonstrating spreadsheet and curve plot software, and its integration with database.
- 23. Demonstrating on-line user guide, and help function and mail facility.
- 24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
- 25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:
 - a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers and valves for correct position under each condition.
 - b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
 - c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.
 - d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
 - e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
 - f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
 - g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.
- M. Training Content for Advanced Operators:

- 1. Making and changing workstation graphics.
- 2. Creating, deleting and modifying alarms including annunciation and routing.
- 3. Creating, deleting and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
- 4. Creating, deleting and modifying reports.
- 5. Creating, deleting and modifying points.
- 6. Creating, deleting and modifying programming including ability to edit control programs off-line.
- 7. Creating, deleting and modifying system graphics and other types of displays.
- 8. Adding DDC controllers and other network communication devices such as gateways and routers.
- 9. Adding operator workstations.
- 10. Performing DDC system checkout and diagnostic procedures.
- 11. Performing DDC controllers operation and maintenance procedures.
- 12. Performing operator workstation operation and maintenance procedures.
- 13. Configuring DDC system hardware including controllers, workstations, communication devices and I/O points.
- 14. Maintaining, calibrating, troubleshooting, diagnosing and repairing hardware.
- 15. Adjusting, calibrating and replacing DDC system components.
- N. Training Content for System Managers and Administrators:
 - 1. DDC system software maintenance and backups.
 - 2. Uploading, downloading and off-line archiving of all DDC system software and databases.
 - 3. Interface with Project-specific, third-party operator software.
 - 4. Understanding password and security procedures.
 - 5. Adding new operators and making modifications to existing operators.
 - 6. Operator password assignments and modification.
 - 7. Operator authority assignment and modification.
 - 8. Workstation data segregation and modification.
- O. Video of Training Sessions:
 - 1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
 - 2. Stamp each recording file with training session number, session name and date.
 - 3. Provide Owner with two copies of digital files on USB drives for later reference and for use in future training.
 - 4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION