SECTION 23 09 00 – BUILDING AUTOMATION SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

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

B. See "Sequences of Operation" for requirements that relate to this Section.

1.2 RELATED DOCUMENTS

A. Drawings and Specification Sections of the Contract, including General and Supplementary Conditions, apply to this Section.
   1. General Requirements Section 01 00 00
   2. Section 01 00 00 – General and Special Requirements
   3. Section 01 33 00 – Submittal Requirements
   4. Section 27 05 26 – Commissioning of HVAC
   5. Section 05 45 19 – Commissioning of Integrated Automation
   6. Section 23 31 03 – Detection and Alarm (Fire and Smoke Alarm Systems)
   7. Section 01 60 00 – Materials and Equipment
   8. Section 23 05 00 – Common Work Results for HVAC
   9. Section 23 05 93 – Testing, Adjusting, and Balancing for HVAC
   10. Section 26 01 00 – General Electrical Provisions for Electrical Work
   11. Section 26 05 00 – Common Work Results for Electrical
   12. Section 26 05 19 – Low Voltage Electrical Power Conductors and Cables
   13. Section 26 05 29 – Hangers and Supports for Electrical Systems
   14. Section 26 05 33 – Raceway and Boxes for Electrical Systems
   15. Section 26 05 53 – Identification for Electrical Systems
   16. Section 26 27 26 – Wiring Devices

1.3 DEFINITIONS

A. BACnet: An industry standard data communication protocol for Building Automation and Control Networks. Refer to AHSRAE standard 135-2010

B. BIBB: BACnet Interoperability Building Blocks

C. DDC: Direct digital controls

D. IP: Internet Protocol

E. I/O: Input/Output

F. LAN: Local area network.

G. MS/TP: Master-slave/token-passing. Refer to AHSRAE standard 135-2010

H. TCP: Transfer Control Protocol

I. Scope Terminology
   1. Provide = Furnish equipment, engineer, program and install
   2. Furnish = Furnish equipment, engineer and program
   3. Mount = securely fasten or pipe
   4. Install = mount and wire
   5. Wire = wire only

1.4 SYSTEM DESCRIPTION

A. The Building Automation System (BAS) contractor shall furnish and install a networked system of HVAC controls. The contractor shall incorporating direct digital control (DDC) for central plant equipment, building ventilation equipment, supplemental heating and cooling equipment, and terminal units.

B. Provide networking to new DDC equipment using communication standards. System shall be capable of BACnet communication according to ASHRAE standard ANSI/ASHRAE 135-2010 for interoperability with smart equipment and for the main IP communication trunk to the BAS Server. The system shall not be limited to only standard protocols, but shall also be able to integrate to a wide variety of third-party devices and applications via drivers and gateways.

C. Provide standalone controls where called for on the drawings or sequences.

1.5 WORK INCLUDED

A. The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation, or identification number and sequence of operation all bearing the name of the manufacturer.

B. Furnish a complete distributed direct digital control system in accordance with this specification section. This includes all system controllers, logic controllers, and all input/output devices. Items of work included are as follows:
   1. Provide a submittal that meets the requirements below for approval.
   2. Coordinate installation schedule with the mechanical contractor and general contractor.
   3. Provide installation of all panels and devices unless otherwise stated.
   4. Provide power for panels and control devices.
   5. Provide all low voltage control wiring for the DDC system.
   6. Provide miscellaneous control wiring for HVAC and related systems regardless of voltage.
   7. Provide engineering and technician labor to program and commission software for each system and operator interface. Submit commissioning reports for approval.
   8. Participate in commissioning for all equipment that is integrated into the BAS (Refer to Commissioning sections of the equipment or systems in other parts of this specification.)
   9. Provide testing, demonstration and training as specified below.

1.6 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:
   1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 5 seconds.
   2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 5 seconds.
   3. Object Command: Reaction time of less than 5 seconds between operator command of a binary object and device reaction.
   4. Object Scan: Transmit change of state and change of analog values to control units or workstation within 5 seconds.
   5. Alarm Response Time: Annunciate alarm at workstation within 2 seconds. Multiple workstations must receive alarms within five seconds of each other.
   6. Program Execution Frequency: Programmable controllers shall execute DDC PI control loops, and scan and update process values and outputs at least once per second.
   7. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
      a. Water Temperature: Plus or minus 1 deg F.
      b. Water Flow: Plus or minus 5 percent of full scale.
      c. Water Pressure: Plus or minus 2 percent of full scale.
      d. Space Temperature: Plus or minus 1 deg F.
      e. Ducted Air Temperature: Plus or minus 1 deg F.
      f. Outside Air Temperature: Plus or minus 2 deg F.
      g. Dew Point Temperature: Plus or minus 3 deg F.
      h. Temperature Differential: Plus or minus 0.25 deg F.
      i. Relative Humidity: Plus or minus 2 percent.
      j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
      k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
      l. Airflow (Terminal): Plus or minus 10 percent of full scale.
      m. Air Pressure (Space): Plus or minus 0.01-inch wg.
      n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
      o. Carbon Monoxide: Plus or minus 5 percent of reading.
      p. Carbon Dioxide: Plus or minus 50 ppm.
      q. Electrical: Plus or minus 5 percent of reading.

1.7 SUBMITTALS

A. Provide submittals for fast track items that need to be approved and released to meet the schedule of the project. Provide submissions for the following items separately:
   1. Valve schedule and cut sheets
   2. Factory mounting and wiring diagrams and cut sheets
   3. Thermostat locations

B. Provide BIM symbols (Revit) for control devices that are to be shown on the coordinated BIM model.

C. Provide a complete submittal with all controls system information for approval before construction starts. Include the following:

1. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
2. Wiring Diagrams: Power, signal, and control wiring.
3. Details of control panel faces, including sizes, controls, instruments, and labeling.
4. Schedule of dampers and actuators including size, leakage, and flow characteristics.
5. If dampers are furnished by other, submit a damper actuator schedule coordinating actuator sizes with the damper schedule.
6. Schedule of valves including leakage and flow characteristics.
7. Written description of the Sequence of Operations.
8. Network riser diagram showing wiring types, network protocols, locations of floor penetrations and number of control panels. Label control panels with network addresses and BACnet device instance numbers. Show all routers, switches, hubs and repeaters.
9. Point list for each system controller including both inputs and outputs (I/O), point numbers, controlled device associated with each I/O point, and location of I/O device.
10. Starter and variable frequency drive wiring details of all automatically controlled motors.
11. Reduced size floor plan drawings showing locations of control panels, thermostats and any devices mounted in occupied space.

D. Wireless Communication: If wireless sensors and / or network are used, submit a radio signal layout showing the signal reach of every wireless mesh device. Show where repeaters are needed so that a wireless signals overlap

E. Product Data: Include manufacturer's technical literature for each control device indicated, labeled with setting or adjustable range of control. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated. Submit a write-up of the application software that will be used on the operator workstation including revision level, functionality and software applications required to meet the specifications.

F. Submit PICS statements for all direct digital controllers and interfaces.

G. Submit a description of the application software that will be used on the operator workstation including revision level, functionality and software applications required to meet the specifications.

H. Wiring Diagrams: Detail the wiring of the control devices and the panels. Show point-to-point wiring from field devices to the control panel. Show point-to-point wiring of hardwired interlocks. Show a ladder diagram or schematic of wiring internal to the panels, including numbered terminals. Clearly designate wiring that is done at a factory, at a panel shop or in the field.

I. Submit blank field check-out and commissioning test reports, customized for each panel or system, which will be filled out by the technician during start-up.

J. Submit sample graphics for approval before starting system commissioning.

K. Variance letter: Submit a letter detailing each item in the submission that varies from the contract specification or sequence of operation in any way.

L. After the BAS system is approved for construction, submit sample operator workstation graphics for typical systems for approval. Print and submit the graphics that the operator will

use to view the systems, change setpoints, modify parameters and issue manual commands. Programming shall not commence until typical graphics are approved.

1.8 QUALITY ASSURANCE

A. Codes
   1. Perform all wiring in accordance with Division 26, NEC, local codes and Owner's requirements.
   2. Uniform Building Code (UBC)
   3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
   4. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilation Systems."
   5. Comply with ASHRAE 135-2010 BACNet: A Data Communication Protocol for Building Automation and Control Networks.
   6. All equipment shall be UL listed and approved and shall meet with all applicable NFPA standards, including UL 916 - PAZX Energy Management Systems,
   7. Provide UL 864 – UUKL Smoke Control, where controllers and networks are used for that purpose.
      a. Provide written approvals and certifications after installation has been completed.
   8. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.
   9. The manufacturer of the building automation system shall provide documentation supporting compliance with ISO-9002 (Model for Quality Assurance in Production, Installation, and Servicing) and ISO-140001 (The application of well-accepted business management principles to the environment). The intent of this specification requirement is to ensure that the products from the manufacturer are delivered through a Quality System and Framework that will assure consistency in the products delivered for this project.

B. Qualifications
   1. Installing contractor shall be in the business of installing and servicing DDC controls for mechanical systems, temperature and ventilation control, environmental control, lighting control, access and security controls, and energy automation as their primary business. Installer Qualifications: An experienced installer who is the authorized representative of the automatic control system manufacturer for both installation and maintenance of controls required for this Project.
   2. Engineering, drafting, programming, and graphics generation shall be performed by the local branch engineers and technicians directly employed by the Building Automation System Contractor.
   3. Supervision, checkout and commissioning of the system shall be by the local branch engineers and technicians directly employed by the Building Automation System Contractor. They shall perform commissioning and complete testing of the BAS system.

C. The BMS contractor shall maintain a service organization consisting of factory trained service personnel and provide a list of ten (10) projects, similar in size and scope to this project, completed within the last five years.

D. Final determination of compliance with these specifications shall rest solely with the Engineers and Owner who will require proof of prior satisfactory performance.

E. For any BAS system and equipment submitted for approval, the BAS contractor shall state what, if any, specific points of system operation differ from these specifications.

1.9 DELIVERY, STORAGE, AND HANDLING

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

1.10 COORDINATION

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

B. Coordinate equipment with Section 26 00 00 "Fire Alarm" to achieve compatibility with equipment that interfaces with that system.

C. Coordinate power for control units and operator workstation with electrical contractor.

D. Coordinate equipment with provider of starters and drives to achieve compatibility with motor starter control coils and VFD control wiring.

E. Coordinate scheduling with the mechanical contractor and general contractor. Submit a schedule for approval based upon the installation schedule of the mechanical equipment.

F. Products Furnished but Not Installed Under This Section
   1. Hydronic Piping:
      a. Control Valves
      b. Temperature Sensor Wells and Sockets
      c. Flow Switches
      d. Flow Meters
   2. Refrigerant Piping
      a. Pressure and Temperature Sensor Wells and Sockets
   3. Sheetmetal accessories
      a. Dampers
      b. Airflow Stations
      c. Terminal Unit Controls

G. Products Installed but Not Furnished Under This Section
   1. Refrigeration Equipment:
      a. Refrigerant Leak Detection System
      b. Proof of flow pressure switches
   2. Rooftop Air Handling Equipment:
      a. Thermostats
      b. Duct Static Pressure Sensors

H. Integrate to equipment as called for in the sequence of operations

1.11 WARRANTY

A. Conform to the warranty requirement of the Contract Documents, General Requirements and this section or a minimum of 12 months. Provide the strictest.

B. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one year from completion of system demonstration.

C. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours.

D. During normal building occupied hours, failure of items that are critical for system operation shall be provided within 4 hours of notification from the Owner's Representative.

E. This warranty shall apply equally to both hardware and software.

PART 2 - PRODUCTS

2.1 ACCEPTABLE SYSTEMS

A. Provide a Building Automation System based upon the following:
   1. Siemens APOGEE System as installed by the Siemens Industry branch office

B. The vendors and products listed shall comply with these specifications. It shall not be assumed that standard products and methods will be acceptable without prior approval. Exceptions shall be noted during the bid process and documented in the submittal process.

2.2 BAS NETWORK

A. All networked control products provided for this project shall be comprised of an industry standard open protocol internetwork. Communication involving control components (i.e. all types of controllers and operator interfaces) shall conform to ASHRAE 135-2010 BACnet standard. Networks and protocols proprietary to one company or distributed by one company are prohibited.

B. Access to system data shall not be restricted by the hardware configuration of the building management system. The hardware configuration of the BMS network shall be totally transparent to the user when accessing data or developing control programs.
   1. Software applications, features, and functionality, including administrative configurations, shall not be separated into several network control engines working together.

C. The operator interface shall be served up by a Web Server imbedded in a controller field panel. The Owner shall provide PCs and Web Browsing tools to interface to the system.

D. The network architecture shall consist of three levels of networks:
   1. Owner furnished network with 1 connection the Field Panel Web Server. All operator interfaces shall be on the Owners network.

2. The Automation level network shall be BACnet/IP over Ethernet. It shall network the Automation Server, Operator workstations, and BC level controllers. Provide network media converters, routers and switches as necessary for a complete network.
3. The Floor level network shall be BACnet over MS/TP. It shall network to all of the DDC controlled equipment on a floor or in a system and network to a router that connects to the Automaton level BAS backbone. Controllers for the central plant and large infrastructure air handlers shall reside on the backbone BACnet/IP network.

E. The primary backbone network between the building level controllers shall be based upon BACnet/IP. Ethernet Network switches shall be strategically placed through the building to cover several floors or several mechanical rooms that are within 300 ft wiring-feet of each other.

F. The Building Level Controllers shall be able to support subnetwork protocols that may be needed depending on the type of equipment or application. Subnetworks shall be limited to :
1. BACnet MS/TP
2. Apogee FLN
3. Modbus

G. BACnet MSTP Setup rules
1. Addressing for the MSTP devices shall start at 00 and continue sequentially for the number of devices on the subnetwork.
2. No gaps shall be allowed in the addresses.
3. Set the MaxMaster property to the highest address of the connected device.
4. MaxMaster property shall be adjusted when devices are added to the subnetwork.

H. Application specific controllers for smaller single zone, supplemental or special systems can reside on the BACnet/IP network or on a subnetwork.

I. Floor level controllers, terminal units, package AC units, auxiliary equipment, VFDs, meters shall reside on one of the subnetworks above.

J. Provide all communication media, connectors, repeaters, bridges, switches, and routers necessary for the internetwork.

K. Use fiber optic cabling for all Ethernet runs longer than 300 ft.

L. Controllers and software shall be BTL listed at the time of installation.

M. Provide all communication media, connectors, repeaters, bridges, switches, and routers necessary for the internetwork.

N. The system shall meet peer-to-peer communication services such that the values in any one BC or AAC level controller can be read or changed from all other controllers with the need for intermediary devices. The software shall provide transparent transfer of all data, control programs, schedules, trends, and alarms from any one controller through the internetwork to any other controller, regardless of subnetwork routers.

O. Systems that use variations of BACnet using Point-to-Point (PTP) between controllers, gateways, bridges or networks that are not peer-to-peer are not allowed.

P. Remote Communications: Provide a TCP/IP compatible communication port for connection to the Owner's network for remote communications. Provide coordination with the Owner for addressing and router configuration on both ends of the remote network.

Q. Where a smoke control application is required, provide UUKL listed network switches, and NFPA approved cabling, enclosures and installation methods.

R. The system shall be installed with a 10% spare capacity on each subnetwork for the addition of future controllers.

2.3 DISTRIBUTED CONTROL REQUIREMENTS

A. The loss of any one DDC controller shall not affect the operation of other HVAC systems, only for the points connected to the DDC controller.

B. The system shall be scalable in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, DDC Controllers, and operator devices.

C. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O, and data collection. The failure of any single component or network connection shall not interrupt the execution of any control strategy, reporting, alarming and trending function, or any function at any operator interface device.

D. DDC Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller on the network without dependence upon a central processing device. DDC Controllers shall also be able to send alarms to multiple operator workstations without dependence upon a central or intermediate processing device.

E. The DDC control panel shall be mounted in the same mechanical room as the equipment being controlled, or an adjacent utility room.

F. Multiple systems can be programmed on the same controller as long as they are in the same room. Systems on separate floors shall have separate controllers.

G. VAV boxes subnetworks shall be connected to the AHU controller that feeds those boxes. If multiple subnetworks are needed, then the VAV shall be grouped into subnetworks in an orderly method, such as per floor, per wing, etc.

H. Remote sensors shall be wired to the control panel of the equipment it is controlling, not across the network.

I. Signals to remote motor control centers shall be hard wired to the control panel, not across the network.

J. Terminal units shall each have their own controller. Only exceptions are:
   1. Groups of reheat coils
   2. Groups of exhaust fans
   3. Groups of chilled beams serving same zone or several adjacent zones

2.4 WEB BASED OPERATOR INTERFACE SOFTWARE

A. Provide a Web-based graphical interface that allows users to access the BAS data via the Internet, extranet, or Intranet (TCP/IP). The Web-based graphical interface shall use HTML-based pages to send and receive data directly from a network of BAS Field Panels to a Web browser.

B. The web server shall support browser access via Microsoft Internet Explorer 6.0 (or later), Firefox, or any browser that supports the compatible plug-in.
   1. Cookies are allowed for compatibility
   2. Microsoft Java Applet (JVM) is allowed for compatibility
   3. Adobe Flash Player shall be allowed for compatibility

C. The web server shall support access via handheld, web enabled devices through apps. The apps shall be available for download from public sites, such as Blackberry App World or Android Market.

D. If a field panel cannot serve up the graphics, then dedicated PC-based Web servers or separate "Web Appliance" devices may be allowed for this purpose.

E. The Web server shall allow monitor and control of data in any field panels networked together on the same automation level TCP/IP Ethernet network.
   1. The Web server must provide a common alarm display that shows alarms in all field panels on the network.
   2. The Web server must be able to provide common graphics that simultaneously display the current value and status for points residing in multiple field panels.
   3. The Web server must be able to display daily mode schedules for points from multiple field panels simultaneously.

F. Access to the Web interface shall be username and password protected. A user's rights and privileges to database objects within the BAS shall be configurable on a per-user basis. An option shall exist to only allow users "read" access to BAS objects via the Web browser. Operator sessions shall be configurable for "auto-logoff" after a designated period of user inactivity.

   1. A graphic selector list shall allow or limit the graphic displays that a user account has access to.
   2. The embedded Web server shall support an unlimited number of user accounts. A minimum of five concurrent user sessions shall be available for simultaneous operator access to the Web server's pages.
   3. The embedded Web server shall be compatible with and allow coexistence within standard IT security policies and tools (e.g., Firewall protection).

G. The embedded Web server shall provide the following functionality to users via Web browser, based on their access and privilege rights:

   1. Point Navigation – Provide a screen that allows users to see all of the points that are active in the system. The points shall include hardwired, software, schedules, trends, alarms and network setup.
      a. The point navigation shall display the point name, descriptor, command priority, alarm status, and current value.

b. The user shall be able to run and print a pre-configured point log report through a web interface client that shows the point name, descriptor, command priority, alarm status, and current value.
c. The interface and report shall allow selection filter such that the operator can select or deselect the types of point that are visible.

2. Alarm Display –displays current BAS alarms to which the user has access will be displayed. Users will be able to acknowledge active alarms, erase resolved alarms, and directly link to the Point Commanding feature.
   a. The alarm display must provide a filter that displays all alarms whether acknowledged or not.
   b. The alarm display must provide a filter that displays only alarms that have not yet been acknowledged.
   c. The alarm display must provide a persistent indication whenever there is one or more unacknowledged alarm in any connected field panel.

3. Point details – users will have access to point detail information including operational status, operational priority, physical address, and alarm limits, for point objects to which they have access rights.

4. Point Commanding – users will be able to override and command points they have access to via the Web browser interface.

5. Scheduling – allows operators, depending on their current user privileges, to override schedules selected by date, and to modify the properties of a selected schedule.
   a. The scheduler display must be able to represent facility mode schedules in a graphical format.

6. Trend Data Report – allows users to run and print a pre-configured trend data report for historical data reporting, including a representation of the alarm status of the each point for each Trend sample. The report shall allow selection of individual points or wildcard selection of points.
   a. Trend data shall be exportable to a data file, such as .csv or other comparable.

7. Network navigation - Provide a screen that allows users to navigate to the panels and terminal units via the network architecture.

H. Graphic Displays – The BAS contractor shall provide a graphical display for each system that is controlled.
   1. Display of system graphics shall be available for viewing over the Web browser. Graphic displays will automatically refresh with the latest change of values. Users shall have the ability to command and override points directly from the graphic display as determined by their user accounts rights. The Graphic Display shall accommodate a minimum of 10 customized graphics.
   2. The Graphic Display shall accommodate the terminal unit graphics related to the Application Specific Controllers tied in to the Field Panels within the system.

I. The web server shall be able to send SMTP text messages to notify users of alarm status. The owners shall provide a mail server and a connection port. SSL shall not be required.

J. The operator shall be able to add modify and delete controller database program, including points, schedules, alarms, and trends.
   1. The operator shall be able to edit the custom program in the field panel that executes the sequences of operations, control loops and logic for the systems controlled.
   2. The operator shall be able to add terminal unit controllers that reside on field panel subnetworks.

K. Internet connections, ISP services, as well as necessary firewalls or proxy servers shall be provided by the Owner as required to support the Web access feature.

2.5 ELECTRONIC DOCUMENTATION

A. Provide software applications and files to view documentation through the GUI.

B. Provide a CAD viewer to view all project AutoCAD documents that are made available by the Architect and Owner.

C. Provide all controls cut sheets in PDF format. Make them available to any user accessing the system over the Internet.

D. Provide a text version of the sequence of operation. Make the written sequence available from the graphic that represents each system. The sequence shall pop up in a printable format such as HTML or PDF.

2.6 CONTROLLER SOFTWARE (i.e. Building Controller software, , DDC software, Field Panel software)

A. Provide a full capability user license to the owner for the operator to be able to see, modify, create, upload, download and save control programs to the DDC controllers.

B. The software program shall be provided as an integral part of DDC Controllers and shall not be dependent upon any higher level computer or another controller for execution.

C. The software application shall be accessible from a PC using the Windows environment, but shall use all of its own services and data files so as to not be susceptible to Microsoft Windows operating systems based viruses.

D. The software shall be provided with an interactive HELP function to assist operators with syntax, abbreviations, commands and saving programs.

E. Point naming and communication format:
   1. All points, panels, and programs shall be identified by a 30-character name. All points shall also be identified by a 16-character point descriptor. The same names shall be displayed at both Building Controller and the Operator Interface.
   2. All digital points shall have a consistent, user-defined, two-state status indication with 8 characters minimum (e.g., Summer, Enabled, Disabled, Abnormal).
   3. The Building Controller Software shall be capable of BACnet communications. The BACnet Building Controller (B-BC) shall have demonstrated interoperability during at least one BTL Interoperability Workshop, have demonstrated compliance to BTL through

BTL listing and shall substantially conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135-2004, Annex L.

F. System Security
   1. User access shall be secured using individual security passwords and user names.
   2. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.
   3. Building Controllers shall be able to assign a minimum of 50 passwords access and control priorities to each point individually. The logon password (at any Operator Interface or portable operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. All other points shall not be displayed at the Operator Interface or portable terminal. Passwords and priorities for every point shall be fully programmable and adjustable.
   4. User Log On/Log Off attempts shall be recorded.
   5. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.
   6. Use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security in the DDC controller software.

G. User Defined Control Applications: The applications software shall program DDC routines to meet the sequences of operations.
   1. Building Controllers shall have the ability to perform energy management routines including but not limited to time of day scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides, start stop time optimization, automatic daylight savings time switch over, night setback control, enthalpy switch over, peak demand limiting, temperature-compensated duty cycling, heating/cooling interlock, supply temperature reset, priority load shedding, and power failure restart.
   2. The Building Controllers shall have the ability to perform the following pre tested control algorithms:
      a. Two position with differential control and time delays
      b. Floating control
      c. Proportional control
      d. Proportional plus integral control
      e. Proportional, integral, plus derivative control
      f. Automatic tuning of control loops
      g. Model-free adaptive control
   3. Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.
   4. Each controller shall support plain language text comment lines in the operating program to allow for quick troubleshooting, documentation, and historical summaries of program development.

H. Peer-to-peer access to other DDC controllers
   1. It shall be possible to use any actual or virtual point data or status, any system calculated data, a result from any process, or any user-defined constant in any controller in the system.
   2. Any process shall be able to issue commands to points in any and all other controllers in the system.
   3. Processes shall be able to generate operator messages and advisories to other operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of an advanced annunciation feature, such as:

a. Generate a report
b. Annunciate an alarm
c. Issue a text message or email

I. Alarm Management
1. Alarm management shall be provided within the controller software to monitor and direct alarm information to operator devices.
2. Each Building Controller shall perform distributed, independent alarm analysis, minimize network traffic and prevent alarms from being lost. At no time shall the Building Controllers ability to report alarms be affected by either operator or activity at a PC workstation, local I/O device or communications with other panels on the network.
3. Conditional alarming shall allow generation of alarms based upon user defined multiple criteria.
4. An Alarm “shelving” feature shall be provided to disable alarms during testing. (Pull the Plug, etc.).
5. Binary Alarms. Each binary alarm object shall be set to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
6. Analog Alarms. Each analog alarm object shall have both high and low alarm limits. Alarming must be able to be automatically and manually disabled.
7. All alarm shall include the point's user-defined language description and the time and date of occurrence.
8. Alarm reports and messages shall be routed to user-defined list of operator workstations, or other devices based on time and other conditions. An alarm shall be able to start programs, print reports, be logged in the event log, generate custom messages, and display graphics.
9. The user shall be able to add a 200-character alarm message to each alarm point to more fully describe the alarm condition or direct operator response. Each Building Controller shall be capable of storing a library of at least 50 alarm messages. Each message may be assigned to any number of points in the Controller.
10. Operator-selected alarms shall be capable of initiating a trigger to an advanced annunciation, such as text, email, etc.
11. An alarm history log shall report the start of the alarm condition, acknowledgement by a user and return of the alarm to normal condition.

J. Scheduling:
1. Provide a comprehensive menu driven program to automatically start and stop designated multiple objects or events in the system according to a stored time.
2. Schedules shall reside in the building controller and shall not rely on external processing or network.
3. It shall be possible to define a group of objects as a custom event (i.e., meeting, athletic activity, etc.). Events can then be scheduled to operate all necessary equipment automatically.
4. For points assigned to one common load group, it shall be possible to assign variable time delays between each successive start and/or stop within that group.
5. The operator shall be able to define the following information:
a. Time, day
b. Commands such as on, off, auto, etc.
c. Time delays between successive commands.
d. There shall be provisions for manual overriding of each schedule by an authorized operator.

6. It shall be possible to schedule calendar-based events up to one year in advance based on the following:
    a. Weekly Schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop, and night economizer. When a group of objects are scheduled together as an Event, provide the capability to adjust the start and stop times for each member.
    b. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by the standard schedule for that day of the week.

K. Peak Demand Limiting (PDL):
1. The Peak Demand Limiting (PDL) program shall limit the consumption of electricity to prevent electrical peak demand charges.
2. PDL shall continuously track the amount of electricity being consumed, by monitoring one or more electrical kilowatt-hour/demand meters. These meters may measure the electrical consumption (kWh), electrical demand (kW), or both.
3. PDL shall sample the meter data to continuously forecast the demand likely to be used during successive time intervals.
4. If the PDL forecasted demand indicates that electricity usage is likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads.
5. Once the demand peak has passed, loads that have been shed shall be restored and returned to normal control.

L. Temperature-compensated duty cycling
1. User defined conditions shall be able to initiate a Duty Cycle Control Program.
2. The Duty Cycle Control Program (DCCP) shall be configured to periodically stop and start loads according to various patterns.
3. The loads shall be cycled such that there is a net reduction in both the electrical demands and the energy consumed.

M. Automatic Daylight Savings Time Switchover. The system shall provide automatic time adjustment for switching to/from Daylight Savings Time.

N. Night setback control. The system shall provide the ability to automatically adjust setpoints for night control.

O. Enthalpy switchover (economizer). The Building Controller Software (BCS) shall control the position of the air handler relief, return, and outside air dampers. If the outside air dry bulb temperature falls below changeover setpoint the BCS will modulate the dampers to provide 100 percent outside air. The user will be able to quickly change over to an economizer system based on dry bulb temperature and will be able to override the economizer cycle and return to minimum outside air operation at any time.

P. Control Loop Algorithm
1. Provide a PID (proportional-integral-derivative) closed-loop control algorithm with direct or reverse action and anti-windup. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, setpoint, and weighting parameters shall be accessible from the operator workstation.

Q. Adaptive Loop Tuning
   1. Building Controllers shall also provide high resolution sampling capability for verification of DDC control loop performance. Documented evidence of tuned control loop performance shall be provided on a monthly, seasonal, quarterly, annual period.
   2. For Model-Free Adaptive Control loops, evidence of tuned control loop performance shall be provided via graphical plots or trended data logs. Graphical plots shall minimally include depictions of setpoint, process variable (output), and control variable (e.g., temperature). Other parameters that may influence loop control shall also be included in the plot (e.g., fan on/off, mixed-air temp).
   3. For PID control loops, operator-initiated automatic and manual loop tuning algorithms shall be provided for all operator-selected PID control loops. Evidence of tuned control loop performance shall be provided via graphical plots or trended data logs for all loops.
      a. In automatic mode, the controller shall perform a step response test with a minimum one-second resolution, evaluate the trend data, calculate the new PID gains and input these values into the selected LOOP statement.
      b. Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

R. Logic programming: Provide a software routine that can build ladder logic to control using many conditional statements.
   1. The logic programming syntax shall be able to combine ladder logic with other software features, such as combining status, scheduling, PDL and alarm conditions into one conditional decision.
   2. Logic programming shall be able to reference conditions in any other controller in the system.

S. Staggered Start:
   1. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started, along with the time delay between starts, shall be user definable in an application and shall not require written scripts or ladder logic.
   2. Upon the resumption of power, each Building Controller shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.

T. Totalization Features:
   1. Run-Time Totalization. Building Controllers shall automatically accumulate and store run-time hours for all digital input and output points. A high runtime alarm shall be assigned, if required, by the operator.
   2. Consumption totalization. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for all analog and digital pulse input type points.
   3. Event totalization. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for all points. The event totalization feature shall be able to store the records associated with events before reset.

U. Data Collection:

1. A variety of historical data collection utilities shall be provided to manually or automatically sample, store, and display system data for all points.
2. Building Controllers shall store point history data for selected analog and digital inputs and outputs:
3. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building Controllers point group.
4. Two methods of collection shall be allowed: either by up to four pre-defined time intervals or upon a pre-defined change of value. Sample intervals of l minute to 7 days shall be provided.
5. Each Building Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.
6. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either user-defined interval, manual command or when the trend buffers are full. All trend data shall be available for use in third-party personal computer applications.

2.7 BUILDING CONTROLLERS (B-BC)

A. Provide all necessary hardware for a complete operating system as required. The Building Controller shall be able to operate as a standalone panel and shall not be dependent upon any higher level computer or another controller for operation.

B. Basis of design is Siemens PX Modular and Compact Controllers (PXC).

C. This controller shall have the BTL listing and meet the BACnet device profile of a Building Controller (B-BC).
   1. The Building Level Controller shall have the capability to be the BACnet/IP Broadcast Management Device (BBMD) and support foreign devices.
   2. The Building Level Controller shall have the capability to act as a BACnet router between MS/TP subnetworks and BACnet/IP.

D. This level of controller shall be used for the following types of systems:
   1. Chiller plant systems
   2. Heating plant systems
   3. Cooling Towers
   4. Pumping systems
   5. VAV air handlers
   6. Air handlers over 15,000 cfm
   7. Systems with over 24 input/output points

E. Computing power and memory minimum:
   1. A 32-bit, stand-alone, multi-tasking, multi-user, real-time 100MHz digital control microprocessor module.
   2. Inputs shall be 16-bit minimum analog-to-digital resolution
   3. Outputs shall be 10-bit minimum digital-to-analog resolution
   4. Memory module (24 Megabyte, minimum) to accommodate all Primary Control Panel software requirements, including but not limited to, its own operating system and databases (see Controllers Software section), including control processes, energy management applications, alarm management applications, historical/trend data for points

specified, maintenance support applications, custom processes, operator I/O, dial-up communications.
5. Real time clock and battery
6. Data collection/ Data Trend module sized for 10,000 data samples.
7. Flash Memory Firmware: Each Building Level Control Panel shall support firmware upgrades without the need to replace hardware.

F. Onboard or Modular hardware and connections:
1. Primary Network communication module, if needed for primary network communications.
2. Secondary Network communication module, if needed for secondary network communications.
3. RJ45 port 10/100Mbaud
4. RS485 ports for subnetworks and point expansion
5. Man to Machine Interface port (MMI)
6. USB Port

G. Input and Output Points Hardware
1. Input/output point modules as required including spare capacity.
2. Monitoring of the status of all hand-off-auto switches.
3. Monitoring of all industry standard types of analog and digital inputs and outputs, without the addition of equipment to the primary control panel.
4. Local status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Each primary control panel shall perform diagnostics on all inputs and outputs and a failure of any input or output shall be indicated both locally and at the operator workstation.
5. Graduated intensity LEDs or analog indication of value for each analog output.

H. Code compliance
1. Approvals and standards: UL916; CE; FCC
2. Provide UL864-UUKL where called for in the sequences of operations.

I. Accessories:
1. Appropriate NEMA rated metal enclosure.
2. Power supplies as required for all associated modules, sensors, actuators, etc.

J. Keypad.
1. Where called for in the sequence of operation, or on the plans, a local keypad and display shall be provided for each controller. The keypad shall be provided for interrogating and editing data. An optional system security password shall be available to prevent unauthorized use of the keypad and display.

K. The operator shall have the ability to manually override automatic or centrally executed commands at the primary control panels via local, point discrete, on-board hand/off/auto operator override switches. If on board switches are not available, provide separate control panels with HOA switches. Mount panel adjacent to primary control panel. Provide hand/off/auto switch for each digital output, including spares.

L. Each Building Level Control Panel shall continuously perform self-diagnostics on all hardware modules and network communications. The System Level Control Panel shall provide both

local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication with any system.

M. Panel setup, point definitions and sequencing diagrams shall be backed up on EEPROM memory.

N. Power loss. In the event of the loss of power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 30 days.

O. Building Level control panels shall provide at least two serial data communication ports for operation of operator I/O devices such as industry standard printers, operator terminals, modems and portable laptop operator's terminals. Primary control panels shall allow temporary use of portable devices without interrupting the normal communications, operation of permanently connected modems, printers or terminals.

P. Building Level Controllers shall have the capability to serve as a gateway between Modus subnetworks and BACnet objects. Provide software, drives and programming.

Q. Isolation shall be provided at all primary control panel terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standards 587-1980.

R. Spare Capacity: Provide enough inputs and outputs to handle the equipment shown to be "future" on drawings and 10% more of each point type. Provide all hardware modules, software modules, processors, power supplies, communication controllers, etc. required to ensure adding a point to the spare point location only requires the addition of the appropriate sensor/actuator and field wiring/tubing.

S. Environment.
1. Controller hardware shall be suitable for the anticipated ambient conditions.
2. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
3. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).

T. Immunity to power and noise.
1. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
3. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
    a. RF-Conducted Immunity (RFCI) per ENV 50141 (IEC 1000-4-6) at 3V.
    b. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact.
    c. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500V signal, 1 kV power.
    d. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max).
4. Isolation shall be provided at all Building Controller's AC input terminals to suppress induced voltage transients consistent with:

a. IEEE Standard 587 1980
b. UL 864 Supply Line Transients
c. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)

2.8 ADVANCED APPLICATION CONTROLLERS

A. Provide all necessary hardware for a complete operating system as required. The Advanced Application level control panel shall be able to operate as a standalone panel and shall not be dependent upon any higher level computer or another controller for operation.

B. Basis of design is Unitary Equipment Controller (PXCxx-UCM).

C. This controller shall have the BTL listing and meet the BACnet device profile of an Advanced Application Controller (B-AAC).

D. Communication:
1. BAS Network: The Advanced Application Controller shall support the following Data Link Layers:
   a. MS/TP Master
2. Serial Communication: Temporary use of portable devices shall not interrupt the BAS communication, nor the normal operation of permanently connected printers or terminals.
   a. Provide at least one EIA-232C serial data communication port for operation of operator I/O devices such as industry standard printers, operator terminals, and portable laptop operator's terminals.
   b. A USB port shall alternatively be available to support local HMI tools connection.

E. Software
1. The software programs specified in this section shall be provided as an integral part of Advanced Application Controllers and shall not be dependent upon any higher level computer or another controller for execution.
2. Advanced Application Controllers shall have the ability to perform energy management routines including but not limited to
   a. scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides
   b. automatic daylight savings time switch over
   c. night setback control
   d. economizer switch over using enthalpy, dry bulb or a combination
   e. peak demand limiting,
   f. temperature-compensated duty cycling
   g. heating/cooling interlock
   h. supply temperature reset
   i. priority load shedding
   j. power failure restart
3. The software shall have a routine for automatic tuning of control loops
4. System Security in the Field Panel
   a. User access shall be secured using individual security passwords and user names.
   b. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.

c. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.
d. Use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security in the field panel.

5. User Defined Control Applications:
   a. Controllers shall be fully-programmable. Controllers shall execute custom, job-specific sequences to automatically perform calculations and special control routines. Factory installed or pre-configured sequences shall only be allowed if they exactly match the sequence specified herein.
   b. Programs shall combine control logic, control loop algorithms, and energy management routines
   c. Each controller shall support plain language text comment lines in the operating program to allow for quick troubleshooting, documentation, and historical summaries of program development.
   d. Controller shall provide a HELP function key, providing enhanced context sensitive on-line help with task oriented information from the user manual.

F. This level of controller shall be used for the following types of systems:
1. Systems with custom sequences that meet all of the criteria below:
2. No primary pumping systems
3. Secondary Pumping systems that are remote from Central Plants
4. Air handlers up to 15,000 cfm
5. Systems up to 20 input/output points
6. Room control sequences that do not fit into an ASC controller
7. BAS Network or Architecture or Sequences do not require the system to be on an IP network
8. No systems that require integration to meters, VFDs or other smart equipment
9. Integration to smart thermostats is allowed

G. Each System Level Control Panel shall, at a minimum, be provided with:
1. Appropriate NEMA rated metal enclosure.
2. A 32-bit,multi-tasking, real-time 100 MHz digital control microprocessor with plug-in, enclosed processors.
3. Each Advanced Application Controller shall have sufficient memory, a minimum of 24 megabyte, to support its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, and operator I/O.
4. Real time clock and battery
5. Data collection/ Data Trend module sized for 10,000 data samples.
6. Power supplies as required for all associated modules, sensors, actuators, etc.
7. Monitoring of all industry standard types of analog and digital inputs and outputs, without the addition of equipment to the primary control panel.
8. Local status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.
9. Each control panel shall perform diagnostics on all inputs and outputs and a failure of any input or output shall be indicated both locally and at the operator workstation.
10. Graduated intensity LEDs or analog indication of value for each analog output.

H. Power loss. In the event of the loss of power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for the operating system software and firmware.
   1. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
   2. Brownout protection and power recovery circuitry protect the controller board from power fluctuations.
   3. Battery backup shall be provided to support the real-time clock for 10 years
   4. The program and database information stored SDRAM memory shall be battery backed for a minimum of 30 days and up to 60 days. This eliminates the need for time consuming program and database re-entry in the event of an extended power failure.

I. Database Restore: Each AAC controller shall automatically save the latest programmed database. The controller shall be able to automatically restore a lost or corrupt database without involvement from the operator.

J. Each System Level Control Panel shall continuously perform self-diagnostics on all hardware modules and network communications. The System Level Control Panel shall provide both local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication with any system.

K. Each Control Panel shall support firmware upgrades without the need to replace hardware.
   1. The AAC level controller shall be upgradable to a BC level controller with a flash upgrade of the firmware.

L. System Level control panels shall provide at least two RS-232C serial data communication ports for operation of operator I/O devices such as operator terminals, and additional memory. Control panels shall allow temporary use of portable operator interface devices without interrupting the normal communications.

M. Immunity to noise.
   1. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
   2. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
      a. RF-Conducted Immunity (RFCI) per ENV 50141 (IEC 1000-4-6) at 3V.
      b. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact.
      c. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500V signal, 1 kV power.
      d. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max).
   3. Isolation shall be provided at all Advanced Application Controller's AC input terminals to suppress induced voltage transients consistent with:
      a. IEEE Standard 587 1980
      b. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)

N. Agency Compliance
   1. UL UL916 PAZX (all models)
   2. UL916 PAZX7 (all models)
   3. FCC Compliance CFR47 Part 15, Subpart B, Class B
   4. Australian EMC Framework

5. European EMC Directive (CE)
6. European Low Voltage Directive (LVD)
7. BACnet Testing Laboratories (BTL) Certified

O. Spare Capacity: Provide enough inputs and outputs to handle the equipment shown to be "future" on drawings and 10% more of each point type. Provide all hardware modules, software modules, processors, power supplies, communication controllers, etc. required to ensure adding a point to the spare point location only requires the addition of the appropriate sensor/actuator and field wiring/tubing.

P. Local Operator Interfaces: Provide if called for elsewhere in the specification or the sequences of operations.
1. Controllers shall support an optional Operator Interface Module.

2.9 APPLICATION SPECIFIC CONTROLLERS

A. Each Application Level Control Panel shall operate as a stand-alone controller capable of performing its user selectable control routines independently of any other controller in the system. Each application specific controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.

B. Basis of design is Siemens BTEC controller.

C. This controller shall have the BTL listing and meet the BACnet device profile of an Application Specific Controller (B-ASC).

D. Provide a Application Specific Control Panel for each of the following types of equipment (if applicable):
1. Constant Air Volume (CAV) boxes
2. Chilled beams
3. Duct mounted reheat coils
4. Fan coil Units
5. Fan Powered Variable Air Volume (VAV) Boxes
6. Reheat Coils
7. Supplemental AC units
8. Variable Air Volume (VAV) Boxes
9. Other terminal equipment

E. Each Application Specific Controller shall, at a minimum, be provided with:
1. Appropriate NEMA rated enclosure
2. Floor Level network communications ability
3. Power supplies as required for all associated modules, sensors, actuators, etc.
4. Software as required for all sequences of operation, logic sequences and energy management routines.
5. A portable operator terminal connection port
6. Auxiliary enclosure for analog output transducers, isolation relays, etc. Auxiliary enclosure shall be part of primary enclosure or mounted adjacent primary enclosure
7. Each controller measuring air volume shall include provisions for manual and automatic calibration of the differential pressure transducer in order to maintain stable control and insuring against drift over time

8. Each controller measuring air volume shall include a differential pressure transducer
9. Approvals and standards: UL916; CE; FCC

F. Each Application Specific Controller shall continuously perform self-diagnostics on all hardware and secondary network communications. The Application Specific Controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failure to establish communication to the system.

G. Provide each Application Specific Controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Provide uninterruptible power supplies (UPSs) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of all applications are not acceptable.

H. The Application Specific Controller shall be powered from a 24 VAC source provided by this contractor and shall function normally under an operating range of 18 to 28 VAC (-25% to +17%), allowing for power source fluctuations and voltage drops. Install plenum data line and sensor cable in accordance with local code and NEC. The controllers shall also function normally under ambient conditions of 32 to 122 F (0 to 50 C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.

2.10 ROUTERS

A. Provide a router for each subnetwork to connect the floor level network to the base building backbone level network. The router shall connect BACnet MS/TP subnetworks to BACnet over Ethernet.

B. The router shall be capable of handling all of the BACnet BIBBs that are listed for the controller that reside on the subnetwork.

2.11 CONTROL PANELS

A. Controllers in mechanical rooms shall be mounted in NEMA 1 enclosures.

B. Mount on walls at an approved location or provide a free standing rack.

C. Panels shall be constructed of 16 gauge, furniture-quality steel, or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with ANSI 61 gray polyester-powder painted finish, UL listed. Provide common keying for all panels.

D. Provide power supplies for control voltage power.

E. Dedicate 1 power supply to the DDC controller. Other devices shall be on a separate power supply, unless the power for the control device is derived from the controller terminations.

F. Power supplies for controllers shall be a transformer with a fuse or circuit breaker. Power supplies for other devices can be plain transformers.

G. All power supplies for 24V low voltage wiring shall be class 2 rated and less than 100VA. If low voltage devices require more amps, then provide multiple power supplies. If a single device requires more amps, then provide a dedicated power supply in a separate enclosure and run a separate, non-class 2 conduit to the device.

H. Surge transient protection shall be incorporated in design of system to protect electrical components in all DDC Controllers and operator's workstations.

I. All devices in a panel shall be permanently mounted, including network switches, modems, media converters, etc.

J. Provide a pocket to hold documentation.

2.12 GENERAL SPECIFICATIONS FOR DEVICES

A. Provide mounting hardware for all devices, including actuator linkages, wells, installation kits for insertion devices, wall boxes and fudge plates, brackets, etc.

B. If a special tool is required to mount a device, provide that tool.

2.13 SENSORS

A. Terminal Unit Space Thermostats
   1. Each controller performing space temperature control shall be provided with a matching room temperature sensor.
      a. Plain Space Temperature Sensors – Wired: Where called for in the sequences or on the drawings, provide sensors with plain covers.
      b. The sensing element for the space temperature sensor shall be thermistor type providing the following.
         1) Element Accuracy: + /- 1.0°F
         2) Operating Range: 55 to 95°F
         3) Set Point Adjustment Range: 55 to 95°F
         4) Calibration Adjustments: None required
         5) Installation: Up to 100 ft. from controller
         6) Auxiliary Communications Port: as required
         7) Local LCD Temperature Display: as required
         8) Setpoint Adjustment Dial as required
         9) Occupancy Override Switch as required
      c. Auxiliary Communication Port. Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller. RS-232 communications port shall allow the operator to query and modify operating parameters of the local room terminal unit from the portable operator's terminal.

   2. Digital Display temperature sensor specifications – Wired:

a. As called for in the sequences of operations or on the drawings, provide temperature sensors with digital displays.
b. The sensing element for the space temperature sensor must be IC-based and provide the following.
    1) Digitally communicating with the Application Specific Controller.
    2) Mountable to and fully covering a 2 x 4 electrical junction box without the need for an adapter wall plate.
    3) IC Element Accuracy: +/- 0.9°F
    4) Operating Range: 55 to 95°F
    5) Setpoint Adjustment Range: User limiting, selectable range between 55 and 95°F
    6) Display of temperature setpoint with numerical temperature values
    7) Display of temperature setpoint graphically, with a visual Hotter/Colder setpoint indication
    8) Calibration: Single point, field adjustable at the space sensor to +/- 5°F
    9) Installation: Up to 100 ft. from controller
    10) Auxiliary Communications Port: included
    11) Local OLED Temperature Display: included
    12) Display of Temperature to one decimal place
    13) Temperature Setpoint Adjustment included
    14) Occupancy Override Function included
c. Auxiliary Communication Port. Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller. RS-232 communications port shall allow the operator to query and modify operating parameters of the local room terminal unit from the portable operator’s terminal.

3. Provide the following options as they are called for in the sequences or on the drawings:
    a. Setpoint Adjustment. The setpoint adjustment function shall allow for modification of the temperature by the building operators. Setpoint adjustment may be locked out, overridden, or limited as to time or temperature through software by an authorized operator at any central workstation, Building Controller, room sensor two-line display, or via the portable operator's terminal.
    b. Override Switch. An override button shall initiate override of the night setback mode to normal (day) operation when activated by the occupant and enabled by building operators. The override shall be limited to two (2) hours (adjustable.) The override function may be locked out, overridden, or limited through software by an authorized operator at the operator interface, Building Controller, room sensor two-line display or via the portable operator's terminal.
    c. Space Combination Temperature and Humidity Sensors. Each controller performing space temperature control shall be provided with a matching room temperature sensor, which also includes the ability to measure humidity for either monitoring or control purposes. The combination temperature and humidity sensors shall have the same appearance as the space temperature sensors. Humidity elements shall measure relative humidity with a +/- 2% accuracy over the range of 10 to 90% relative humidity. Humidity element shall be an IC (integrated circuit) sensing element. Humidity sensing elements shall be removable and field replaceable if needed.

B. Temperature Sensors

1. All temperature sensors shall meet the following specifications:
    a. Accuracy: Plus or minus 0.2 percent at calibration point.
    b. Wire: Twisted, shielded-pair cable.
    c. Vibration and corrosion resistant
2. Space temperature sensors shall meet the following specifications:
    a. 10k ohm type 2 thermisters
3. Insertion Elements in Ducts shall meet the following specifications:
    a. Single point 10k ohm thermister
    b. Use where not affected by temperature stratification
    c. The sensor shall reach more that 1/3 the distance from the duct wall
    d. Junction box for wire splices
4. Averaging Elements in Ducts shall meet the following specifications:
    a. 72 inches (183 cm) long
    b. Flexible
    c. Use where prone to temperature stratification, in front of coils, or where ducts are larger than 9 sq. ft.
    d. Junction box for wire splices
5. Insertion Elements for Liquids shall meet the following specifications:
    a. Platinum RTD with 4-20mA transmitter
    b. Threaded mounting with matching well
    c. Brass well with minimum insertion length of 2-1/2 inches for pipes up to 4" diameter
    d. Brass well with insertion length of 6 inches for pipes up to 10" diameter
    e. Junction box for wire splices
6. Outside-Air Sensors Platinum RTD with 4-20mA transmitter:
    a. Watertight enclosure, shielded from direct sunlight
    b. Circulation fan
    c. Watertight conduit fitting

C. Where called for in the sequences of operations, provide the following feature on space sensors and thermostats:
1. Security Sensors: Stainless-steel cover plate with insulated back and security screws
2. Space sensors with setpoint adjust: Plain white plastic cover with slide potentiometer to signal a setpoint adjustment to the DDC
3. Space Sensors with LCD display:
    a. Operator buttons for adjusting setpoints, setting fans speeds and overriding unit to on/off
    b. Graphical LCD icons for signaling heating/cooling mode, fans speed, schedule mode, actual temperature and current setpoint

D. Humidity Sensors shall meet the following specifications:
1. Bulk polymer sensor element
2. Accuracy: 2 percent full range with linear output
3. Room Sensors: With locking cover matching room thermostats, span of 0 to 100 percent relative humidity
4. Duct and Outside-Air Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity

E. Air Static Pressure Transmitter shall meet the following specifications:
1. Non-directional sensor with suitable range for expected input, and temperature compensated.

2. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
3. Output: 4 to 20 mA.
4. Building Static-Pressure Range: 0 to 0.25 inches wg.
5. Duct Static-Pressure Range: 0 to 5 inches wg.

F. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; proportional output 4 to 20 mA.

G. Equipment operation sensors as follows:

1. Status Inputs for Fans: Differential-pressure switch with adjustable range of 0 to 5 inches wg.
2. Status Inputs for Pumps: Differential-pressure switch piped across pump with adjustable pressure-differential range of 8 to 60 psig.
3. Status Inputs for direct drive electric motors: Current-sensing relay with current transformers, adjustable and sized for 175 percent of rated motor current.
4. Status inputs for belt drive electric motors: Current sensing transmitter with linear 4-20mA output

H. Electronic Valve/Damper Position indication: Visual scale indicating percent of travel and 0 to 10 V dc, feedback signal.

I. Water-Flow Switches: Pressure-flow switches of bellows-actuated mercury or snap-acting type, with appropriate scale range and differential adjustment, with stainless-steel or bronze paddle. For chilled-water applications, provide vapor proof type.

J. Air Differential Pressure Switches: Diaphragm type air differential pressure switches with die cast aluminum housing, adjustable setpoint, minimum 5 amp switch rating at 120VAC, SPDT switches, and the switch pressure range shall be suited for the application. Provide Dwyer or equal. These switches shall be utilized for filter status.

K. Leak detectors: Provide spot leak detectors that can be secured to the floor or secured to a drain pan. The detection shall used a microchip controlled energized probes. The detector shall operate on 24Vor less. Provide a way to adjust the height of the leak probes. The SPDT contacts shall be inside a watertight enclosure.

2.14 ELECTRO-MECHANICAL THERMOSTATS

A. Fire-Protection Thermostats: UL listed with fixed or adjustable settings to operate at not less than 75 deg F above normal maximum operating temperature, with the following:

1. 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.

B. 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. Setpoint shall be adjustable.

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

C. Electric space thermostats: Provide a charged element type stat with snap acting SPDT switch. The switch shall be rated for 16A or 1HP at 120V.

D. Aquastat: Provide a charged element type stat with snap acting SPDT switch. The switch shall be rated for 16A or 1HP at 120V.

2.15 SMOKE DETECTORS

A. Provide a smoke detector for each unit above 2000 cfm. Turn it over to the mechanical contractor for installation. Wire it to stop the fan upon sensing smoke.

2.16 AUTOMATIC CONTROL VALVES

A. General:
   1. All automatic control valves shall be fully proportioning, unless specified otherwise. The valves shall be quiet in operation and fail-safe in either normally open or normally closed position in the event of control air failure. All valves shall be capable of operating at varying rates of speed to correspond to the exact dictates of the controllers and variable load requirements. The valves shall be capable of operating in sequence with other valves and/or dampers when required by the sequence of operation. All control valves shall be sized by the control vendor and shall be guaranteed to accommodate the flow rates as scheduled. All control valves shall be suitable for the pressure conditions and shall close against the differential pressures involved. Body pressure rating and connection type construction shall conform to fitting and valve schedules. Control valve operators shall be sized to close against a differential pressure equal to the design pump heads plus 10 percent.
   2. Cold water, hot water and steam valves, throttling type, and bypass valves shall have equal percentage flow characteristics.
   3. Unless otherwise specified, control valves 2 inches and smaller shall have cast iron or bronze bodies with screwed NPT connections.
   4. Valves between 2-1/2 inch and 4 inch shall have cast iron bodies with flanged connections.
   5. All automatic control valves installed exposed to the elements shall be provided with electric actuators with operating characteristics and accessories as described in herein. Coordinate with electrical contractor for power availability and point of connection.
   6. All automatic control valves controlled by the BAS shall be furnished by the controls contractor unless noted otherwise in these documents.
   7. All automatic control valves shall be installed by the mechanical trade.
   8. The controls contractor shall provide wiring as follows:
      a. All line voltage power for electric valve actuators shall be wired by the controls contractor from the nearest available power panel. Coordinate with electrical trade.
      b. All wiring between the central control system (ATC/BMS) and the valve actuator shall be wired by the controls contractor.
      c. All wiring between the valve actuator and their associated thermostats, pressure switches, control devices, etc. shall be wired by the controls contractor.
      d. All wiring shall comply with code requirements. Segregate high and low voltage wiring & circuits and segregate the FAS and controls (BMS) terminals.

B. Hot Water / Condenser Water / Control Valves
   1. Single-seated.
   2. Fully proportioning with modulating plug or V-port inner valves.
   3. Body pressure rating and connection type construction shall conform to fitting and valve schedules. The ANSI rating of the valve shall match the ANSI rating of the piping in which the valve is installed. Minimum ANSI rating shall be ANSI 125.
   4. Stainless steel stems and trim.
   5. Spring loaded Teflon packing
   6. Quiet in operation.
   7. Fail-safe in either normally open or normally closed position in the event of power failure.
   8. Capable of operating in sequence with other valves and/or dampers when required by the sequence of operation.
   9. Capable of operating at varying rates of speed to correspond to the exact dictates of the controller and variable load requirements.

C. Differential Pressure Control Valves :
   1. Provide for all water systems where modulating water flow conditions are required to prevent excessive pump pressure build-up. Provide a valve for each closed loop water system. Valve to be globe type. Provide valves 2" and smaller with screwed end bodies and provide valves 2-1/2" and larger with flanged ends.

D. Butterfly Valves
   1. Furnish automatic butterfly valves for isolation requirements as shown on the drawings or required herein.
   2. Butterfly valves shall have body ratings in accordance with the piping specifications.
   3. Valves that are in high static locations or where flanges are ANSI300 per the piping design shall be high performance, fully lugged with carbon steel body ANSI 300 as required by pipe specifications.
   4. Valves that are in locations where ANSI150 flanges are allowed shall be ANSI 150 valves.
   5. Valves shall be bubble tight with 316 stainless steel disc, stainless steel shaft and reinforced Teflon seat.
   6. Actuators shall be fail in place with factory mounted open and closed position limit switches mounted.
   7. Provide fail in place, electric actuators with waterproof enclosure and crankcase heater for actuator and accessories mounted outside.
   8. Provide manual override hand wheels for each valve.
   9. Butterfly valves will only be approved for cooling tower bypass and all two-position (open or close) applications.
   10. Valves must have full lug type body connections.

E. Steam Valves:

   1. Steam control valves shall be of linear flow characteristics for modulating service.

   2. Sizing Criteria:
      a. 15 psig or less; pressure drop 80% of inlet psig.
      b. 16 to 50 psig; pressure drop 50% of inlet psig.
      c. Over 50 psig; pressure drop as scheduled on plans.

d. Steam valves shall fail normally open or closed, as scheduled on plans, or as follows:
   1) Heating coils in air handlers: normally open.
   2) Steam to hot water heat exchanger: normally closed.
   3) Other applications: as required by sequences of operation.

2.17 ELECTRONIC ACTUATOR SPECIFICATION

A. ELECTRONIC VALVE ACTUATORS

1. Actuator shall be fully modulating, floating (tri-state), two position, and/or spring return as indicated in the control sequences. Specified fail safe actuators shall require mechanical spring return.
2. Modulating valves shall be positive positioning, responding to a 2-10VDC or 4-20mA signal. There shall be a visual valve position indicator.
3. The actuator shall have the capability of adding auxiliary switches or feedback potentiometer if specified.
4. Actuator shall provide minimum torque required for proper valve close-off. The actuator shall be designed with a current limiting motor protection. A release button (clutch) or handle on the actuator shall be provided to allow for manual override (except when actuator is spring return type).
5. Actuators shall be UL listed.

B. ELECTRONIC DAMPER ACTUATORS

1. Actuator shall be direct coupled (over the shaft), enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The actuator-to-shaft clamp shall use a "V" bolt and "V" shaped, toothed cradle to attach to the damper shaft for maximum holding strength. Single bolt or set screw type fasteners are not acceptable.
2. Actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator. End switches to deactivate the actuator at the end of rotation or magnetic clutch are not acceptable.
3. For power-failure/safety applications, a mechanical, spring return mechanism shall be used.
4. Actuators with spring return mechanisms shall be capable of either clockwise or counterclockwise spring return operation by simply changing the mounting orientation.
5. Proportional actuators shall accept a 2-10VDC, 4-20mA signal, or be of the 2 point floating type and provide a 2-10VDC actuator position feedback signal.
6. All actuators shall have an external manual gear release (clutch) or manual crank to aid in installation and for allowing manual positioning when the actuator is not powered.
7. All actuators shall have an external direction of rotation switch to aid in installation and to allow proper control response.
8. Actuators shall be provided with a factory-mounted 3-foot electrical cable and conduit fitting to provide easy hook-up to an electrical junction box.
9. Actuators shall be listed under Underwriters Laboratories Standard 873 and Canadian Standards Association. They must be manufactured under ISO 9001.

PART 3 - EXECUTION

3.1 EXAMINATION

A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.

B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.

C. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others.

3.2 INSTALLATION

A. Provide all relays, switches, sources of emergency and UPS battery back-up electricity and all other auxiliaries, accessories and connections necessary to make a complete operable system in accordance with the sequences specified. All field wiring shall be by this contractor.

B. Install controls so that adjustments and calibrations can be readily made. Controls are to be installed by the control equipment manufacturer.

C. Mount surface-mounted control devices on brackets to clear the final finished surface on insulation.

D. Install equipment level and plumb.

E. Install control valves horizontally with the power unit up.

F. Unless otherwise noted, install wall mounted thermostats and humidistat 60" above the floor measured to the center line of the instrument, or as otherwise directed by the Architect.

G. Install averaging elements in ducts and plenums in horizontal crossing or zigzag pattern.

H. Install outdoor sensors in perforated tube and sunshield.

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

J. Install labels and nameplates on each control panel listing the name of the panel referenced in the graphics and a list of equipment numbers served by that panel.

K. Furnish hydronic instrument wells, valves, and other accessories to the mechanical contractor for installation.

L. Furnish automatic dampers to mechanical contractor for installation.

3.3 ELECTRICAL WIRING SCOPE

A. This contractor shall be responsible for power that is not shown on the electrical drawings, to controls furnished by this contractor. If power circuits are shown on the electrical drawings, this contractor shall continue the power run to the control device. If power circuits are not shown, this contractor shall coordinate with the electrical contractor to provide breakers at distribution panels for power to controls. This contractor is then responsible for power from the distribution panel.
   1. Coordinate panel locations. If enclosures for panels are shown on the electrical drawings, furnish the enclosures according to the electrician's installation schedule.

B. This contractor shall not be responsible for power to control panels and control devices that are furnished by others, unless it is part of the control interlock wiring.

C. Refer to Coordination section for what devices this contractor is responsible to mount and which are turned over to others to mount.

D. This contractor shall be responsible for wiring of any control device that is furnished as part of this section of specification.

E. Wiring for controls furnished by others:
   1. Provide control wiring for HVAC controls furnished by others. Wiring may include, but not limited to, interlocks, standalone thermostats, safeties and remote control devices such as valves, sensors, etc.

F. Interlock wiring shall be run in separate conduits from BAS associated wiring.

G. Provide network wiring for equipment that is called to be integrated to the BAS.

3.4 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. All low voltage control wiring shall be class 2. Control wiring that is not class 2 shall be run in separate conduits from class 2 wiring.

B. Floor level network wiring between terminal units can be combined with thermostat and other low voltage wiring in the same conduit. All other network wiring shall be in dedicated conduits.

C. Install raceways, boxes, and cabinets according to Division 26 Section "Raceways and Boxes."

D. Install building wire and cable according to Division 26 Section "Conductors and Cables."

E. Installation shall meet the following requirements:

   1. Conceal cable and conduit, except in mechanical rooms and areas where other conduit and piping are exposed.
   2. Install exposed cable in raceway or conduit.
   3. Install concealed cable using plenum rated cable.
   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. All wiring in lab areas shall be in conduit.
8. All unsupported risers shall be rigid steel conduit. Supported risers shall be EMT.

F. Rigid conduit shall be steel, hot dip galvanized, threaded with couplings, ¾ inch minimum size, manufactured in accordance with ANSI C-80-1. Electrical metallic tubing (EMT) with compression fittings or intermediate metallic conduit (IMC) may be used as conduit or raceway where permitted by the NEC.

G. Concealed control conduit and wiring shall be provided in all spaces except in the Mechanical Equipment Rooms and in unfinished spaces. Install in parallel banks with all changes in directions made at 90 degree angles.

H. Install conduit adjacent to machine to allow service and maintenance.

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

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

K. Ground equipment.

3.5 COMMUNICATION WIRING

A. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.

B. Do not install communication wiring in raceway and enclosures containing Class 1 wiring.

C. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.

D. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.

E. Cable bundling:
1. RS485 cabling run open air in accessible areas can be bundled with other class 2 low voltage cabling.
2. RS485 cabling run between terminal units in conduits above ceilings or under floors or in inaccessible areas can be bundled with other class 2 low voltage cabling.
3. RS485 cabling run between floors shall be in a communication only conduit.
4. RS485 conduit run long distances between utility rooms or between buildings shall be in a communication only conduit.
5. Ethernet cabling shall be in a communication only conduit.
6. Ethernet and RS485 can be run together.
7. Fiber optics can be run with Ethernet and RS485 cabling as long as the conduit is bent to fiber optic standards and junction boxes are sized for fiber optic use.

F. RS485 Cabling
   1. RS485 cabling shall be used for BACnet MS/TP networks.
   2. RS485 shall use low capacitance, 20-24 gauge, twisted shielded pair.
   3. The shields shall be tied together at each device.
   4. The shield shall be grounded at one end only and capped at the other end.
   5. Provide end of line (EOL) termination devices at each end of the RS485 network or subnetwork run, to match the impedance of the cable, 100 to 120ohm.

G. Ethernet Cabling
   1. Ethernet shall not be run with any Class 1 or low voltage Class 2 wiring.
   2. CAT6, unshielded twisted pair (UTP) cable shall be used for BAS Ethernet.
   3. Solid wire shall be used for long runs, between mechanical rooms and between floors. Stranded cable can be used for patch cables and between panels in the same mechanical room up to 50 feet away.
   4. When the BAS Ethernet connects to an Owner's network switch, document the port number on the BAS As-builts.

H. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to the manufacturer's instructions.

I. All runs of communication wiring shall be unspliced length when that length is commercially available.

J. All communication wiring shall be labeled to indicate origination and destination data.

K. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.6 IDENTIFICATION

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the DDC system.
   1. Labels shall use white lettering (12-point type or larger) on a red background.
   2. Warning labels shall read as follows: **C A U T I O N This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.**

B. Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects.
   1. Labels shall use white lettering (12-point type or larger) on a red background.
   2. Warning labels shall read as follows: **C A U T I O N This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.**

3.7 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including piping and electrical connections. Report results in writing.

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove malfunctioning units, replace with new units, and retest.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment, and retest.
3. Calibration test controllers by disconnecting input sensors and stimulating operation with compatible signal generator.

B. Engage a factory-authorized service representative to perform startup service.

C. Replace damaged or malfunctioning controls and equipment.

1. Start, test, and adjust control systems.
2. Demonstrate compliance with requirements, including calibration and testing, and control sequences.
3. Adjust, calibrate, and fine tune circuits and equipment to achieve sequence of operation specified.

3.8 SYSTEM CHECKOUT AND STARTUP

A. Inspect each termination in the MER control panels and devices to make sure all wires are connected according to the wiring diagrams and all termination are tight.

B. After the controls devices and panels are installed and power is available to the controls, perform a static checkout of all the points, including the following:
1. Inspect the setup and reading on each temperature sensor against a thermometer to verify its accuracy.
2. Inspect the setup and reading on each humidity sensor against a hygrometer to verify its accuracy.
3. Inspect the reading on each CO2 sensor using a calibration kit to verify the sensor range accuracy matches the DDC setup.
4. Inspect the reading of each status switch to verify the DDC reads the open and close correctly.
5. Command each relay to open and close to verify its operation.
6. Command each 2-position damper actuator to open and close to verify operation.
7. Command each 2-position valve to open and close to verify operation.
8. Ramp each modulating actuator to 0%, 25%, 50%, 75% and 100% to verify its operation.
9. Ramp each modulating output signal, such as a VFD speed, to verify its operation.
10. Test each safety device with a real life simulation, for instance check freezestats with ice water, water detectors with water, etc.

C. Document that each point was verified and operating correctly. Correct each failed point before proceeding to the dynamic startup.

D. Verify that each DDC controller communicates on its respective network correctly.

E. After all of the points are verified, and power is available to the mechanical system, coordinate a startup of each system with the mechanical contractor. Include the following tests:
1. Start systems from DDC.
2. Verify that each setpoint can be met by the system.
3. Change setpoints and verify system response.

4. Change sensor readings to verify system response.
5. Test safety shutdowns.
6. Verify time delays.
7. Verify mode changes.
8. Adjust filter switches and current switches for proper reactions.
9. Adjust proportional bands and integration times to stabilize control loops.

F. Perform all program changes and debugging of the system for a fully operational system.

G. Verify that all graphics at the operator workstations correspond to the systems as installed. Verify that the points on the screens appear and react properly. Verify that all adjustable setpoints and manual commands operate from the operator workstations.

H. After the sequence of operation is verified, setup the trends that are listed in the sequence of operations for logging and archiving for the commissioning procedure.

3.9 SYSTEM COMMISSIONING, DEMONSTRATION AND TURNOVER

A. The BAS Contractor shall prepare and submit for approval a complete acceptance test procedure including submittal data relevant to point index, functions, sequence, inter-locks, and associated parameters, and other pertinent information for the operating system. Prior to acceptance of the BAS by the Owner and Engineer, the BAS contractor shall completely test the BAS using the approved test procedure.

B. After the BAS contractor has completed the tests and certified the BAS is 100% complete, the Engineer shall be requested, in writing, to approve the satisfactory operation of the system, sub-systems and accessories. The BAS contractor shall submit Maintenance and Operating manuals at this time for approval. An acceptance test in the presence of the Engineer and Owner's representative shall be performed. The Owner will then shake down the system for a fixed period of time (30 days).

C. The BAS contractor shall fix punch list items within 30 days of acceptance.

D. When the system performance is deemed satisfactory in whole or in part by these observers, the system parts will be accepted for beneficial use and placed under warranty.

3.10 PROJECT RECORD DOCUMENTS

A. Project Record Documents: Submit three (3) copies of record (as-built) documents upon completion of installation. Submittal shall consist of:
1. Project Record Drawings. As-built versions of the submittal shop drawings provided as AutoCAD compatible files in electronic format and as 11 x 17 inch prints.
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements in the Control System Demonstration and Acceptance section of this specification.
3. Operation and Maintenance (O & M) Manual.
    a. As-built versions of the submittal product data.
    b. Names, addresses, and 24-hour telephone numbers of installing contractors and service representatives for equipment and control systems.

c. Operator’s Manual with procedures for operating control systems, logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
d. Programming manual or set of manuals with description of programming language and of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
e. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
f. Documentation of all programs created using custom programming language, including setpoints, tuning parameters, and object database.
g. Graphic files, programs, and database on electronic media.
h. List of recommended spare parts with part numbers and suppliers.
i. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware, including computer equipment and sensors.
j. Complete original original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
k. Licenses, guarantees, and warranty documents for equipment and systems.

B. Operating manual to serve as training and reference manual for all aspects of day-to-day operation of the system. As a minimum include the following:
1. Sequence of operation for automatic and manual operating modes for all building systems. The sequences shall cross-reference the system point names.
2. Description of manual override operation of all control points in system.
3. BMS system manufacturers complete operating manuals.

C. Provide maintenance manual to serve as training and reference manual for all aspects of day-to-day maintenance and major system repairs. As a minimum include the following:
1. Complete as-built installation drawings for each building system.
2. Overall system electrical power supply schematic indicating source of electrical power for each system component. Indicate all battery backup provisions.
3. Photographs and/or drawings showing installation details and locations of equipment.
4. Routine preventive maintenance procedures, corrective diagnostics troubleshooting procedures, and calibration procedures.
5. Parts list with manufacturer's catalog numbers and ordering information.
6. Lists of ordinary and special tools, operating materials supplies and test equipment recommended for operation and servicing.
7. Manufacturer's operation, set-up, maintenance and catalog literature for each piece of equipment.
8. Maintenance and repair instructions.
9. Recommended spare parts.

D. Provide Programming Manual to serve as training and reference manual for all aspects of system programming. As a minimum include the following:
1. Complete programming manuals, and reference guides.
2. Details of any custom software packages and compilers supplied with system.
3. Information and access required for independent programming of system.

3.11 TRAINING

A. During System commissioning and at such time as acceptable performance of the Building Automation System hardware and software has been established, the BAS contractor shall provide on-site operator instruction to the owner's operating personnel. Operator instruction during normal working hours shall be performed by a competent building automation contractor representative familiar with the Building Automation System's software, hardware and accessories.

B. At a time mutually agreed upon, during System commissioning as stated above, the BAS contractor shall give 16-hours of onsite training on the operation of all BAS equipment. Describe its intended use with respect to the programmed functions specified. Operator orientation of the automation system shall include, but not be limited to:
   1. Explanation of drawings and operator’s maintenance manuals.
   2. Walk-through of the job to locate all control components.
   3. Operator workstation and peripherals.
   4. DDC Controller and ASC operation/sequence.
   5. Operator control functions including scheduling, alarming, and trending.
   6. Explanation of adjustment, calibration and replacement procedures.

C. Additional 8-hours of training shall be given after the 30 day shakedown period.

D. Since the Owner may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If the Owner requires such training, it will be contracted at a later date. Provide description of available local and factory customer training. Provide costs associated with performing training at an off-site classroom facility and detail what is included in the manufacturer’s standard pricing such as transportation, meals, etc.

END OF 23 09 00