SECTION 25 10 00 – BUILDING CONTROL AND AUTOMATION SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, and the following specification sections apply to all Work herein:

1.	Section 25 05 00	Common Work Results BCAS
2.	Section 25 05 53	Access Doors for BCAS
3.	Section 25 08 00	Commissioning of BCAS Equipment
4.	Section 25 50 00	Sequence of Operation
5.	Section 23 05 13	Common Motor Requirements for HVAC
6.	Section 23 05 93	Testing, Balancing, and Adjusting of HVAC Systems
7.	Section 23 21 13	HVAC Piping
8.	Section 23 34 00	HVAC Fans
9.	Section 23 37 00	Air Outlets and Inlets
10.	Section 23 41 00	Particulate Air Cleaning Devices
11.	Section 23 64 16	Centrifugal Water Chilling Units
12.	Section 23 73 00	Factory-Built Air Handling Units
13.	Section 23 81 26	Self-Contained Air Cooled and Chilled Water Air Conditioners
14.	Section 26 29 23	Individual Motor Controllers
15.	Section 26 32 13	Electric Generating System
16.	Section 26 33 53	Uninterruptible Power Supply
17.	Section 26 50 00	Lighting
18.	Section 28 31 15	Fire Detection, Alarm and Communication System

B. Refer to Division 1 Specifications for the following LEED requirements:

1. Commissioning
2. Commissioning Plan
3. Commissioning Checklists

1.2 SUMMARY

A. General: The control system shall be as indicated on the drawings and described in the specifications, and consist of a peer-to-peer network of digital building control panels and Network Area Controller(s) (NAC) within each facility. Access to the system, either locally in each building, or remotely from a central site or sites, shall be accomplished through standard web browsers, via the Internet and/or local area network. Each NAC shall be capable of communication with LonMark/LonTalk controllers, BACnet controllers and other open or legacy protocol systems/devices. The web browser shall provide users an interface with the system though dynamic color graphics of building areas and systems.

B. The Facility Management and Control System (FMCS) as provided in this Division shall be based on the Niagara Framework™ (or "Niagara"), a Java-based framework technology developed by Tridium. Systems not developed based upon Niagara Framework™ technology are not acceptable.

C. Direct Digital Control (DDC) technology shall be used to provide the functions necessary for control of systems defined for control on this project.

D. The control system shall accommodate simultaneous multiple user operation. Access to the control system data should be limited by operator password. An operator shall be able to log onto any web browser capable of accessing the LAN and have access to all designated data.

E. The control system shall be designed such that each mechanical system will operate under stand-alone control. As such, in the event of a network communication failure, or the loss of other controllers, the control system shall continue to independently operate the unaffected equipment.

1.3 SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for server and browser for web-based systems.

1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the user interface within 45 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciation. Each user interface on the network shall receive alarms within 5 sec of other user interfaces.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
10. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table-1 Reporting Accuracy	
Measured Variable	**Measured Variable**
Space Temperature	Space Temperature
Ducted Air	Ducted Air
Outside Air	Outside Air
Dew Point	Dew Point
Water Temperature	Water Temperature
Delta-T	Delta-T
Relative Humidity	Relative Humidity

Table-1 Reporting Accuracy	
Measured Variable	**Measured Variable**
Water Flow	Water Flow
Airflow (terminal)	Airflow (terminal)
Airflow (measuring stations)	Airflow (measuring stations)
Airflow (pressurized spaces)	Airflow (pressurized spaces)
Air Pressure (ducts)	Air Pressure (ducts)
Air Pressure (space)	Air Pressure (space)
Water Pressure	Water Pressure
Electrical	Electrical
Carbon Monoxide (CO)	Carbon Monoxide (CO)
Carbon Dioxide (CO2)	Carbon Dioxide (CO2)

Note 1: Accuracy applies to 10%–100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

Table 2 – Control Stability and Accuracy		
Controlled Variable	**Control Accuracy**	**Range of Medium**
Air Pressure	±0.2 In.w.g. ±0.01 In.w.g.	0-6 In. w.g. -0.1 to 0.1 In. w.g.
Airflow	±10% of Full Scale	
Space Temperature	±2.0ºF	
Duct Temperature	±3.0ºF	
Humidity	±5% RH	
Fluid Pressure	±1.5 psi ±1.0 In. w.g.	1-150 psi 0-50 In. w.g. differential

B. System shall use the BACnet protocol for communication to the server and for communication between control modules. I/O points, schedules, setpoints, trends and alarms specified in 25 50 00 – "Sequence of Operations" shall be BACnet objects.

1.4 DEFINITIONS

BACnet Interoperability Building Blocks (BIBB)	A BIBB defines a small portion of BACnet functionality that is needed to perform a task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database.
Controller	Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.
Direct Digital Control	Microprocessor-based control including Analog/Digital conversion and program logic.

Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token	Data link protocol as defined by the BACnet standard.
Point-to-Point	Serial communication as defined in the BACnet standard.
Primary Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.
Protocol Implementation Conformance Statement	A written document that identifies the particular options specified by BACnet that are implemented in a device.
Router	A device that connects two or more networks at the network layer.
Wiring	Raceway, fittings, wire, boxes and related items.

1.5 ABBREVIATIONS

A. The following abbreviations may be used in graphics, schematics, point names, and other UI applications where space is at a premium.

AC	Air Conditioning
AHU	Air Handling Unit
AI	Analog Input
AO	Analog Output
AUTO	Automatic
AUX	Auxiliary
BI	Binary Input
BO	Binary Output
C	Common
CHW	Chilled Water
CHWP	Chilled Water Pump
CHWR	Chilled Water Return
CHWS	Chilled Water Supply
COND	Condenser
CW	Condenser Water
CWP	Condenser Water Pump
CWR	Condenser Water Return
CWS	Condenser Water Supply
DA	Discharge Air
EA	Exhaust Air
EF	Exhaust Fan
FCU	Fan Coil Unit
HOA	Hand / Off / Auto
HRU	Heat Recovery Unit
MAX	Maximum
MIN	Minimum
MISC	Miscellaneous
NC	Normally Closed
NO	Normally Open
OA	Outdoor Air
R/A	Return Air

RH	Relative Humidity
S/A	Supply Air
SF	Supply Fan
SP	Static Pressure
TEMP	Temperature
UH	Unit Heater
VAV	Variable Air Volume
W/	with
W/O	without

1.6 REFERENCE STANDARDS

A. All testing, balancing, and adjusting shall be performed in accordance with the latest applicable industry standards, those standards referenced in the applicable Division 25 and Division 23 specifications, including the following:

National Electric Code	
International Building Code (IBC)	Section 719 Ducts and Air Transfer Openings Section 907 Fire Alarm and Detection Systems Section 909 Smoke Control Systems Chapter 28 Mechanical
International Mechanical Code (IMC)	
ANSI/ASHRAE Standard 135, BACnet	A Data Communication Protocol for Building Automation and Control Systems

B. All equipment and material to be furnished and installed on this Project shall be UL or ETL listed, in accordance with the requirements of the Authority having jurisdiction, and suitable for its intended use on this Project.

C. LEED® Reference Standards:

1. LEED 2009 Reference Guide for New Construction.
2. SMACNA "IAQ Guidelines for Occupied Buildings Under Construction."

1.7 LEED REQUIREMENTS

A. Comply with the requirements of Section 25 05 00, Common Work Results for BCAS, Paragraph 1.4.

1.8 SUBMITTALS

A. The following submittal data shall be furnished according to the Conditions of the Construction Contract, Division 1 Specifications, and Section 25 05 00. In addition, the contractor shall provide shop drawings or other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2006 (or newer) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and three 11” x 17” prints of each drawing. When manufacturer’s cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General

catalogs shall not be accepted as cut sheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:

1. DDC System Hardware

   a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
   b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

      1) Direct digital controllers (controller panels)
      2) Transducers and transmitters
      3) Sensors (including accuracy data)
      4) Actuators
      5) Valves
      6) Relays and switches
      7) Control panels
      8) Power supplies
      9) Batteries
      10) Operator interface equipment
      11) Wiring

   c. Wiring diagrams and layouts for each control panel. Show termination numbers.
   d. Schematic diagrams for all field sensors and controllers. Riser diagrams showing control network layout, communication protocol, and wire types.

2. Central System Hardware and Software

   a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.
   b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:

      1) Central Processing Unit (CPU) or server
      2) Monitors
      3) Keyboards
      4) Power supplies
      5) Battery backups
      6) Interface equipment between CPU or server and control panels
      7) Operating System software
      8) Operator interface software
      9) Color graphic software
      10) Third-party software

   c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports

with computer manufacturers' model numbers and functions. Show interface wiring to control system.

d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems

a. Riser diagrams showing control network layout, communication protocol, and wire types.
b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
e. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
f. A point list for each control system. List I/O points and software points specified in Section 25 50 00. Indicate alarmed and trended points.
g. Provide sample graphic for each type of system provided.
h. Room Schedule for VAV boxes listing each VAV box and all associated parameters for each VAV box, Box Location, Controller Address, Inlet Size, K Factor, Min. CFM, Clg Max Flow.
i. Control Damper Schedule
j. Control Valve Schedule

4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.
5. Description of process, report formats, and checklists to be used in Section 25 08 00, Commissioning of Building Control and Automation System.
6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules

1. Within one month of contract award, provide a schedule of the work indicating the following:

a. Intended sequence of work items
b. Start date of each work item
c. Duration of each work item
d. Planned delivery dates for ordered material and equipment and expected lead times
e. Milestones indicating possible restraints on work by other trades or situations

2. Weekly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

C. LEED Submittals:

1. Credit EQ 4.1: Manufacturer's product data for interior sealants, sealant primers, and adhesives, including printed statement of VOC content and Material Safety Data Sheet (MSDS). VOC content shall be clearly indicated via highlight, clouds, arrows, etc. within the body of the submittal and should be clearly stated on a front cover page for each product in the submittal.

D. The manufacturer shall include a Specification Compliance Review as described in Section 25 05 00. The Compliance Review will be a paragraph-by-paragraph review of the Specifications with the designations “C”, “D”, or “N/A” marked in the margin beside each paragraph

1.9 WARRANTY

A. Comply with the requirements of the General Conditions and Section 25 05 00.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with these Specifications, control system hardware and software by one of the following manufacturers will be acceptable:

1. Alerton Technologies
2. Automated Logic Corporation
3. Honeywell
4. Johnson Controls
5. Tekplan Solutions
6. Convergentz – Tridium and Trane

2.2 MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.3 COMMUNICATION

A. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate ANSI/ASHRAE Standard 135 BACnet, LonWorks technology, MODBUS, OPC, and other open and proprietary communication protocols in one open, interoperable system.

B. The supplied computer software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. In addition, adherence to industry standards including ANSI / ASHRAE™ Standard 135, BACnet and LonMark to assure interoperability between all system components is required. For each LonWorks device that does not have LonMark certification, the device supplier must provide an XIF file and a resource file for the device. For each BACnet device, the device supplier must provide a PICS document showing the installed device’s compliance level. Minimum compliance shall support the ability

to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet (BACnet Ethernet/IP,) and/or RS-485 (BACnet MSTP) as specified.

C. All components and controllers supplied under this Division shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.

D. The supplied system must incorporate the ability to access all data using standard Web browsers without requiring proprietary operator interface and configuration programs. An Open DataBase Connectivity (ODBC) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.

E. A hierarchical topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network. Systems employing a "flat" single tiered architecture shall not be acceptable.

1. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 5 seconds for network connected user interfaces.
2. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.

F. The Network Area Controller (NAC) shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control functions over the control devices connected to the NAC. It shall be capable of executing application control programs to provide:

1. Calendar functions
2. Scheduling
3. Trending
4. Alarm monitoring and routing
5. Time synchronization
6. Integration of LonWorks controller data, BACnet controller data, and any device connected through an optional software driver installed in the NAC
7. Network Management functions for all LonWorks based devices

G. The Network Area Controller (JACE 3/6/7) must provide the following hardware features as a minimum:

1. Two Ethernet Ports – 10/100 Mbps
2. One RS-232 port
3. One RS-485 port
4. Battery Backup
5. Flash memory for long term data backup (If battery backup or flash memory is not supplied, the controller must contain a hard disk with at least 1 gigabyte storage capacity)
6. The NAC must be capable of operation over a temperature range of 32 to 122°F
7. The NAC must be capable of withstanding storage temperatures of between 0 and 158°F

8. The NAC must be capable of operation over a humidity range of 5 to 95% RH, non-condensing

H. The NAC shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the NAC shall be an ODBC-compliant database or must provide an ODBC data access mechanism to read and write data stored within it.

I. The NAC shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 32 simultaneous users.

J. Event Alarm Notification and actions

1. The NAC shall provide alarm recognition, storage; routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers.
2. The NAC shall be able to route any alarm condition to any defined user location whether connected to a local network or remote via dial-up telephone connection, or wide-area network.
3. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including but limited to:

    a. To alarm
    b. Return to normal
    c. To fault

4. Provide for the creation of a minimum of eight of alarm classes for the purpose of routing types and or classes of alarms, i.e.: security, HVAC, Fire, etc.
5. Provide timed (schedule) routing of alarms by class, object, group, or node.
6. Provide alarm generation from binary object “runtime” and /or event counts for equipment maintenance. The user shall be able to reset runtime or event count values with appropriate password control.

K. Control equipment and network failures shall be treated as alarms and annunciated.

L. Alarms shall be annunciated in any of the following manners as defined by the user:

1. Screen message text
2. Email of the complete alarm message to multiple recipients. Provide the ability to route and email alarms based on:

    a. Day of week
    b. Time of day
    c. Recipient

3. Pagers via paging services that initiate a page on receipt of email message
4. Graphic with flashing alarm object(s)
5. Printed message, routed directly to a dedicated alarm printer

M. The following shall be recorded by the NAC for each alarm (at a minimum):

1. Time and date
2. Location (building, floor, zone, office number, etc.)

3. Equipment (air handler #, accessway, etc.)
4. Acknowledge time, date, and user who issued acknowledgement.
5. Number of occurrences since last acknowledgement.

N. Alarm actions may be initiated by user defined programmable objects created for that purpose.

O. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user.

P. A log of all alarms shall be maintained by the NAC and/or a server (if configured in the system) and shall be available for review by the user.

Q. Provide a "query" feature to allow review of specific alarms by user defined parameters.

R. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.

S. An Error Log to record invalid property changes or commands shall be provided and available for review by the user.

2.4 WEB BROWSER CLIENTS

A. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Internet Explorer™ or Google Chrome™. Systems requiring additional software (to enable a standard Web browser) to be resident on the client machine, or manufacture-specific browsers shall not be acceptable.

B. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function with the FMCS, shall not be acceptable.

C. The Web browser shall provide the same view of the system, in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology as is provided by the Graphical User Interface (programmer's tool). Systems that require different views or that require different means of interacting with objects such as schedules, or logs, shall not be permitted.

D. The Web browser client shall support at a minimum, the following functions:

1. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.
2. Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the GUI shall be supported by the Web browser interface.
3. HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.
4. Storage of the graphical screens shall be in the Network Area Controller (NAC), without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.

5. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.
6. Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:

    a. Modify common application objects, such as schedules, calendars, and set points in a graphical manner.

        1) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
        2) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.

    b. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
    c. View logs and charts
    d. View and acknowledge alarms
    e. Setup and execute SQL queries on log and archive information

7. The system shall provide the capability to specify a user’s (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.
8. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

2.5 SYSTEM PROGRAMMING

A. The Graphical User Interface software (GUI) shall provide the ability to perform system programming and graphic display engineering as part of a complete software package. Access to the programming functions and features of the GUI shall be through password access as assigned by the system administrator.

B. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide “real-time” data updates. Any real-time data value or object property may be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.

C. Programming Methods

1. Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user’s application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to

other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification. Links will vary in color depending on the type of link; i.e., internal, external, hardware, etc.

2. Configuration of each object will be done through the object's property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.
3. The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real time for easy diagnosis of the logic execution. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system.
4. All programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects shall not be allowed.
5. The system shall support object duplication within a customer's database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

2.6 LonWorks NETWORK MANAGEMENT

A. The Graphical User Interface software (GUI) shall provide a complete set of integrated LonWorks network management tools for working with LonWorks networks. These tools shall manage a database for all LonWorks devices by type and revision, and shall provide a software mechanism for identifying each device on the network. These tools shall also be capable of defining network data connections between LonWorks devices, known as "binding". Systems requiring the use of third party LonWorks network management tools shall not be accepted.

B. Network management shall include the following services: device identification, device installation, device configuration, device diagnostics, device maintenance and network variable binding.

C. The network configuration tool shall also provide diagnostics to identify devices on the network, to reset devices, and to view health and status counters within devices.

D. These tools shall provide the ability to "learn" an existing LonWorks network, regardless of what network management tool(s) were used to install the existing network, so that existing LonWorks devices and newly added devices are part of a single network management database.

E. The network management database shall be resident in the Network Area Controller (NAC), ensuring that anyone with proper authorization has access to the network management database at all times. Systems employing network management databases that are not resident, at all times, within the control system, shall not be accepted.

2.7 OPERATOR INTERFACE

A. The Server shall conform to the device profile as specified in ASHRAE/ANSI 135 BACnet Annex L.

B. Operator Interface. Server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.

C. Communication. Server and controllers shall communicate using BACnet protocol. Server control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J.

D. Hardware. Each Server shall consist of the following:

1. Computer. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The following hardware requirements also apply:

a. The hard disk shall have sufficient memory to store:

1) All required server software.
2) A DDC database at least twice the size of the delivered system database.
3) One year of trend data based on the points specified to be trended at their specified trend intervals.

b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.

c. Minimum hardware configuration shall include the following:

1) Dual or Quad Core Processor
2) 6 GB RAM
3) 500 GB hard disk providing data at 3.0 Gb/sec
4) 16x DVD-RW drive
5) Serial, parallel, and network communication ports and cables as required for proper DDC system operation

E. System Software.

1. Operating System. Server shall have an industry-standard professional-grade operating system.

2. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions, numerical count of alarms and warnings on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

a. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.

b. Animation. Graphics shall be able to animate by displaying different image files for changed object status.

c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.

d. Format. Graphics shall be saved in an industry-standard format.

3. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics that are saved in the same formats as are used for system graphics.
4. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.
5. System Software Licensing Agreement:

    a. The software licensing shall have no restrictions on which brand of JACE, Supervisor or System Programming tools can interact with the system. The intent of this system is to be fully “open” and non-proprietary. The Niagara Compatibility Statement (NiCS) must be set to the following: Station Compatibility must = ALL and Tool Compatibility must = ALL.

F. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

1. Automatic System Database Configuration. Each server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
2. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.
4. Security. Each operator shall be required to log on to the system with user name and password in order to view, edit, add, or delete data.

    a. Operator Access. The user name and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System Administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.
    b. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time shall be user adjustable.
    c. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.
    d. Access to Software Application is password protected, each password is setup by the user during application setup

e. Software Application resides in the Niagara Framework, which means it rests comfortably on a secure private network, and therefore can be protected and accessed through a VPN.

5. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.
6. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Section 25 50 00 (Sequences of Operation). Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
7. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms. The system shall support up to 250 characters in each alarm message.
8. Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, operator interface or server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
9. Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms, and archive closed alarms to the server hard disk.
10. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified in Section 25 50 00 (Sequences of Operation). Trends shall be BACnet trend objects.
11. Trends & Displays. Software Application trends and queries can be saved as templates and viewed at a later date over any range of time.
12. Queries

    a. All user queries are executed via standard internet browser
    b. The web query initiates Software Application to pull the requested data
    c. Then Software Application builds the requested data table and trend graph, and serves up the display onto the web page where it is viewable via the Internet

13. Trend Chart Characteristics.

    a. When the mouse is dragged over a trend line, the respective data name pops up as a highlight for that section
    b. Granular Display – scalable to nearly any level

        1) The time frame for comparison is adjustable from a range of many months down to a few minutes span

    c. All Data – All the Time

1) All data stored in the database can be referenced for any relevant report

d. Data is exportable to CSV for manipulation or application with Microsoft Excel or other such program

14. Scalability

a. Software Application can store all or just some of the building automation system points.
b. Multiple buildings can be “recorded” by the Software Application

15. Analysis

a. Software Application can store all or just some of the building automation system points.
b. The building automation system data is accepted into the Niagara Framework
c. Software Application resides inside the Niagara Framework
d. Software Application exports data to Data Server for storage in a Microsoft SQL Server Database

16. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.
17. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
18. Standard Reports. Furnish the following standard system reports:

a. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
b. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
c. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

1) Alarm History.
2) Trend Data. Operator shall be able to select trends to be logged.
3) Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.
4) Trends, Queries, and Trend Graphs are granular – data ranges can be displayed with spans of many months down to just a few minutes
5) All data tables & trend graphs are viewable via Standard Internet Browser
6) No Workstation software required
7) Multiple buildings can be “recorded” at the same time

19. Energy Reports. System shall include an easily configured energy reporting tool that provides the capabilities described in this section.

a. The energy reporting tool shall be accessible through the same user interface (Web browser) as is used to manage the BAS.

b. The energy reporting tool shall be preconfigured by the Contractor to gather and store energy demand and consumption data from each energy source that provides metered data to the BAS. Meter data shall be stored at 5-minute intervals unless otherwise specified in the Sequence of Operation provided in section 25 50 00. This data shall be maintained in an industry standard SQL database for a period of not less than five years.

c. The energy reporting tool shall allow the operator to select an energy source and a time period of interest (day, week, month, year, or date range) and shall provide options to view the data in a table, line graph, bar graph, or pie chart. The tool shall also allow the operator to select two or more data sources and display a comparison of the energy used over this period in any of the listed graph formats, or to total the energy used by the selected sources and display that data in the supported formats.

d. The energy reporting tool shall allow the operator to select and energy source and two-time periods of interest (day, week, month, year, or date range) and display a graph that compares the energy use over the two time periods in any of the graph formats listed in the previous paragraph. The tool shall also allow the operator to select multiple energy sources and display a graph that compares the total energy used by these sources over the two-time periods.

e. The energy reporting tool shall allow the operator to easily generate the previously described graphs "on the fly," and shall provide an option to store the report format so the operator can select that format to regenerate the graph at a future date. The tool shall also allow the user to schedule these reports to run on a recurring basis using relative time periods, such as automatically generating a consumption report on the first Monday of each month showing consumption over the previous month. Automatically generated reports shall be archived on the server in a common industry format such as Adobe PDF or Microsoft Excel with copies e-mailed to a user editable list of recipients.

f. Utility – Application Software is designed to accept meter inputs from any building utility.

    1) Specifically, any data input that can be viewed as a Niagara Common Object

g. The energy reporting tool shall be capable of collecting and displaying data from the following types of meters:

    1) Electricity
    2) Gas
    3) Oil
    4) Steam
    5) Chilled Water
    6) Potable Water
    7) Heating and cooling degree days. (May be calculated from sensor data rather than metered.)

h. The user shall have the option of using Kw (Kwh) or Btu/hr (Btu) as the units for demand and consumption reports. Multiples of these units (MWH, kBtu, etc.) shall be used as appropriate. All selected sources shall be automatically

converted to the selected units. The user shall similarly have the option of entering facility area and occupancy hours and creating reports that are normalized on an area basis, an annual use basis, or an occupied hour basis.

i. Reporting & Displays

1) Application Software has standard reports to allow for timely and accurate viewing and management of input data.

j. Report Characteristics

1) On nearly all Displays, when the mouse is dragged over a report line, bar or pie area, the respective data pops up as a highlight for that section
2) Granular Display – scalable to nearly any level
3) The time frame for comparison is adjustable from a range of many months down to a few minutes span
4) All Data – All the Time
5) All data stored in the database can be referenced for any relevant report
6) Data is exportable to CSV for manipulation or application with Microsoft Excel or other such program

k. Building Consumption is Comparable

1) Metered data is comparable from building to building in the aggregate
2) All sub-metered loads can also be compared

l. The first layer of displayed data is metered consumption by building

1) Any sub-metered loads can also be compared building to building

m. A pie graph compares metered consumption data by building to graphically display the largest consumer

n. After comparison, a building can be selected for detailed and in-depth reporting

o. In Depth Energy Reporting Dashboard – When the user chooses the In-Depth Energy Reporting from the Building Menu Tree, the system shall open up a separate window for the building chosen. This window will contain the following details for the building:

p. Summary Statistics

1) Electricity
2) Total Energy Usage
3) Total Weekday Energy Usage
4) Total Weekend Energy Usage
5) Weekday Maximum Demand
6) Weekend Maximum Demand
7) Power Factor at Maximum Demand
8) Load Factor
9) On Peak Total Energy
10) On Peak Maximum Demand

11) On Peak Time of Maximum Demand
12) Off Peak Total Energy
13) Off Peak Maximum Demand
14) Off Peak Time of Maximum Demand

q. The Summary Statistics Dashboard will also show the following Pie Charts:

1) Total Weekday Energy Usage versus Total Weekend Energy Usage
2) Weekday Maximum Demand versus Weekend Maximum Demand
3) Total On Peak Energy Usage versus Total Off Peak Energy Usage
4) On Peak Maximum Demand versus Off Peak Maximum Demand

20. The Summary Statistics Dashboard will allow the users to select the Time Period of the Data to be summarized.

a. The user shall have the option of entering benchmark data for an individual facility or a group of facilities.
b. The user shall have the option of displaying any or all of the following data on any chart, line, or bar graph generated by the energy reporting tool:

1) Low/High/Average value of the metered value being displayed.
2) Heating and/or Cooling Degree Days for the time period(s) being displayed.
3) The Environmental Index for the facilities and time periods being displayed.

c. Load Duration Curves

1) This Dashboard shall have the ability to compare data as a percentage of time and display 3 separate Line Graphs:
2) Demand over Percentage of Time
3) Power Factor over Percentage of Time
4) Reactive Power over Percentage of Time

d. Load Profiles - This Dashboard is one Line Graph showing the following data over a period of time:

1) Demand
2) Power Factor
3) Reactive Power
4) Outside Air Temperature
5) Outside Relative Humidity

e. Weather Normalization

1) This report compares the performance of the facility in objective terms by normalizing the outside weather conditions.
2) Thus seasons and years can be compared on a more level basis because the swinging variable of ambient conditions has been normalized.
3) This report is most effective when baseline data is present, period of 6 months or greater, and then energy conservation measures are installed.

The report quickly shows the effectiveness of the energy conservation measures that were installed.

21. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.
22. Architecture

    a. Scalability
    b. System can be equipped with all or just one of the measured input profiles
    c. Multiple meters can be used for each utility or measured input data stream. Example – electric meters for HVAC, lighting, & general loads
    d. Multiple buildings can be tracked by the application software
    e. Consumption is comparable between different buildings

23. Meters

    a. Requires no specific brand of meter
    b. Some display points will Not be active if the corresponding meter value is not present.
    c. A qualified meter is one that provides a readable output signal that can be entered into the Niagara Framework as a common object model. Examples – BacNet, Lon, ModBus, XML, SQL, Analog 0-10vDc, etc

24. Analysis

    a. The meter or counter data is accepted into the Niagara Framework
    b. Application Software resides inside the Niagara Framework
    c. Software analyzes the data and exports data point to Data Server for storage
    d. Stores data in a Microsoft SQL Database

25. Queries

    a. All user queries are executed via standard internet browser

    b. The web query initiates the application software to pull the requested data
    c. The software builds the requested data table, graph, or display and serves up the display onto the web page where it is viewable via the Internet

G. Portable Operator's Terminal - (One required). Provide all necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator’s Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

2.8 CONTROLLER SOFTWARE

A. Furnish the following applications for building and energy management. All software application shall reside and operate in the system controllers. Applications shall be editable through the web browser interface.

B. System Security. See Paragraph 2.4.D.5. (Security) and Paragraph 2.4.E.14.c.3. (Operator Activity).

C. Scheduling. Provide the capability to execute control functions according to a user created or edited schedule. Each schedule shall provide the following schedule options as a minimum:

1. Weekly Schedule. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
2. 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 has executed, the system shall discard and replace the exception schedule with the standard schedule for that day of the week.
3. Holiday Schedules. Provide the capability for the operator to define up to 24 special or holiday schedules. These schedules will be repeated each year. The operator shall be able to define the length of each holiday period.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. Binary Alarms. Each binary object shall have the capability to be configured to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.

F. Analog Alarms. Each analog object shall have both high and low alarm limits. The operator shall be able to enable or disable these alarms.

G. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display on graphics.

H. Remote Communication. System shall automatically contact user interfaces or server on receipt of critical alarms. Maintenance Management. The system shall be capable of generating maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in 23 09 93 (Sequences of Operation).

I. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Section 25 50 00 (Sequences of Operation).

J. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs. The calculation interval, PID gains, and other tuning parameters shall be adjustable by a user with the correct security level.

K. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

L. Energy Calculations. The system shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.

M. Anti-Short Cycling. All binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

N. On and Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and a setpoint. The algorithm shall be direct-acting or reverse-acting.

O. Runtime Totalization. Provide software to totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Section 23 09 93 (Sequence of Operations).

2.9 CONTROLLERS

A. General: Application specific controllers (ASC) are microprocessor-based DDC controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. They are not fully user programmable, but are customized for operation within the confines of the equipment they are designed to serve.

1. Each ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
2. Each ASC will contain sufficient I/O capacity to control the target system.

B. Environment. The hardware shall be suitable for the anticipated ambient conditions.

1. Controller used in conditioned ambient spaces shall be mounted in NEMA 1 type rated enclosures. Controllers located where not to be disturbed by building activity (such as above ceiling grid), may be provided with plenum-rated enclosures and non-enclosed wiring connections for plenum cabling. All controllers shall be rated for operation at 0 C to 50 C [32 F to 120 F].
2. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40 C to 65 C [-40 F to 150 F].

C. Serviceability. Provide diagnostic LEDs for power and communications. All wiring connections shall be clearly labeled and made to be field removable.

D. Memory. The Application Specific Controller shall maintain all BIOS and programming information in the event of a power loss for at least 90 days.

E. Immunity to Power and noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%.

F. Transformer. Power supply for the ASC must be rated at minimum of 125% of ASC power consumption, and shall be fused or current limiting type.

2.10 INPUT AND OUTPUT INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output

points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.

C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.

E. Analog Inputs. Analog inputs shall monitor low-voltage (0–10 Vdc), current (4–20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal. Binary outputs on Building Controllers shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0–10 Vdc or a 4–20 mA signal as required to properly control output devices. Analog outputs shall not drift more than 0.4% of range annually.

H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system

2.11 POWER SUPPLIES AND LINE FILTERING

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

a. Unit shall operate between 32°F and 120°F. EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.

1. Provide internal or external transient voltage and surge suppression for servers and controllers. Surge protection shall have:

a. Dielectric strength of 1000 V minimum
b. Response time of 10 nanoseconds or less
c. Transverse mode noise attenuation of 65 dB or greater
d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

2.12 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers, unless otherwise specified elsewhere, shall be as follow.

1. Type. Control dampers shall be the parallel opposed-blade type as specified below or as scheduled on drawings.

a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
b. Other modulating dampers shall be opposed-blade.
c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.

2. Frame. Damper frames shall be 13 gauge galvanized steel channel or ⅛ in. extruded aluminum with reinforced corner bracing.
3. Blades. Damper blades shall not exceed 8 in. in width or 48 in. in length. Blades shall be suitable for medium velocity (2000 fpm) performance. Blades shall be not less than 16 gauge.
4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 10 cfm per ft^2 at 4 in. w.g. differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 1500 fpm.
6. Sections. Individual damper sections shall not exceed 48 in. × 60 in. Each section shall have at least one damper actuator.
7. Modulating dampers shall provide a linear flow characteristic where possible.
8. Linkages. Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators.

1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator’s rotation.
2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range. Proportional actuators shall accept a 0–10 Vdc or a 0–20 mA control signal and shall have a 2–10 Vdc or 4–20 mA operating range. (Floating motor actuators

may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)

4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 60 in.-lb. torque capacity shall have a manual crank.

C. Control Valves.

1. Automatic Temperature Control valves shall be Pressure Independent type, without requiring Flow Meters for operation.
2. All Temperature Control Valves and Actuators shall be furnished and installed by Section HVAC PIPING; Division 23, Section 2.7; pages 23.21.13 – 22 & 23.
3. BUILDING CONTROL AND AUTOMATION SYSTEM contractor shall be responsible for connection, control wiring and sequence operations, utilizing PICV's and other valves as supplied and installed under Division 23.
4. BUILDING CONTROL AND AUTOMATION SYSTEM contractor shall notify and coordinate with the HVAC PIPING contractor (Division 23) the control characteristics required for his system (i.e. 0v to 10v; 4ma to 20ma; 3-point, etc.); to assure proper actuator characteristic are obtained.

D. Temperature Sensor – Outside Air

1. Temperature sensors shall meet, at minimum, the following requirements:

a. Ventilated white PVC sun shield.
b. Weather proof enclosure with conduit fitting.
c. BCAS shall report the monitored temperature with an accuracy of 1.0 Deg. F.
d. Temperature range of -20 Deg. F. to +100 Deg. F.

E. Temperature Sensor - Duct Mounted - Single Point

1. Temperature sensors shall meet, at minimum, the following requirements:

a. Stainless steel probe, minimum 12-inch length or as required to extend two-thirds of the duct width.
b. BCAS shall report the monitored temperature with an accuracy of 1.0 Deg. F.
c. Temperature range of 32 Deg. F to 122 Deg. F.
d. Duct mounted moisture/waterproof housing with conduit fitting.

F. Temperature Sensor - Duct Mounted - Averaging

1. Temperature sensors shall meet, at minimum, the following requirements:

a. Probe length of 12 feet minimum or one linear foot per square foot of duct cross-sectional area, whichever is greater.
b. Copper sheathed construction.
c. BCAS shall report the monitored temperature with an accuracy of 2.0 Deg. F. accuracy.
d. Temperature range of 32 Deg. F to 122 Deg. F.

e. Duct mounted moisture/waterproof housing with conduit fitting.
f. Suitable supports at all bends and at intermediate points to prevent movement in the air stream.

G. Temperature Sensor-Wall Mounted - Tenant Spaces

1. Temperature sensors shall meet, at minimum, the following requirements:

a. White protective enclosure. There shall be no manufacturer's logos, name or thermometer on casing.
b. Space sensor covers shall be appropriate for the application, brushed aluminum, brushed nickel, stainless steel, or manufacturer's standard plastic covers.
c. BCAS shall report the monitored temperature with an accuracy of 1.0 Deg. F.
d. Temperature range of 32 Deg. F. to 100 Deg. F.

H. Temperature Sensor - Wall Mounted - Lobby and Public Spaces

1. Temperature sensors shall meet, at minimum, the following requirements:

a. Brass or stainless-steel button type sensors of maximum diameter 0.25 inches.
b. Sensor shall be painted in accordance with the Architects instructions.
c. BCAS shall report the monitored temperature with an accuracy of 1.0 Deg. F.
d. Temperature range of 32 Deg. F. to 100 Deg. F.

I. Temperature Sensor - Thermowell Mounted

1. Temperature sensors shall meet, at minimum, the following requirements:

a. Rigid stainless-steel probe of length which is, at minimum, .30% of the pipe diameter.
b. BCAS shall report the monitored temperature with an accuracy of 0.5 Deg. F.
c. Temperature range that is appropriate for the application. Range for chilled water and condenser water applications shall be between +32 Deg. F. and +41 Deg. F. at the low end and shall be between +104 Deg. F. and +122 Deg. F. at the upper end.
d. Moisture/waterproof housing with conduit fitting.
e. Stainless steel thermowell.
f. Provided with thermal grease to aid temperature sensing.
g. Sensors required for the determination of temperature differential shall be matched with a maximum variation over the entire temperature range of 0.2 Deg. F.

J. Freezestat

1. Freezestats shall meet, at minimum, the following requirements:

a. Minimum 6 feet to 20 feet vapor tension element, which shall serpentine the inlet face on all coils. Provide additional sensors, wired in series, to provide one linear foot per square foot of coil surface area.
b. Interlock to the associated fan so that fan will shut down when HOA switch is in Hand or Auto position.

c. Auto Reset
d. Set point shall be adjustable in the range of, at minimum, 32 Deg. F. to 45 Deg. F. Provide a scale with temperature setting clearly displayed.
e. Rated for 16 amps at 120 Vac.
f. Provide suitable supports.

K. Relative Humidity Sensor - Outside Air

1. Humidity sensors shall meet, at minimum, the following requirements:

a. Non-corroding outdoor shield to minimize wind effects and solar heating.
b. Weather proof enclosure with conduit fitting.
c. Two wire, 4-20 mA output proportional to relative humidity range of 0% to 100%.
d. 2% accuracy (5 - 95% RH).
e. Operating temperature range shall be appropriate for the climate.

L. Relative Humidity Sensor - Duct Mounted

1. Duct mounted relative humidity sensors shall meet, at minimum, the following requirements:

a. Duct mount moisture resistant enclosure with conduit fitting. 4-20 mA or 0-10V output proportional to relative humidity range of 0% to 100%. Humidity sensor shall be replaceable or transmitter field capable of being calibrated.
b. 2% accuracy (5 - 95% RH).
c. Drift less than 2% over 5 years.
d. Operating temperature range of 32 Deg. F to 122 Deg. F.

M. Relative Humidity Sensor - Wall Mounted - Non-Public Spaces

1. Humidity sensors shall meet, at minimum, the following requirements:

a. Wall mount enclosure with white cover. There shall be no manufacturer's logos, name or thermometer on casing.
b. Two wire, 4-20 mA output proportional to relative humidity range of 0% to 100%.
c. Humidity sensor shall be replaceable.
d. ± 2% accuracy (5 - 95% RH).
e. Operating temperature range of 10 Deg. C. to 33 Deg. C. (50 Deg. F to 90 Deg. F.).

N. Combination Relative Humidity and Temperature Sensors

1. Where there is a requirement for the monitoring of both relative humidity and temperature at the same location, the BCAS contractor may provide a combination relative humidity sensor and temperature sensor. The individual sensors must each meet the specifications detailed above.
2. Contractor shall provide break-out pricing for utilizing of combination sensors in all location requiring a control/sensing device on the Documents.

O. Control Relays - Momentary

1. A. Provide momentary control relays as indicated within the sequences of operation. Relays shall meet, at minimum, the following requirements:

   a. Coil ratings of 120 VAC, 50 mA or 10-30 VACNDC, 40 mA as suitable for the application.
   b. Provide complete isolation between the control circuit and the digital output.
   c. Located in the DCP, UC or other local enclosures.
   d. 10 amp contact rating.
   e. LED status indication.

P. Static Pressure Sensor - Duct Mounted

1. Static pressure sensors shall meet, at minimum, the following requirements:

   a. Input range shall be selected at.200% of normal operating range.
   b. 4-20 mA or 0-10V output proportional to pressure input range.
   c. V 5% accuracy.
   d. Operating temperature range of 32 Deg. F to 122 Deg. F).
   e. Easily accessible, integral non-interacting zero and span adjustment.
   f. Minimum over pressure input protection of five times rated input.

Q. Static Pressure Sensor - Space

1. Static pressure sensors shall meet, at minimum, the following requirements:

   a. Input range of -0.1 to +0.1 inches w.g.
   b. 4-20 mA or 0-10V output proportional to pressure input range.
   c. V 1% accuracy of range.
   d. Temperature range of 20 Deg. F to 120 Deg. F.
   e. Easily accessible, integral non-interacting zero and span adjustment.
   f. Over pressure input protection of five times rated input.
   g. Space static pressure references shall be routed to the static pressure reference riser. Coordinate exact mounting locations of exterior static pressure reference points. Dampening pots for the reference riser shall be manufactured by Dwyer, Model A-306 or approved equal.
   h. Lobby space pressure sensor requirements shall be coordinated with Owner/Architect.

R. Air Flowrate Sensor - Duct Mounted

1. Air flowrate sensors and transducer shall meet, at minimum, the following requirements:

   a. Multiple independent grid measuring devices. Each measuring device shall be dual glass beaded thermistor sensing probes
   b. Size of grid and quantity of measuring devices shall be appropriate for application to achieve the specified accuracy.
   c. Internal materials of the measuring devices and transducer suitable for continuous contact with air.

d. Sensing support grid shall be constructed of aluminum. Microprocessor based digital transmitter.
e. Output signal of 0-10VDC or 4-20 mA proportional to cfm.
f. Temperature range of 0 Deg. F. to 120 Deg. F.
g. 3% accuracy of measured value (not full scale).

S. Air Flowrate Sensor• Fan Inlet

1. Air flowrate sensors and transducer shall meet, at minimum, the following requirements:

a. Multiple independent grid measuring devices. Each measuring device shall be dual glass beaded thermistor sensing probes
b. Size of grid and quantity of measuring devices shall be appropriate for application to achieve the specified accuracy. Coordinate the exact requirements with the fan manufacturer.
c. Internal materials of the measuring devices and transducer suitable for continuous contact with air.
d. Sensing support grid shall be constructed of aluminum.
e. Microprocessor based digital transmitter.
f. Output signal of 0-10VDC or 4-20 mA proportional to cfm.
g. Temperature range of 0 Deg. F. to 120 Deg. F.
h. V 3% accuracy of measured value (not full scale).

T. Current Sensing Relay

1. Current metering transformers and relays shall meet, at minimum, the following specifications:

a. Rated for the applicable load.
b. The output relay shall have an accessible trip adjustment over its complete operating range. Provide LED indication of relay status.
c. Long term drift shall not exceed 5% of full range per 6 months.
d. Current transformer and relay shall have over current and over voltage protection.
e. Split core or solid core shall be sized for the application.
f. Relay shall be in dustproof housing.
g. Accuracy-V 2% of reading from 10% to 100% of full scale range, V 2% full scale from 0 to 10% of full scale range.
h. Temperature range of 5 Deg. F. to 140 Deg. F.

U. Water Flowmeter - Bi-Directional • Insertion Type

1. Turbine flowmeter shall meet, at minimum, the following requirements:

a. Stainless steel insertion probe with non-metallic rotors.
b. 24 V 4 VDC @ 90 mA supply voltage.
c. V 2% accuracy of actual reading from 0.4 to 20 ft. /s.
d. Turndown ratio of 30:1.
e. DC linearity of 0.1% of span.
f. Pulse output proportional to flowrate.
g. Insertion type with dual turbine blades.

h. Suitable for maximum flowrate in line.
i. Rated for as necessary to withstand the maximum pressure of the system.
j. Temperature range-standard: 180 Deg. F. continuous, 93 Deg. C. peak.

2. Provide valve to allow for removal and re-insertion without disruption to the water service. The valve shall meet the requirement specified in 17130.

V. Water Differential Pressure Sensor

1. Water differential pressure sensors shall meet, at minimum, the following requirements:

a. Cast aluminum NEMA 1 enclosure.
b. Output of 4-20 mA proportional to the pressure sensed.
c. Over pressure protection of five times the rated input.
d. Easily accessible, integral non-interacting zero and span adjustment.
e. Operating range of 0 to 30 psig.
f. Accuracy of "if 2% of full scale reading.
g. Valved tappings shall be installed by the Division 23 subcontractor. Furnish the valves to the Division 23 subcontractor.

W. Differential Pressure Switch• Air• Fan Shutdown

1. Provide air differential pressure switches to shut down the associated fan in the event of sensing high differential pressure. Air differential pressure switches shall meet, at minimum, the following requirements:

a. UL approved.
b. SPOT or two SPST switches rated for 10 amps minimum at 120 Vac.
c. Adjustable setpoint with a setpoint range of 0 to 10 inches w.g.
d. 1/4 inch compression fittings suitable for copper sensing tubing.
e. Temperature range of 0 Deg. F. to 160 Deg. F..
f. Manual reset.

X. Differential Pressure Switch - Air• Fan Status

1. Provide air differential pressure switches to indicate fan status. Air differential pressure switches shall meet, at minimum, the following requirements:

a. UL approved.
b. SPOT or two SPST switches rated for 10 amps minimum at 120 Vac.
c. Setpoint and range suitable for the associate fans system to sense operating status of fan.
d. 1/4 inch compression fittings suitable for copper sensing tubing.
e. Temperature range of 0 Deg. F. to 160 Deg. F..

Y. Water Pressure Sensor

1. Pressure sensors shall meet the following requirements:

a. Input range of 200% of measured variable.
b. 4-20 mA or 0-10V output proportional to water pressure.

c. 0.5% accuracy of range.
d. Temperature range of 32 Deg. F to 100 Deg. F..
e. Easily accessible, integral non-interacting zero and span adjustment.
f. Over pressure input protection of two times rated input.
g. Stainless steel wetted parts.
h. Burst pressure of 5 times rated input
i. Pressure Rating shall be in accordance with piping requirements.

Z. Carbon Monoxide Detection Sensor

1. Carbon monoxide detection sensors shall meet, at minimum, the following requirements:

a. Negligible temperature and humidity effect on accuracy.
b. 0-10 VDC or 4-20 mA transducer interface with the BCAS proportional to 0 to 400 ppm of CO concentration.
c. 10 to 26 VAC or VOC voltage.
d. No maintenance or period sensor replacement needed.

AA. Carbon Dioxide Detection Sensor

1. Carbon dioxide detection sensors shall meet, at minimum, the following requirements:

a. Negligible temperature and humidity effect on accuracy.
b. 0-10 VOC or 4-20 mA transducer interface with the BCAS proportional to 0 to 2,000 ppm of carbon dioxide concentration.
c. 24 VAC or VDC @ 400 mA max voltage.
d. No maintenance or periodic sensor replacement needed.
e. Accuracy- V 5% of reading or V 100 ppm, whichever is greater.
f. Operating temperature of 32 Deg. F. to 122 Deg. F..
g. Suitable for duct mounting or outside air installations as appropriate.

BB. Emergency Fan Operation Switch

1. Provide emergency fan operation switches to activation the central plant ventilation system. Fan operation switches shall meet, at minimum, the following requirements:

a. Yellow cover plate.
b. Red illuminated latching type mushroom activation button.
c. Labeled "EMERGENCY VENTILATION".
d. Clear polycarbonate tamper proof cover.
e. SPST contacts.

2. If it meets the above requirements, provide Safety Technologies International STI Stopper Station with Mini Stopper II, or approved equal.

CC. Emergency Plant Shutdown Switch

1. A. Provide emergency plant shut down switches to shut down all electrical operating equipment in the central plant. Plant shut down switches shall meet, at minimum, the following requirements:

a. Blue cover plate.
b. Red illuminated latching type mushroom activation button.
c. Labeled "EMERGENCY PLANT SHUTDOWN".
d. Clear polycarbonate tamper proof cover.
e. SPST contacts.

2. If it meets the above requirements, provide Safety Technologies International STI Stopper Station with Mini Stopper II, or approved equal.

DD. Local Control Panels.

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) cam-lock or key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
2. Interconnections between internal and face-mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600-volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.

2.13 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

2.14 FIBER OPTIC CABLE SYSTEM

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. 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 through the General Contractor to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

3.2 PROTECTION

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

A. Site

1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Test and Balance.

1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

C. Life Safety.

1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in Section 25 50 00 (Sequences of Operation).
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23. Interlock smoke dampers to air handlers as specified in Section 25 50 00 (Sequences of Operation).
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.
4. The contractor shall provide a graphical user interface for all fire pull alarms. Division 28 contractor will install a gateway server that will allow BAS integration. Integration will be at the network level and will monitor (not control) the following objects:

a. Alarm
b. Trouble
c. Supervisor

D. Elevator.

1. The Division 14 contractor shall provide a Bacnet interface card for the entire elevator system. The Division 25 contractor shall integrate into the Bacnet xxx and monitor (not control) the following objects:

a. Current floor,
b. Cab direction
c. Target floor
d. Weight
e. Mode
f. Door position
g. Alarms

E. Lighting.

1. The Division 26 contractor shall provide a Bacnet or DALI interface that enables the Division 25 contractor to control the lighting system through one central platform. The Division 25contractor shall provide controls for the following properties:

a. Scheduling
b. Dimming
c. Demand Limiting Lighting
d. Override

F. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:

1. All communication media and equipment shall be provided as specified in Section 25 50 00.
2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Section 25 50 00.
3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. The contractor is responsible for providing all HVAC controls described in the contract documents regardless of where within the contract documents these HVAC controls are described.
5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Paragraph 1.6 herein.

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

3.6 WIRING

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.

B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.

C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.

E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceways.

F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

G. Do not install wiring in raceway containing tubing.

H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 10 ft. intervals.

I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.

J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

L. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.

M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

O. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.

P. Include one pull string in each raceway 1 in. or larger.

Q. Use color-coded conductors throughout with conductors of different colors.

R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 in. from high-temperature equipment (e.g. steam pipes or flues).

T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

U. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.

V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.

W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

3.7 COMMUNICATION WIRING

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.

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

C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.

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

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

F. 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 manufacturer’s instructions.

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

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

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

J. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135.

3.8 FIBER OPTIC CABLE

A. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

3.9 INSTALLATION OF SENSORS

A. Install sensors in accordance with the manufacturer's recommendations.

B. Mount sensors rigidly and adequately for environment within which the sensor operates.

C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.

D. All wires attached to sensors shall be sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.

E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.

F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 1 ft. of sensing element for each 1 $ft.^2$ of coil area.

G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 10 ft. downstream.

H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.

J. Differential Air Static Pressure.

1. Supply Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the height-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
3. Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.
6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.

K. Freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset.

L. Install humidity sensors for duct mounted humidifiers at least 10 ft. downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch according to manufacturer's instructions.

3.11 ACTUATORS

A. General. Mount and link control damper actuators according to manufacturer's instructions.

1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
3. Provide all mounting hardware and linkages for actuator installation.

B. Electric/Electronic

1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall be mounted following manufacturer’s recommendations.
2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.12 WARNING LABELS

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the control 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 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.

3.13 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels shall be labeled at each end within 2 in. of termination with control system address or termination number.

B. Permanently label or code each point of field terminal strips to show the instrument or item served.

C. Identify control panels with minimum ½ in. letters on laminated plastic nameplates.

D. Identify all other control components with permanent labels. All plug-in components shall be labeled such that label removal of the component does not remove the label.

E. Identify room sensors related to terminal boxes or valves with nameplates, but label shall not be visible on the face of the sensor. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

F. Identifiers shall match record documents.

3.14 CONTROLLERS

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in Section 23 09 93 (Sequences of Operation).

3.15 PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.

B. Operator Interface.

1. Standard Graphics. Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List or Sequence of Operation.
2. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

3.16 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration.

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
7. Alarms and Interlocks:

    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action

3.17 BCAS MOCKUP

A. Provide a mockup of select components and features of the BCAS during the early stages of construction. The BCAS mockup shall be constructed at the BCAS subcontractor's facilities and remain intact as long as necessary to obtain the Engineer and Owner approvals.

B. The BCAS mockup shall include, at minimum, the following hardware components:

1. NDS.
2. OIW.
3. ROW.
4. HHD.
5. Partial MLAN.
6. At least two CCP on the project in the final panel enclosure.

7. Select FLAN to support the DCP/UC listed below.

8. DCP, mounted in the final panel enclosures, serving the following systems:

   a. Central CHW Plant.

   b. Secondary CHW Plant.

   c. Condenser Water System.

   d. Typical Floor Dual Path AHU.

   e. Typical Floor Overhead VAV AHU.

   f. Outside AHU.

   g. Lobby AHU.

9. UC serving the following systems:

   a. All FPTU UC associated with the typical floor AHU above for one floor.

   b. All UC serving CAVTU for outside, toilet and relief air on the one typical floor.

10. LCRP serving the following:

    a. Lobby lighting.

    b. Exterior lighting.

    c. Garage lighting.

    d. Accent lighting.

11. One FPTU shall be provided by the Mechanical subcontractor for the BCAS mockup.

12. One CAVTU shall be provided by the Mechanical subcontractor for the BCAS mockup.

13. One VFD shall be provided by the Mechanical subcontractor.

14. Any temporary power required for the BCAS mockup including components provided by the Mechanical or Electrical subcontractor shall be provided by the BCAS subcontractor.

15. Actuators and sensors associated with the above systems are not required as part of the mockup.

C. Provide a software based I/O point operational simulator to confirm proper operation of each type of I/O configuration.

D. The BCAS mockup shall include, at minimum, the following software components:

1. All NDS. OIW, ROW, HHD and operator software required by Section 25 11 00 for the entire BCAS.

2. All monitoring and control software including system graphics required by Section 25 15 00 for the entire BCAS. The graphics required for each system shall be created. Repetitive graphics for identical units are not required.

3. All operating sequences of operation software required by Section 25 80 00 for the systems listed above.

4. Software interface to the VFD.

5. Software interface to the Lighting Relay Panel.

E. Provide demonstration of the above components, software and operating features to the Owner, Consultant and General Contractor in a BCAS Mockup Review Session. It is anticipated that each feature and function of the hardware and software will be reviewed over a one week period. The Consultant will create a Deficiency List from the BCAS Mockup Review Session. The BCAS subcontractor shall correct all deficiencies noted and a follow up BCAS Mockup review session will be schedule.

F. If there are deficiencies remaining after the initial BCAS mockup demonstration that require further testing by the Consultant, then the expenses of the Owner and Consultant incurred in providing the additional follow-up tests to verify compliance with the specifications, including travel, subsistence, accommodation and normal consulting fees, shall be paid by the BCAS subcontractor at no additional cost to the Owner.

3.18 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration.

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
5. As each control input and output is checked, a log shall be completed showing the date, technician’s initials, and any corrective action taken or needed.

6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:

    a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
    b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
    c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
    d. Interface to the building fire alarm system.
    e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and disk formats.

10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

B. Acceptance.

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

3.19 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.20 TRAINING

A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.

B. Training shall enable students to accomplish the following objectives.

1. Day-to-day Operators:

a. Proficiently operate the system
b. Understand control system architecture and configuration
c. Understand DDC system components
d. Understand system operation, including DDC system control and optimizing routines (algorithms)
e. Operate the user interface and peripherals
f. Log on and off the system
g. Access graphics, point reports, and logs
h. Adjust and change system set points, time schedules, and holiday schedules
i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
j. Understand system drawings and Operation and Maintenance manual
k. Understand the job layout and location of control components
l. Access data from DDC controllers and ASCs
m. Operate portable operator's terminals

2. Advanced Operators:

a. Make and change graphics on the workstation
b. Create, delete, and modify alarms, including annunciation and routing of these
c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
d. Create, delete, and modify reports
e. Add, remove, and modify system's physical points
f. Create, modify, and delete programming
g. Add panels when required
h. Add operator interface stations
i. Create, delete, and modify system displays, both graphical and others
j. Perform DDC system field checkout procedures
k. Perform DDC controller unit operation and maintenance procedures
l. Perform user interface and peripheral operation and maintenance procedures
m. Perform DDC system diagnostic procedures

n. Configure hardware including PC boards, switches, communication, and I/O points
o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
p. Adjust, calibrate, and replace system components

3. System Managers/Administrators:

a. Maintain software and prepare backups
b. Interface with job-specific, third-party operator software
c. Add new users and understand password security procedures

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.

D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.

E. The instructor(s) shall be factory-trained and experienced in presenting this material.

F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.21 CONTROL DAMPER INSTALLATION

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure ¼ in. larger than damper dimensions and shall be square, straight, and level.

C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8 in.) of each other.

D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

E. Install extended shaft or jackshaft according to manufacturer’s instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.

G. Provide a visible and accessible indication of damper position on the drive shaft end.

H. Support ductwork in area of damper when required to prevent sagging due to damper weight.

I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.22 SMOKE DAMPER INSTALLATION

A. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the engineer no less than two weeks prior to inspection by the code authority having jurisdiction.

B. Provide complete submittal data to controls system subcontractor for coordination of duct smoke detector interface to HVAC systems.

3.23 DUCT SMOKE DETECTION

A. Submit data for coordination of duct smoke detector interface to HVAC systems as required in Part 1, "Submittals."

B. This Contractor shall provide a dry-contact alarm output in the same room as the HVAC equipment to be controlled.

3.24 CONTROLS COMMUNICATION PROTOCOL

A. General. The electronic controls packaged with this equipment shall communicate with the building direct digital control (DDC) system. The DDC system shall communicate with these controls to read the information and change the control setpoints as shown in the sequences of operation, and control schematics. The information to be communicated between the DDC system and these controls shall be in the standard object format as defined in ANSI/ASHRAE Standard 135 (BACnet). Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of Standard 135.

B. Distributed Processing. The controller shall be capable of stand-alone operation and shall continue to provide control functions if the network connection is lost.

C. I/O Capacity. The controller shall contain sufficient I/ O capacity to control the target system.

D. The Controller shall have a physical connection for a laptop computer or a portable operator’s tool.

E. Environment. The hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 40°F to 140°F.
2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 32°F to 120°F.

F. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.

G. Memory. The Controller shall maintain all BIOS and programming information in the event of a power loss for at least 30 days.

H. Power. Controller shall be able to operate at 90% to 110% of nominal voltage rating.

I. Transformer. Power supply for the Controller must be rated at minimum of 125% of ASC power consumption and shall be fused or current limiting type.

END OF SECTION 25 10 00