Delta Controls Guide Specs

enteliSYSTEM™

Based upon ASHRAE 13-2007 DDC Specification Guidelines

Division 25 (CSI 2014 format)

Legend:

Note to Specifier: areas requiring editing/selection by the designer

Specification items of special importance that the designer should be aware of

Word Users Note: For both of the above notes in the document, you can either delete the specially formatted text within the spec or select it and change it to the "Normal" style to shut off the special effects. The *"note to specifier"* is set to the Style type "Note to Specifier" while the *"Specification items of special importance…"* is set to the Style type "Critical Feature"

Spec format is (use the Headings 1-7): These are on a multilevel list style called "Specifications" If you need to modify it, click on the multilevel list icon on the "Home" tab, then right click on the right click on the List Style near the bottom of the dialogue box that shows "Specification" when you hover over it. You can easily modify the colors

Part # (Heading 1, Outline level 1)

#.# SECTION (Heading 2, Outline level 2)

    A. Details (Heading 3, Outline level 3)

        #. Sub details (Heading 4, Outline level 4)

            a.) Sub-sub details (Heading 5, Outline level 5)

                i. more lists (Heading 6, Outline level 6)

                    (i) yet more lists (Heading 7, Outline level 7)

Part 1 General

1.0 SECTION INCLUDES

    A.   Description

    B.   Approved Control System Contractors and Manufacturers

    C.   Quality Assurance

    D.   Codes and Standards

    E.   System Performance

    F.   Submittals

    G.   Warranty

    H.   Ownership and licensing of Engineering and Operating Software

1.1 DESCRIPTION

    A.   General: The control system shall consist of a high-speed, peer-to-peer, BACnet Testing Labs listed network of DDC controllers, all of the same family and manufacturer, residing and communicating on a BACnet IP (Internet Protocol) and/or BACnet over Ethernet network. All operator workstation/server software shall also be BTL listed at time of bidding. The system software shall combine engineering and user functionality into a singular instance interface, (no dissimilar manufacturers), be server based and accessible via the owner's network portal to the internet.

    B.   Users will interface with the system network via dashboard style multi-tasking dynamic color graphics. Access and manipulation of the system must be available via ALL of the following media and devices: current versions of Windows, Android and Apple OS devices operating in workstation, tablet or smartphone device platforms. *Note to specifier: remove this paragraph if dynamic graphics are not required for this project.*

C. The dashboard style package interface shall be of the same manufacturer as the controller manufacturer and have pre-built dashboard "widgets" as well as support custom dashboard widget development, as well as audit log, alarm management, trending graphics, remote access, set point adjustment, schedule changes, calendar changes, point overrides over the Owner's WAN and the Internet.

D. The system shall incorporate all owner-defined, specified herein collected data as well as derived virtual data, (examples: building environmental, weather, utility, attendance and comparison data) and represent the information in a non-text, graphic form such as charts, graphs and other standard representations that various financial and operational personnel can utilize.

E. Each mechanical system, building floor plan, control device, and energy meter will be depicted by point-and-click real-time dynamic graphics as well as standard information tree format. The owner shall be presented with a minimum of 8 standard widgets, (SEE SECTION 2.3, Paragraph F), for use in their system as listed herein.

F. The owner shall provide at minimum for the first two years a connection to the Internet via high-speed cable modem, ADSL, ISDN, T1 or through the facility ISP. The owner shall be responsible for paying for all Internet access fees and connection charges.

G. The system will include fully functional access control software that supports credential readers, door controllers and card users at no additional cost. Advanced lighting control software shall also be included and shall support daylight harvesting, scene lighting and central switching strategies.

1.2   APPROVED CONTROL SYSTEM CONTRACTORS AND MANUFACTURERS

A. The system shall match and expand the existing Delta Controls System. All new panels and software must communicate seamlessly as part of the existing Delta Controls network and use the existing programming, setup and graphical interfacing tools. The new panels will exchange data and accept all editing commands from the existing Delta Controls Operator Workstation as well as enteliWEB™ dashboard interface located as shown on the drawings.

Note to Specifier: above paragraph is for an expansion/extension of an existing Delta Controls system. Substitute the following paragraph A for the preceding paragraph A if it is a new installation.

A. The base bid shall be Delta Controls. Other manufacturers may bid subject to meeting all requirements of the specification and receiving approval from the engineer 30 days prior to bid. A comparison of the alternate system to the base bid system must be submitted 45 days prior to bid for review process. If approved, other manufacturer's bids shall be shown as an add or deduct from the base bid on the bid form. Include project references with contact information for at least three installations of the proposed system with the request for approval package.

Note to Specifier: preferred approach is base bid with alternates. If this isn't an option, substitute the following paragraph A for the preceding paragraph A.

A. The following are the approved Control System Contractors and manufacturers:

Contractor	Manufacturer	System
	Automated Logic	WebCTRL BACnet version only
	Delta Controls	**enteliSYSTEM**
	Siemens	Apogee BACnet version only

Note:
1. The above Contractors are listed alphabetically and do not display a preference.

2. The Contractor shall use only products from the corresponding manufacturer and product line listed.

3. The above list of manufacturers applies to operator workstation software, controller software, the custom application programming language, Building Controllers, Advanced Application Controllers, and Application Specific Controllers. All other

products specified herein (e.g., sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.3   QUALITY ASSURANCE

A.   Contractor/Manufacturer Qualifications

1. *The Installer shall have an established working relationship with the Control System Manufacturer.*
2. *The Installer shall have successfully completed Control System Manufacturer's classes on the control system. The Installer shall present for review the certification of completed training, including the hours of instruction and course outlines upon request.*
3. *All products used in this installation shall be new, currently under manufacture, and shall be applied in standard off the shelf products. This installation shall not be used as a test site for any new products unless explicitly approved by the Owner in writing. Spare parts shall be available for at least 5 years after completion of this contract.*

1.4   CODES AND STANDARDS

A.   All work, materials, and equipment shall comply with the rules and regulations of all codes and ordinances of the local, state, and federal authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications. As a minimum, the installation shall comply with the current editions in effect 30 days prior to receipt of bids of the following codes:

1. *National Electric Code (NEC)*
2. *Uniform Building Code (UBC)*
3. *Section 608, Shutoff for Smoke Control*
4. *Section 403.3, Smoke Detection Group B Office Buildings and Group R, Division 1 Occupancies*
5. *Section 710.5, Wiring in Plenums*
6. *Section 713.10, Smoke Dampers*
7. *Section 1106 Refrigeration Machinery Rooms*
8. *Section 1107, Refrigeration Machinery Room Ventilation*
9. *Section 1108, Refrigeration Machinery Room Equipment and Controls*
10. *Section 1120, Detection and Alarm Systems*
11. *Uniform Mechanical Code (UMC)*
12. *ASHRAE 135-2016*
13. *FCC Regulation, Part 15- Governing Frequency Electromagnetic Interference*
14. *Underwriters Laboratories UL916*

1.5   SYSTEM PERFORMANCE

A. Performance Standards. The system shall conform to the following:

1. *Graphic Display. The system shall be dashboard based, and also capable of displaying a graphic with 20 dynamic points/objects with all current data within 10 seconds.*
2. *Graphic Refresh. The system shall update a graphic with 20 dynamic points/objects with all current data within 8 seconds*
3. *Object Command. The maximum time between the command of a binary object by the operator and the reaction by the device shall be less than 2 seconds. Analog objects should start to adjust within 2 seconds*
4. *Object Scan. All changes of state and change of analog values will be transmitted over the high-speed Ethernet network such that any data used or displayed at a controller or workstation will have been current within the previous 2 seconds*
5. *Alarm Response Time. The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed 45 seconds*
6. *Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 1 second. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control*
7. *Performance. Programmable controllers shall be able to execute DDC PID control loops at a frequency of at least once per second. The controller shall scan and update the process value and output generated by this calculation at this same frequency*
8. *Multiple Alarm Annunciation. All workstations on the network must receive alarms within 5 seconds of each other*
9. *Reporting Accuracy. The system shall report all values with an end-to-end accuracy as listed or better than those listed in Table 1*
10. *Energy Reporting. The operating software shall have as standard, dashboard widgets which can be selected by the operator to create individual interface points as well as multitrend graphics as standard.*
11. *Stability of Control. Control loops shall maintain measured variable at setpoint within the tolerances listed in Table 2*

B. TABLE 1: Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC [±1ºF]
Ducted Air	±0.5ºC [±1ºF
Outside Air	±1.0ºC [±2ºF]
Dewpoint	±1.5ºC [±3ºF]
Water Temperature	±0.5ºC [±1ºF]
Delta-T	±0.15ºC[±0.25ºF]
Relative Humidity	±5% RH
Water Flow	±5% of full scale
Airflow (terminal)	±10% of full scale *(see Note 1)*

Measured Variable	Reported Accuracy
Airflow (measuring stations)	±5% of full scale
Air Pressure (ducts)	±25 Pa [±0.1 "W.G.]
Air Pressure (space)	±3 Pa [±0.01 "W.G.]
Water Pressure	±2% of full scale *(see Note 2)*
Electrical (A, V, W, Power factor)	5% of reading *(see Note 3)*
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 ppm
Note 1: 10%-100% of scale	
Note 2: For both absolute and differential	
Note 3: Not including utility-supplied	

C.   TABLE 2: Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±*50 Pa [±0.2" w.g.]* ±*3 Pa [±0.01" w.g.]*	*0-1.5 kPa [0-6" w.g.]* *-25 to 25 Pa [-0.1 to 0.1" w.g.]*
Airflow	±*10% of full scale*	
Temperature	±*0.5ºC [±1.0ºF]*	
Humidity	±*5% RH*	
Fluid Pressure	±*10 kPa [±1.5 psi]*	*0-1 kPa [1-150 psi]*
" " differential	±*250 Pa [±1.0" w.g.]*	*0-12.5 kPa [0-50"w.g.]*

1.6   SUBMITTALS

A.   Product Data and Shop Drawings: Contractor shall provide shop drawings or other submittals on all hardware, software, and installation to be provided.   No work may begin on any segment of this project until submittals have been reviewed and approved for conformity with the design intent. Six copies are required. All drawings shall be done in DXF format and provided on magnetic/optical disk and as full-size drawings. When manufacturer's cut sheets 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 drawings 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. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:

1. *Direct Digital Control System Hardware*

   a) A complete bill of materials of equipment to be used shall be listed indicating quantity, manufacturer, model number, and other relevant technical data.

   b) Manufacturer's description and technical data, such as performance curves, product specification sheets, and installation/maintenance instructions for the items listed below and other relevant items not listed below:

      i   *Direct Digital Controller (controller panels)*
      ii   *Transducers/Transmitters*
      iii *Sensors (including accuracy data)*
      iv   *Actuators*
      v   *Valves*
      vi   *Relays/Switches*
      vii *Control Panels*
      viii *Power Supply*
      ix   *Batteries*
      x   *Operator Workstation Equipment*
      xi   *Wiring*

   c) Wiring diagrams and layouts for each control panel. Show all termination numbers

   d) Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware

2. *Central System Hardware and Software*

a) A complete bill of material of equipment used indicating quantity, manufacturer, model number, and other relevant technical data.

b) Manufacturer's description and technical data, such as product specification sheets and installation/maintenance instructions for the items listed below and other relevant items not listed below:

> i   *Central Processing Unit*
> ii   *Monitors*
> iii   *Printers*
> iv   *Keyboard*
> v   *Power Supply*
> vi   *Battery Backup*
> vii   *Interface Equipment Between CPU and Control Panels*
> viii *Operating System Software*
> ix   *Operator Workstation Software*
> x   *Color Graphic Software*
> xi   *Third-party Software*

c) A schematic diagram for all control wiring, communication wiring and power wiring shall be provided. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers, function and data link protocol(s). Show all interface wiring to the control system

d) Provide detailed riser diagrams of wiring between central control unit, operator workstation(s), routers, gateways and all control panels

e) Examples of the color graphic dashboard screens shall be provided. Provide 3 screen shots from 5 existing projects representing various For each screen, provide a conceptual layout of pictures and data, and show or explain which other screens can be directly accessed.

3. *Controlled Systems:*

a) A schematic diagram of each controlled system. The schematics shall have all control points/objects labeled and with point/object names shown or listed. The schematics shall graphically show the location of all control elements in the system

b) A schematic wiring diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, it shall be labeled with the same name. All terminals shall be labeled

c) An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number

d) A mounting, wiring, and routing plan view drawing. The drawing shall be done in ¼" scale. The design shall take into account HVAC, electrical and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work

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/object list for each system controller including inputs and outputs (I/O), point/object number, the controlled device associated with the I/O point/object, and the location of the I/O device. Software flag points/objects, alarm points/objects, etc

4. *Quantities of items submitted shall be reviewed, but are the responsibility of the Contractor*

5. *A description of the proposed process along with all report formats and checklists to be used in Part 3: "Control System Demonstration and Acceptance."*

6. *A BACnet Protocol Implementation Conformance Statement (PICS) for each type of controller and Operator Workstation included in the submittal. PICS to include for each product, as a minimum, a list of BACnet functional groups supported, BACnet services supported, BACnet data link options available and BACnet objects provided*

    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 dates of individual work items.
c) Duration of individual work items
d) Planned delivery dates for major material and equipment, and expected lead times
e) Milestones indicating possible restraints on work by other trades or situations

2. *Provide monthly written status reports indicating work completed, revisions to expected delivery dates, etc. An updated project schedule shall be included.*

    C.   Project Record Documents: Upon completion of installation, submit three copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and shall include:

1. *Project Record Drawings. These shall be as-built versions of the submittal shop drawings. One set of magnetic media including DXF drawing files also shall be provided*
2. *Testing and Commissioning Reports and Checklists. Completed versions of all reports and checklists, along with all trend logs, used to meet the requirements of Part 3: "Control System Demonstration and Acceptance."*
3. *Certification of the pressure test required in Part 3: "Control Air Tubing."*
4. *Operation and Maintenance (O & M) Manual. This shall include as-built versions of the submittal product data. In addition to the information required for submittals, the O & M manual shall include:*

   a) Names, addresses, and 24-hour telephone numbers of Contractors installing equipment, and the control systems and service representatives of each
   b) Operators Manual with procedures for operating the control systems, including logging on/off, alarm handling, producing point/object reports, trending data, overriding computer control, and changing setpoints and other variables
   c) One set of Programming Manuals with a description of the programming language (including syntax), statement descriptions (including algorithms and calculations used), point/object database creation and modification, program creation and modification, and use of the editor
   d) Engineering, Installation, and Maintenance Manual(s) that explain how to design and install new points/objects, panels, and other hardware; preventive maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware
   e) A listing and documentation of all custom software created using the programming language, including the setpoints, tuning parameters, and object database. One set of magnetic/optical media containing files of the software and database also shall be provided
   f) One set of magnetic/optical media containing files of all color graphic screens created for the project
   g) A list of recommended spare parts with part numbers and suppliers
   h) Complete original issue documentation, installation, and maintenance information for all third-party hardware provided, including computer equipment and sensors
   i) Complete original issue diskettes for all software provided, including operating systems, programming language, operator workstation software, and graphics software
   j) Licenses, guarantee, and warranty documents for all equipment and systems

k) Recommended preventive maintenance procedures for all system components, including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions

D. Training Manuals: The Contractor shall provide a course outline and training manuals for all training classes at least six weeks prior to the first class. The Owner may modify any or all of the training course outline and training materials to meet the needs of the Owner. Review and approval by the Owner shall be completed at least three weeks prior to the first class.

E. Instructions for Development of Widgets

1. *The submittal package shall include a factory generated, written instruction manual defining the process of building additional widgets. The manual shall be sufficiently detailed that a qualified employee of the owner should be able to generate new widgets.*

1.7   WARRANTY

A. Warrant all work as follows:

1. *Labor and materials for the control system specified shall be warranted free from defects for a period of 12 months after final completion and acceptance. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. The Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.*

2. *All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up. If the work specified is split into multiple contracts or a multi-phase contract, then each contract or phase shall have a separate warranty start date and period*

3. *At the end of the final start-up, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the Owner, the Owner shall sign certificates certifying that the control system's operation has been tested and accepted in accordance with the terms of this specification. The date of acceptance shall be the start of warranty.*

4. *Operator workstation software, project-specific software, graphic software, database software, and firmware updates which resolve known software deficiencies as identified by the Contractor shall be provided at no charge during the warranty period. Any upgrades or functional enhancements associated with the above mentioned items also can be provided during the warranty period for an additional charge to the Owner by purchasing an in-warranty technical support agreement from the Contractor. Written authorization by the Owner must, however, be granted prior to the installation of any of the above-mentioned items.*
5. *Exception: The Contractor shall not be required to warrant reused devices, except for those that have been rebuilt and/or repaired. The Contractor shall warrant all installation labor and materials, however, and shall demonstrate that all reused devices are in operable condition at the time of Owner's acceptance.*

1.8   OWNERSHIP OF PROPRIETARY MATERIAL

A.   All project-developed software and documentation shall become the property of the Owner. These include, but are not limited to:

1. *Project graphic images*
2. *Record drawings*
3. *Project database*
4. *Project-specific application programming code*
5. *All documentation*

Part 2   Products

2.0   SECTION INCLUDES

A.   Materials

B.   Communication

C.   Operator Workstation and Dashboard Widgets

D.   Controller Software

E.   Building Controllers

F.   Advanced Application Controllers

G.   Application Specific Controllers

H.   Input/ Output Interface

I.   Power Supplies and Line Filtering

J.   Auxiliary Control Devices

K.   Room Control

L.   Wiring and Raceways

M.   Fiber Optic Cable System

2.1   MATERIALS

A.   All products used in this project installation shall be new, currently under manufacture, and shall be applied in similar installations for a minimum of two years. This installation shall not be used as a test site for any new products unless explicitly approved by the Owner's Representative in writing. Spare parts shall be available for at least five years after completion of this contract.

2.2   COMMUNICATION

A.   All control products provided for this project shall comprise a BACnet internetwork. Communication involving control components (i.e., all types of controllers and Operator Workstations) shall conform to ANSI/ASHRAE Standard 135-2016, BACnet.

B.   Each BACnet device shall operate on the BACnet Data Link/Physical layer protocol specified for that device as defined in this section.

C.   The Contractor shall provide all communication media, connectors, repeaters, bridges, hubs, switches, and routers necessary for the internetwork.

D.   All controllers shall have a communication port for connections with the Operator Workstations using the BACnet Data Link/ Physical layer protocol.

E.   Communication services over the internetwork shall result in operator interface and value passing that is transparent to the internetwork architecture as follows:

1. *Connection of an Operator Workstation device to any one controller on the internetwork will allow the operator to interface with all other controllers as if that interface were directly connected to the other controllers. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any one controller on the internetwork.*
2. *All database values (e.g., objects, software variables, custom program variables) of any one controller shall be readable by any other controller on the internetwork. This value passing shall be automatically performed by a controller when a reference to an object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform internetwork value passing.*

F.   The time clocks in all applicable controllers shall be automatically synchronized daily. An operator change to the time clock in any controller shall be automatically broadcast to all controllers on the network.

G.   The network shall have the following minimum capacity for future expansion:

1. *Each Building Controller shall have routing capacity for 99 controllers.*
2. *The Building Controller network shall have capacity for 1000 Building Controllers.*
3. *The system shall have an overall capacity for 12,500 Building Controller, Advanced Application Controller, and Application Specific Controller input/output objects.*

H.   Secure Connections

1. *Communication links between buildings or sites over non-secure, untrusted networks (including the internet) shall utilize the BACnet Secure Connect protocol as detailed in ASHRAE 135 Addendum 2016bj.*

2. *Provide a BACnet Secure Connect Node at each building as shown on the plans. Provide a BACnet/SC Hub for the network. Communication between the nodes and the Hub must be encrypted. Hubs and Nodes must be authorized to join the Secure Connect network by the system operator.*
3. *Provide the software tools to support Authentication Certificates for all controllers communicating on the BACnet/SC network.*
4. *Communication between sites shall not require the use of BACnet Broadcast Management Devices (BBMD) with static IP addresses.*
5. *The BACnet/SC hub shall use a DNS name i.e. hostname + domain name and not require a static IP address. The nodes shall support DHCP and shall not require dedicated IP addresses.*

2.3   OPERATOR WORKSTATION

A.   Operator Workstation. Existing servers and workstations shall be utilized and remain active on the system. Each of these workstations and or servers shall be able to access all information in the system. These workstations shall reside on the same Ethernet protocol network as the Building Controllers.

B.   Workstation information access shall use the BACnet protocol. Communication shall use the ISO 8802-3 (Ethernet) Data Link/ Physical layer protocol.

Data Sharing	Alarm & Event	Scheduling	Trending	Device Mgmt.	Network Mgmt
DS-RP-A,B	AE-N-A	SCHED-A	T-V-A	DM-DDB-A,B	NM-CE-A
DS-RPM-A,B	AE-N-I-B	SCHED-I-B	T-VMT-A	DM-DOB-A,B	NM-CEB
DS-WP-A,B	AE-N-E-B	SCHED-E-B	T-VMT-I-B	DM-DCC-A,B	
DS-WPM-A,B	AE-ACK-A,B	SCH-VM-A	T-VMT-E-B	DM-PT-A,B	
DS-COV-A,B	AE-ASUM-A,B	SCH-AVM-A	T-ATR-A	DM-TM-B	
DS-COVU-A,B	AE-ESUM-A,B	SCH-WS-A	T-ATR-B	DM-TS-A	

Data Sharing	Alarm & Event	Scheduling	Trending	Device Mgmt.	Network Mgmt
DS-V-A	AE-INFO-A,B	SCH-WS-I-B	T-A-A	DM-ATS-A	
DS-AV-A	AE-VN-A			DM-MTS-A	
DS-M-A	AE-AVN-A			DM-UTC-A,B	
DS-AM-A	AE-VM-A			DM-RD-A	
	AE-AVM-A			DM-BR-A	
	AE-AS-A			DM-LM-A,B	
				DM-OCD-A,B	
				DM-ANM-A	
				DM-ADM-A	

C. System Software

1. *Operating System. Furnish a concurrent multi-tasking operating system. The operating system also shall support the use of other common software applications that operate under Microsoft Windows. Examples include Microsoft Excel, Microsoft Word, and Microsoft Access. Acceptable operating systems are Windows 10 Professional Enterprise and Windows 2019 Server.*

2. *System Graphics. The operator workstation software shall be a graphical user interface (GUI). The system shall allow display of up to 10 dynamic and animated graphic screens at once for comparison and monitoring of system status. Provide a method for the operator to easily move between graphic displays and change the size and location of graphic displays on the screen. The system graphics shall be able to be modified while on-line. An operator with the proper password level shall be able to add, delete, or change dynamic objects on a graphic. Dynamic objects shall include analog and binary values, dynamic text, static text, and animation files. Graphics shall have the ability to show animation by shifting image files based on the status of the object.*

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. The graphics generation package also shall provide the capability of capturing or converting graphics from other programs such as Visio or AutoCAD*

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. Graphics shall be created by drag-and-drop selection of graphic symbols and drag-and-link with BACnet objects with dynamic and interactive display fields.*

5. *Multilingual. Software shall be supported in the following languages English, Spanish, French, German, and Chinese.*

6. *Web Services. Furnish a web services portal to support BACnet Web Services as per ASHRAE BACnet/WS 135-2012am. Provide for data connections to mobile applications and third party business solutions.*

D. System Applications. Each workstation shall provide operator interface and off line storage of system information. Provide the following applications at each workstation:

1. *System Database Save and Restore. Each workstation shall store on the hard disk a copy of the current database of each Building Controller. This database shall be updated whenever an operator initiates a save command.*

2. *Database Save and Restore. A system operator with the proper password clearance shall be able to save the database from any system panel. The operator shall be able to clear a panel database via the network and may initiate a download of a specified database to any panel in the system from the network. Panel database saving shall be automatic based upon an operator defined schedule.*

3. *System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password protection.*

4. *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.*

5. *Security. Each operator shall be required to log on to the system with a user name and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system supervisor shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the functions accessible to viewing and/or changing each system application. System shall support LDAP to allow central control over user security status, restriction and/ or deletion of users.*

6. *System Diagnostics. The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers.*

7. *Alarm Processing. Any object in the system shall be configurable to alarm in and out of normal state. The operator shall be able to configure the alarm limits, alarm limit differentials, states, and reactions for each object in the system.*

8. *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 upon acronyms or other mnemonics.*

9. *Alarm Reactions. The operator shall be able to determine (by object) what if any actions are to be taken during an alarm. Actions shall include logging, printing, starting programs, displaying messages, dialing out to remote stations, paging, providing audible annunciation.*

10. *Trend Logs. The operator shall be able to define a custom trend log for any data object in the system. This definition shall include change-of-value digital, change-of-value analog, time interval, start time, and stop time. Trend data shall be sampled and stored on the Building Controller panel, and be archivable on a central data archiving machine(s). Provide a standard SQL connector to make the trend log data accessible for use in spreadsheets and standard database programs.*

11. *Alarm and Event Log. The operator shall be able to view all system alarms and change of states from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and clear alarms.*
12. *Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object and property in the system. The status shall be available by menu, on graphics, or through custom programs.*
13. *Clock Synchronization. The real-time clocks in all building control panels and workstations shall be using the BACnet Time Synchronization service. The system also shall be able to automatically synchronize all system clocks daily from any operator-designated device in the system. The system shall automatically adjust for daylight savings and standard time, if applicable.*
14. *Timeline Analysis. Provide a graphical timeline tool that will display system events in chronological order. It shall be possible for the operator to display who logged into the system and when they logged in or out. These shall also allow the operator to add any other system event (like a temperature alarm) to the same timeline to see the chronological order of events, alarms, commands and system edits. Track all programming changes including which operator made them and when.*

E. Workstation Applications Editors. Each PC workstation shall support editing of all system applications. Provide editors for each application at the PC workstation. The applications shall be downloaded and executed at one or more of the controller panels.

1. *Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and setpoints for all controllers.*
2. *Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and month. This shall consist of a monthly calendar for each schedule. Exception schedules and holidays shall be shown clearly on the calendar. Provide a method for allowing several related objects to follow a schedule. The start and stop times for each object shall be adjustable from this master schedule.*
3. *Custom Application Programming. Provide the tools to create, modify, and debug custom application programming. The operator shall be able to create, edit, and download custom programs at the same time that all other system applications are operating. The system shall be fully operable while custom routines are edited, compiled, and downloaded. The programming language shall have the following features:*

a) The language shall be English language oriented, be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and allow for free-form programming (i.e., not column-oriented or "fill in the blanks").

b) A full-screen character editor/programming environment shall be provided. The editor shall be cursor/mouse-driven and allow the user to insert, add, modify, and delete custom programming code. It also shall incorporate word processing features such as cut/paste and find/replace.

c) The programming language shall allow independently executing program modules to be developed. Each module shall be able to independently enable and disable other modules.

d) The editor/programming environment shall have a debugging/simulation capability that allows the user to step through the program and observe any intermediate values and/or results. The debugger also shall provide error messages for syntax and execution errors.

e) The programming language shall support conditional statements (IF/THEN/ELSE/ELSE-IF) using compound Boolean (AND, OR, and NOT) and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

f) The programming language shall support floating-point arithmetic using the following operators: +, -, /, x, square root, and x-to-the-y-power. The following mathematical functions also shall be provided: natural log, log, trigonometric functions (sine, cosine, etc.), absolute value, and minimum/maximum value from a list of values.

g) The programming language shall have predefined variables that represent time of day, day of the week, month of the year, and the date. Other predefined variables shall provide elapsed time in seconds, minutes, hours, and days. These elapsed time variables shall be able to be reset by the language so that interval-timing functions can be stopped and started within a program. Values from all of the above variables shall be readable by the language so that they can be used in a program for such purposes as IF/THEN comparisons, calculations, etc.

h) The language shall be able to read the values of the variables and use them in programming statement logic, comparisons, and calculations.

i) The programs shall support online changes with the ability to read real time values without exiting the program. Sample programs and syntax help functions shall be resident in the program.

    F.   Widgets

1. *Furnish ten graphical user interface screen widgets for use in the dashboard with the following content:*

a) Energy consumption comparison pie-chart (in color) showing total energy in MMBTU by building.

b) Energy consumption comparison pie-chart (in color) showing total energy in BTU by meter.

c) Multitrend template for comparing up to 5 trend points on the same graph

d) Load profile line chart showing the current month's electrical demand in kW versus the same month last year.

e) Map showing the physical location of each building in the system along with a pop-up of the number of current alarms at each building.

f) A dynamic point schedule for each mechanical system that shows all input and output points in a table format. Changes in object names made by the system operator (like "DAT" changing to "Supply Air Temperature") must be automatically updated in the point list without operator entries.

g) An alarm summary view that includes all alarms from priority one thru eight.

h) Energy alerts for all major mechanical equipment including, chillers, boilers, towers, AHU's over 15,000 CFM or RTU's over 15,000 CFM.

2. *In addition to the above, software must include a custom widget development component that can be used by the owner to develop additional widgets without purchase of additional software.*

2.4   CONTROLLER SOFTWARE

A.   Furnish the following applications software for building and energy management. All software applications shall reside and operate in the system controllers. Editing of applications shall occur at the operator workstation

B.   System Security

1. *User access shall be secured using individual security passwords and user names.*

2. *Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.*

3. *User Log On/Log Off attempts shall be recorded.*

C.   Scheduling. Provide the capability to schedule each object or group of objects in the system. Each schedule shall consist of the following:

1. *Provide an event scheduling system that allows the operator to specify a single event, multiple day event and/or recurring events. The event schedule specifies both the on/off times and the date in a calendar planning format similar to Microsoft Outlook®.*

2. *Calendar Schedules. Provide the capability for the operator to define up to 99 special schedules. These schedules may be placed on the scheduling calendar and will be repeated each year. The operator shall be able to define the length of each holiday period.*

D. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the appropriate workstations based on time and other conditions.

E. Remote Communication. The system shall have the ability to communicate out of the system top the internet in the event of an alarm using BACnet Point-To-Point attributes. Messaging capability shall include both text messaging and email service.

F. Maintenance Management. The system shall monitor equipment status and generate maintenance messages based upon user-designated run-time, starts, and/or calendar date limits.

G. Sequencing. Provide application software to properly sequence the start and stop of chillers, boilers, and pumps to minimize energy usage in the facility.

H. PID Control. A PID (proportional-integral-derivative) algorithm with direct or reverse action and anti-windup shall be supplied. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, setpoint, and PID gains shall be user-selectable.

I. Staggered Start. This application shall prevent all controlled equipment from simultaneously restarting after a power outage.

J. Energy Calculations. Provide software to allow instantaneous power (e.g., kW) or flow rates (e.g., L/s [GPM]) to be accumulated and converted to energy usage data. Provide an algorithm that calculates a sliding-window kW demand value.

K. Anti-Short Cycling. All binary output objects shall be protected from short cycling. This feature shall allow minimum on-time and off-time to be selected.

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

M. Run-time Totalization. Provide software to totalize run-times for all binary input objects. A high run-time alarm shall be assigned, if required, by the operator.

2.5 BUILDING CONTROLLERS

A. General. Provide an adequate number of BACnet® Building Controllers to achieve the performance specified in the Part 1 Article on "System Performance." Each of these panels shall meet the following requirements. Additionally, provide Building Controllers where shown on the drawings.

1. *The Energy Management and Control System shall be comprised of one or more independent, standalone, microprocessor-based Building Controllers to manage the global strategies described in the System Software section.*
2. *The Building Controller shall have sufficient memory to support its operating system, database, and programming requirements.*
3. *Data shall be shared between networked Building Controllers.*
4. *The operating system of the Building Controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information, and allow central monitoring and alarms.*
5. *Controllers that perform scheduling shall have a battery or super-cap backed up real-time clock.*
6. *The Building Controller shall support the following BACnet Interoperability Building Blocks (BIBBs):*

Data Sharing	Alarm & Event	Scheduling	Trending	Device & Network Mgmt.
DS-RP-A,B	AE-N-A	SCH-I-B	T-VM-I-B	DM-DDB-A,B
DS-RPM-A,B	AE-N-I-B	SCH-E-B	T-VM-E-B	DM-DOB-A,B
DS-WP-A,B	AE-N-E-B		T-ATR-B	DM-DCC-B
DS-WPM-B	AE-ACK-B			DM-TS-A,B
DS-COVU-A,B	AE-ASUM-B			DM-UTC-A,B
	AE-ESUM-B			DM-ATS-A
				DM-RD-B
	AE-INFO-B			DM-BR-B
				DM-R-B
				DM-OCD-B
				NM-CE-A

B.   Communication

1. *Each Building Controller shall support a direct Ethernet connection. The Building Controller shall be connected to the BACnet network using the ISO 8802-3 (Ethernet) Data Link/ Physical layer protocol, or BACnet IP (Annex J).*
2. *Each Building Controller shall perform BACnet routing if connected to a network of Custom Application and Application Specific Controllers.*
3. *The controller shall provide a service communication port using BACnet Data Link/ Physical layer protocol P-T-P for connection to a hand-held workstation/ and/or modem.*
4. *The Building Controller secondary communication network shall support BACnet MS/TP.*

C.   Environment. Controller 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 0°C to 40°C [32°F to 100°F] and 10 to 90% RH.*
2. *Controllers used in conditioned space shall be mounted in dust proof enclosures, and shall be rated for operation at 0°C to 50°C [32°F to 120°F].*

D.   Building Controllers shall be fully peer to peer.

E.   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.

F.   Memory. The Building Controller shall have as a minimum standard SRAM of 256 KB, standard DRAM of 1MB and standard non-volatile 1 MB of flash memory in lieu of EPROM.

G.   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% nominal voltage. The Building Controller shall maintain all database information including BIOS and programming information in the event of a power loss for at least 72 hours. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m [3 ft].

H.   Inputs/Outputs.

1. *Inputs. Controller input/output board shall support dry contact, 0-5 VDC and 0-10 VDC- voltage, 4-20 mA- current and thermistor-resistive signal types on an individual basis for connecting any status or sensing device. Analog resolution shall be minimum 16-bit A to D.*
2. *Outputs. Controller input/output board shall support plug-and-play I/O modules or built in HAO modules configured with manual-auto-off override switch, potentiometer and input channel for feedback status or an unrelated analog or digital input. Output supported shall be 0-10 VDC. All HAO's shall be supervised.*
3. *Diagnostics. Controller input board shall have variable intensity LEDs providing input status indication. Outputs shall have variable intensity LEDs indicating the output voltage with Color indication of HAO's status when present.*
4. *Bump-less Transfer. On analog outputs with override switches, provide a Hand-Auto-Off switch either built-in or external to the board that allows for manual positioning of the output, then transferring the output to automatic without any "bump" in the output voltage (don't go through off before transferring from manual to auto).*

2.6   ADVANCED APPLICATION CONTROLLERS

A.   General. Provide an adequate number of BACnet® Advanced Application Controllers to achieve the performance specified in the Part 1 Article on "System Performance." Each of these panels shall meet the following requirements.

1. *The Advanced Application Controller shall have sufficient memory to support its operating system, database, and programming requirements.*
2. *Advanced Application Controllers shall be fully peer to peer.*
3. *The operating system of the Controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms.*
4. *All equipment that requires scheduling shall be scheduled in that equipment's controller.*
5. *Both firmware and controller database shall be loadable over the network.*
6. *Advanced Application Controllers shall support the following BACnet Interoperability Building Blocks (BIBBs):*

Data Sharing	Alarm & Event	Scheduling	Trending	Device & Network Mgmt.
DS-RP-A,B	AE-N-I-B	SCH-I-B	T-VM-I-B	DM-DDB-A,B
DS-RPM-B	AE-N-E-B	SCH-E-B	T-VM-E-B	DM-DOB-A,B
DS-WP-A,B	AE-ACK-B		T-ATR-B	DM-DCC-B
DS-WPM-B	AE-ASUM-B			DM-TS-B
DS-COV-A,B	AE-ESUM-B			DM-RD-B
	AE-INFO-B			DM-BR-B

Data Sharing	Alarm & Event	Scheduling	Trending	Device & Network Mgmt.
				DM-R-B
				DM-OCD-B

B.   Communication

1. *Each Advanced Application Controller shall reside on a BACnet network using the MS/TP or Ethernet Data Link/ Physical layer protocol.*
2. *The controller shall provide a service communication port using BACnet Data Link/ Physical layer protocol for connection to portable operator's workstation and allow access to the entire network.*

C.   Environment. Controller 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 0°C to 40°C [32°F to 100°F].*
2. *Controllers used in conditioned space shall be mounted in dust proof enclosures and shall be rated for operation at 0°C to 50°C [32°F to 120°F].*

D.   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.

E.   Memory. The Advanced Application Controller shall utilize non-volatile FLASH memory to maintain its operating system and backup all operator entered changes to setpoints, schedules, and commands.

F.   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% nominal voltage. Operation shall be protected against electrical noise of 5 to120 Hz and from keyed radios up to 5 W at 1 m [3 ft].

2.7   APPLICATION SPECIFIC CONTROLLERS

A.   General. Provide BACnet® Application Specific Controllers (ASCs) as required to execute the sequence of operations. ASC's are microprocessor-based DDC controllers which through hardware or firmware design are able to control a wide variety of equipment. They shall be fully user-configurable.

1. *Each ASC shall be capable of standalone 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.*
3. *Both firmware and controller database shall be loadable over the network*
4. *ASC's shall come with an integrated housing to allow for easy mounting and protection of the circuit board. Only wiring terminals shall be exposed.*

5. *Application Specific Controllers shall support the following BACnet Interoperability Building Blocks (BIBBs):*

Data Sharing	Alarm & Event	Scheduling	Trending	Device & Network Mgmt.
DS-RP-B				DM-DDB-B
DS-RPM-B				DM-DOB-B
DS-WP-B				DM-DCC-B
DS-COV-B				DM-TS-B
				DM-RD-B

B.   Communication

1. *The controller shall reside on a BACnet network using the MS/TP or Ethernet Data Link/ Physical layer protocol.*
2. *Each controller shall have a BACnet Data Link/ Physical layer compatible connection for a laptop computer or a portable operator's tool. This connection shall be extended to a space temperature sensor port where shown and allow access to the entire network.*

C.   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°C to 65°C [40°F to 150°F] and/or suitably installed in a heated or fan cooled enclosure*
2. *Controllers used in conditioned space shall be mounted in dust proof enclosures, and shall be rated for operation at 0°C to 50°C [32°F to 120°F].*

D.   Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips.

E.   Memory. The Application Specific Controller shall use non-volatile memory and maintain all BIOS and programming information in the event of a power loss.

F.   Immunity to power and noise. ASC shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%. Operation shall be protected against electrical noise of 5-120 Hz and from keyed radios up to 5 W at 1 m [3 ft].

G.   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.

H.   Input/Output. ASC shall support as a minimum, directly connected, a combination of analog outputs and binary outputs and universal software selectable analog or digital inputs. ASC inputs shall support 0-5 VDC-voltage, 4-20mA-current, thermistor-resistance and dry contacts. ASC outputs shall support 0-10 VDC-voltage, digital triac rated at 0.5 amps at 24 VAC

2.8   AUXILIARY CONTROL DEVICES

A. Motorized control dampers, unless otherwise specified elsewhere, shall be furnished by the controls contractor.

B. Electric damper/valve actuators.

1. *The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator.*

2. *Where shown, for power-failure/safety applications, an internal mechanical, spring-return mechanism shall be built into the actuator housing.*

3. *All non-spring-return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring-return actuators with more than 7 N•m [60 in-lb] torque capacity shall have a manual crank for this purpose.*

C. Control valves.

1. *Control valves shall be two-way or three-way type for two-position or modulating service as shown.*

2. *Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:*

   a) Water Valves:

      i *Two-way: 150% of total system (pump) head.*

      ii *Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.*

   b) Steam Valves: 150% of operating (inlet) pressure.

   c) Water Valves:

      i *Body and trim style and materials shall be per manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.*

   d) Steam Valves:

      i *Body and trim materials shall be per manufacturer's recommendations for design conditions and service. Linear ports for modulating service.*

D. Binary Temperature Devices

1. *Low-limit thermostats. Low-limit thermostats shall be vapor pressure type with an element 6 m [20 ft] minimum length. Element shall respond to the lowest temperature sensed by any 30 cm [1 ft] section. The low-limit thermostat shall be manual reset only and be supplied as DPST.*

E. Temperature sensors.

1. *Temperature sensors shall be thermistors.*

2. *Space sensors shall be equipped with the following:*

   a) Programmable buttons for setpoint adjustment and override
   b) 3-value, 96-segment LCD display
   c) Communication port connected to entire network

3. *Temperature sensors shall be 16 bit A/D.*

   F.   Humidity sensors.

1. *Duct and room sensors shall have a sensing range of 20% to 80%.*
2. *Duct sensors shall be provided with a sampling chamber.*
3. *Outdoor air humidity sensors shall have a sensing range of 20% to 95% RH. They shall be suitable for ambient conditions of -40°C to 75°C [-40°F to 170°F].*
4. *Humidity sensor's drift shall not exceed 3% of full scale per year.*

   G.   Flow switches.

1. *Flow-proving switches shall be either paddle or differential pressure type, as shown.*

   H.   Pressure transducers

1. *Transducer shall have linear output signal. Zero and span shall be field adjustable.*
2. *Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage*
3. *Water pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Transducer shall be complete with 1 - 5vdc or 4 to 20 mA output, required mounting brackets, and block and bleed valves.*
4. *Water differential pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall be complete with 1 – 5vdc or 4 to 20 mA output, required mounting brackets, and five-valve manifold.*

   I.   Differential pressure type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 enclosure, with scale range and differential suitable for intended application, or as shown.

   J.   Local control panels

1. *All indoor control cabinets shall be fully enclosed NEMA 1 construction with [hinged door], key-lock latch, removable sub-panels. A single key shall be common to all field panels and sub-panels*
2. *Interconnections between internal and face-mounted devices pre-wired with color coded stranded conductors neatly installed in plastic troughs and/or tie wrapped. Control terminations for field connection shall be individually identified per control drawings*

3. *Provide 120v receptacle at each local panel location.*

2.9 ROOM CONTROL

A. General: Provide BTL Listed, Advanced Application Controllers dedicated to interfacing to and controlling all the subsystems within designated rooms (as shown on the plans).

B. Room controller shall monitor, at a minimum, the room temperature, relative humidity, lighting illuminance in LUX, lighting color rendition (light temperature in degrees Kelvin), motion detection and noise level.

C. If indicated on the point list, Room Controller shall interface with the window shade system via SMI (Standard Motor Interface).

D. If indicated on the point list, Room Controller shall include an Infra-Red control interface to the in-room audio-visual equipment.

E. Room controller shall interface with the room's HVAC equipment to provide temperature and humidity control of the space. The occupied/unoccupied status of the room will be determined by the controller based upon passive infrared sensor(s), and noise level.

2.10 WIRING AND RACEWAYS

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

B. All insulated wire to be copper conductors, UL labeled for 90C minimum service.

Part 3 Execution

3.0 SECTION INCLUDES

A.   Examination

B.   Protection

C.   Coordination

D.   General Workmanship

E.   Field Quality Control

F.   Existing Equipment

G.   Wiring

H.   Actuators

I.   Identification of Hardware and Wiring

J.   Controllers

K.   Programming

L.   Control System Checkout and Testing

M.   Control System Demonstration and Acceptance

N.   Cleaning

O.   Training

P.   Sequences of Operation

3.1 EXAMINATION

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

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

3.2 PROTECTION

A.   The Contractor shall protect all work and material from damage by its work or employees, and shall be liable for all damage thus caused

B.   The Contractor shall be responsible for its 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 its 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 its work to correct the condition without extra charge*
2. *Coordinate and schedule work with all other work in the same area, or with work, which is dependent upon other work, to facilitate mutual progress.*

B.   Submittals. Refer to the "Submittals" Article in Part 1 of this specification for requirements

C.   Test and Balance
1. *The Contractor shall furnish 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*

D.   Life Safety
1. *Duct smoke detectors required for air handler shutdown are supplied and installed under Division 26. The Division 26 Contractor shall interlock smoke detectors to air handlers for shutdown as described in Part 3: "Sequences of Operation".*
2. *Smoke dampers and actuators required for duct smoke isolation are provided under another Division 23 Section*
3. *Fire/smoke dampers and actuators required for fire rated walls are provided under another Division 25 Section. Control of these dampers shall be by Division 28.*

E.   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 Part 2: "Communication" of this specification.*
2. *Each supplier of controls product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequences of operation described in this section.*
3. *The Contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this Section and those provided under other sections or divisions of this specification.*

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

D.   All wiring shall be verified for its integrity to ensure continuity and freedom from shorts and grounds

E.   All equipment, installation, and wiring shall comply with acceptable 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 the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this specification

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

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

3.6   EXISTING EQUIPMENT

A.   Wiring: The contractor may reuse any abandoned wires. The integrity of the wire and its proper application to the installation is the responsibility of the Contractor. The wire shall be properly identified and tested as per this specification. Unused or redundant wiring must be properly identified as such.

B.   Local Control Panels: The Contractor may re-use any existing local control panel to locate new equipment. All redundant equipment within these panels must be removed. Panel face cover must be patched to fill all holes caused by removal of unused equipment, or replaced with new.

C.   Unless otherwise directed, the Contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the Contractor find existing equipment which requires maintenance, the Owner is to be notified immediately

D.   Temperature Sensor Wells: The Contractor may reuse any existing wells in piping for temperature sensors. These wells shall be modified as required for proper fit of new sensors

E.   Indicator Gauges: Where these devices remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy. Maintain the operation of existing pneumatic transmitters and gauges.

F.   Room Thermostats: Deliver to Owner.

G.   Electronic Sensors and Transmitters: Unless specifically noted otherwise, remove and deliver to the Owner.

H.   Controllers and Auxiliary Electronic Devices: Deliver to the Owner.

I.   Pneumatic Controllers, Relays and Gauges: Deliver to Owner.

J.   Damper Actuators, Linkages and Appurtenances: Deliver to Owner.

K.   Control Valves: Replace with new.

L.   The mechanical system must remain in operation between the hours of 7 a.m. and 6 p.m., Monday through Friday. No modifications to the system shall cause the mechanical system to be shut down for more than 15 minutes or to fail to maintain space comfort condition during any such period. Perform cutover of controls that cannot meet these conditions outside of those hours

M.   The scheduling of fans through existing or temporary time-clocks or control system shall be maintained throughout the DDC system installation.

N.   Install control panels where shown

O.   Modify existing starter control circuits, if necessary, to provide Hand/Off/Auto control of each starter controlled.

P.   Patch holes and finish to match existing

3.7   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 with those in 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 per NEC and Division 26 requirement.

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

3.8   ACTUATORS

A.   Mount and link control damper actuators per 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° available for tightening the damper seals. 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.*

3.9   IDENTIFICATION OF HARDWARE AND WIRING

A.   All wiring and cabling, including that within factory fabricated panels, shall be labeled at each end within 5 cm [2"] of termination with the DDC address or termination number.

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

C.   Identify control panels with minimum 1 cm [½"] letters on laminated plastic nameplates.

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

E.   Identify room sensors relating to terminal box or valves with nameplates.

3.10   CONTROLLERS

A.   Provide a separate controller for each AHU or other HVAC system.

B.   Building Controllers and Advanced Application Controllers shall be selected to provide a minimum of 15% spare I/O point/object capacity for each point/object type found at each location. If input /objects are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point/object used.

1. *Future use of spare capacity shall require providing the field device, field wiring, point/object database definition, and custom software. No additional controller boards or point/object modules shall be required to implement use of these spare points*

3.11   PROGRAMMING

A.   Provide sufficient internal memory for the specified sequences of operation and trend logging. There shall be a minimum of 25% of available memory free for future use.

B.   Point/object Naming: System point/object names shall be modular in design, allowing easy operator interface without the use of a written point/object index. Object names shall be case-sensitive and clearly spell out the function of each object. Submit naming scheme to owner for prior approval. Do not use cryptic abbreviations. Valid examples are:

1. *AHU-1 Supply Air Temperature*
2. *CH-1 Chilled Water Supply Temperature*
3. *FC-1 Room Temperature*
4. *VAV-103 Room Temperature Trend*

C.   Software Programming

1. *Provide programming for the system and adhere to the sequences of operation provided. The Contractor also shall provide all other system programming necessary for the operation of the system, but not specified in this document. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:*

a) Text-based:

    i   *must provide actions for all possible situations*
    ii   *must be modular and structured*
    iii *must be commented*

b) Graphic-based

    i   *must provide actions for all possible situations*
    ii   *must be documented*

c) Parameter-based

    i   *must provide actions for all possible situations*
    ii   *must be documented*

D.   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/object information on the graphic displays shall dynamically update. Show on each graphic all input and output points/objects for the system. Also show relevant calculated points/objects such as setpoints*
2. *Show terminal equipment information on a "graphic" summary table. Provide dynamic information for each point/object*
3. *The Contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all Operator Workstation software and their functions as described in this section. This includes any operating system software, the Operator Workstation database, and any third-party software installation and integration required for successful operation of the operator interface*

3.12 CONTROL SYSTEM CHECKOUT AND TESTING

A. Start-up 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 per 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 and optimum Start/Stop routines.*
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

3.13 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 its 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, startup, 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/object 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 Workstation*

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 setpoint, 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 setpoint, 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 setpoint, and the status of shed-able equipment outputs.

c) Optimum Start. The Contractor shall supply a trend data output showing the capability of the algorithm. The hour by hour 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 setpoints, 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.

f) 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."*

3.14 CLEANING

A.	The Contractor shall clean up all debris resulting from its activities daily. The Contractor shall remove all cartons, containers, crates, etc., under its 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 of its 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.

3.15 TRAINING

A.	General
1.	*Provide a minimum of one onsite training class 8 hours in length during the construction period for personnel designated by the owner.*
2.	*Provide two additional training sessions at 6 and 12 months following building's turnover. Each session shall be 8 hrs in length and must be coordinated with the building Owner.*

B.	Train the designated staff of Owner's Representative and Owner to enable Day-to-day Operators to:
1.	*Proficiently operate the system.*
2.	*Understand control system architecture and configuration.*
3.	*Understand DDC system components.*
4.	*Understand system operation, including DDC system control and optimizing routines (algorithms).*
5.	*Operate the workstation and peripherals.*
6.	*Log on and off the system.*
7.	*Access graphics, point/object reports, and logs.*
8.	*Adjust and change system setpoints, time schedules, and holiday schedules.*
9.	*Recognize malfunctions of the system by observation of the printed copy and graphical visual signals.*
10.	*Understand system drawings, and Operation and Maintenance manual.*
11.	*Understand the job layout and location of control components.*
12.	*Access data from DDC controllers and Application Specific Controllers (ASC's).*
13.	*Operate portable operator's terminals.*

C. Train the designated staff of Owner's Representative and Owner to enable Advanced Operators to:

1. *Make and change graphics on the workstation*
2. *Create, delete, and modify alarms, including annunciation and routing of these*
3. *Create, delete, and modify point/object trend logs, and graph or print these*
4. *Create, delete, and modify reports*
5. *Add, remove, and modify system's physical points/objects*
6. *Create, modify, and delete programming*
7. *Add panels when required*
8. *Add Operator Workstation stations*
9. *Create, delete, and modify system displays — both graphical and otherwise*
10. *Perform DDC system field checkout procedures*
11. *Perform DDC controller unit operation and maintenance procedures*
12. *Perform workstation and peripheral operation and maintenance procedures*
13. *Perform DDC system diagnostic procedures*
14. *Configure hardware including PC boards, switches, communication, and I/O points/objects*
15. *Maintain, calibrate, troubleshoot, diagnose, and repair hardware*
16. *Adjust, calibrate, and replace system components*

D. Train the designated staff of Owner's Representative and Owner to enable System Managers/Administrators to:

1. *Maintain software and prepare backups*
2. *Interface with job-specific, third-party operator software*
3. *Add new users and understand password security procedures*

E. Provide course outline and materials as per "Submittals" Article in Part 1 of this specification. The instructor(s) shall provide one copy of training material per student.

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

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

3.16 SEQUENCES OF OPERATION