SECTION 15975 - CONTROL SYSTEM EQUIPMENT

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. The Building Automation System (BAS) manufacturer shall furnish and install a fully integrated building automation system, incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified. All systems in this project will be controlled through the DDC system, no exceptions. Provide open communications system. System shall be capable of utilizing standard protocols as follows as well as be able to integrate third-party systems via existing vendor protocols. System shall be native BACnet communication according to ASHRAE standard SPC-135A/95.

B. The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation or identification number and sequence of operation all bearing the name of the manufacturer. The installing manufacturer shall certify in writing, that the shop drawings have been prepared by the equipment manufacturer and that the equipment manufacturer has supervised their installation. In addition, the equipment manufacturer shall certify, in writing, that the shop drawings were prepared by their company and that all temperature control equipment was installed under their direct supervision.

C. All materials and equipment used shall be standard components, regularly manufactured for this and/or other systems and not custom designed specially for this project. All systems and components shall have been thoroughly tested and proven in actual use for at least three years.

D. BAS manufacturer shall be responsible for all BAS and Temperature Control wiring for a complete and operable system. All wiring shall be done in accordance with all local and national codes.

E. The DDC system shall possess a fully modular architecture, permitting expansion in the future through additional DDC panels, sensors, actuators, and/or operator terminals.

F. The DDC system shall monitor and control the equipment with respect to the indicated "Sequences of Operation" and Points List. Provide sufficient number of input/output units as determined by specific applications.

G. Provide all hardware and software necessary for a complete and operable system specified herein. This includes all relays, sensors, power supplies, etc. required to perform the sequences intended.

H. The Owner shall enlist the service of a Commissioning Agent and a Testing, Adjusting, and Balancing Agency under separate contracts. The Control Contractor shall coordinate

with all contractors including, but not limited to, the Commissioning Agent and Testing, Adjusting, and Balancing Agency.

1.02 WORK BY OTHERS

A. Mechanical Contractor shall provide:

1. Install automatic valves and separable wells that are specified to be supplied by the DDC contractor.
2. Furnish and install all necessary valved pressure taps water, drain, and overflow connections, and piping.
3. Provide, on magnetic starters furnished, all necessary auxiliary contacts, with buttons and switches in the required configuration.
4. Install all automatic dampers.
5. Assemble multiple section dampers with required inter-connecting linkages and extend required number of shafts through duct for external mounting of damper motors.
6. Provide access doors or other approved means of access through ducts for service to equipment.

B. General Contractor shall:

1. Provide all necessary cutting, patching and painting.
2. Provide access doors or other approved means of access through ceilings and walls for service to control equipment.

C. Electrical Contractor shall provide:

1. 120V power to all BAS and/or temperature control panels
2. Wiring of all power feeds through all disconnect starters to electrical motor.
3. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by BAS manufacturer
4. Wiring of any electrical sub-metering devices furnished by **BAS** manufacturer.

D. Products installed but not furnished under this section

1. Division 16 Section "Fire Alarm Systems"
   a. Duct Mounted Smoke Detectors

2. Division 15 Section "Hydronic Piping"

   a. Flow Switches.
   b. Temperature Sensor Wells and Sockets.

3. Division **15** Section "Duct Accessories"

   a. Automatic Control Dampers.
   b. Terminal Unit Controls.

4. Division 15 Section "Valves"

a. Control Valves.

5. Division 15 Section "Meters and Gages"

a. Airflow measuring stations.
b. Hydronic flow meters.

E. Products integrated to but not furnished or installed under this section

1. Division 16 Section "Fire Alarm Systems"

a. Fire Alarm System Trouble.
b. Fire Alarm System Alarm.

2. Division 15 Section "Geothermal Heat Pumps"

a. Geothermal heat pump control.

3. Division 15 Section "Rooftop Air Handling Units"

a. Temperature Control.
b. Volume Control.

4. Division 15 Section "Cabinet Unit Heaters"

a. Fan Speed Control.
b. Thermostats.

5. Division 15 Section "Air Terminals''

a. Terminal Air Unit Controls

6. Division 15 Section "Meters and Gages."

a. Airflow Measuring Stations
b. Water Flow Meters

1.03 RELATED **WORK**

A. Division 01000 General and Special Conditions

B. Division 15000 Mechanical

C. Division 16000 Electrical

1.04 SUBMITTALS

A. DDC Software Manuals: The software manual shall describe programming and testing, starting with a system overview and proceeding to a detailed description of each software feature. The manual shall instruct the user on programming or reprogramming an portion of the DDC system. This shall include control programs, algorithms, mathematical equations, variables, setpoints, time periods, messages, and other information necessary to load, later, test and execute the system.

1. Complete descriptions of programming language, including commands, editing and writing control programs, algorithms, printouts and logs, mathematical calculations and passwords.
2. Instructions on modifying a control algorithm or initiating or disabling control programs.
3. Software Documentation: **All** software programs shall be easily referenced from summary sheets which compare control programs with pertinent information about hardware and wiring information in the field. Documentation shall include:

   a. Complete point identification, including terminal number, symbol, engineering units, and control program reference number.
   b. Field information including location, device, device type and function, electrical parameters, and installation drawing number.
   c. Location identification of DDC system control hardware.

4. Control Software: Upon successful completion of the operational acceptance test, provide a medium and hardware for full storage of the accepted versions.
5. DDC System Summary Forms: Provide data summary forms to be approved by the Owner to define the following information inclusion into the DDC for each point in the system by the Contractor:

   a. Description of each piece of equipment and the function to be controlled.
   b. For each DDC function, a listing of digital and/or analog hardware required to interface the DDC system to the equipment.
   c. Listing of all digital and analog alarms.
   d. Listing of all DDC application programs associated with each piece of equipment. This listing shall include all control algorithms and mathematical equations. The listing shall be in easy-to-understand English format.
   e. Listing of all hardware point and "pseudo" point English descriptor names.
   f. Listing of "failure" mode of all control points and devices.
   g. Preparation or loading of control software will not commence until all submittals, including sequences, point nomenclature, drawings, material lists, control sequence, and other details have been approved by the Owner.

6. DDC Point List: List of each control input and output; the device it is controlling; the location of the device; and the symbol or label of the control point in the software.
7. DDC Temperature Control Drawings: This Contractor shall submit the following drawing for approval by the Engineer and Owner's Representative as specified in the "General Conditions" and shall provide to the Owner five sets of "Construction

Record" control drawings and instruction booklets. AutoCAD 2000 compatible files shall be provided to Owner for all "Construction Record" control drawings indicated below:

a. Control drawings with detailed piping and wiring diagrams, including bill of material and description of operation for each system, including interfaces with equipment manufacturers, and other suppliers of equipment and systems.
b. I/O panel layouts and terminations along with interface panel drawings.
c. Valve and Damper Schedules showing size configuration, and capacity and location of all equipment.
d. Individual data sheets for each control and automation system components.
e. Process and instrumentation diagrams for each system.
f. Termination and Ladder wiring diagrams.
g. Small scale site and equipment plans showing the control component locations in occupied space, equipment rooms, mechanical equipment, etc.

8. DDC Sequence of Operation: A detailed sequence of operation describing exact method of control.

1.05 ELECTRICAL POWER FOR HVAC INSTRUMENTATION AND CONTROLS

A. All electric wiring and wiring connections required for the installation of the temperature control system, as herein specified, shall be provided by the DDC Contractor, unless specifically shown on the Electrical drawings or called for in the Electrical specifications.

B. All wiring, including low voltage wiring, shall comply with the requirements of the Electrical Sections of the specifications. Wiring methods shall be in accordance with the requirements of applicable codes as indicated in Division 16.

C. Data and AC power wiring shall not share the same conduit nor shall they occupy the same enclosure unless an appropriate grounded metallic barrier is installed between these wiring types.

D. Wiring from remote equipment shall be to terminal blocks. The terminal blocks shall be permanently marked for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions which might adversely affect the connected devices. Number the blocks by circuit pairs, such as 1 to 25, 26 to 50, etc. Classify each individual signaling circuit as a circuit pair.

E. Label or code each field wire at each end. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color coded cable with cable diagrams may be used to accomplish cable identification.

F. Splices shall not be made in shielded wiring except where specifically required. Splices shall be made on terminal blocks in approved unction boxes. Outlet boxes shall not be used for splices. Comply with labeling requirements above.

1.06 COORDINATION

A. Certain materials will be furnished, installed, or furnished and installed, under other Sections and Contracts. Examine the Contract Documents to ascertain these requirements.

B. Carefully check space requirements with other Trades to ensure that **all** material can be installed in the spaces allotted.

C. Transmit to Trades doing work in other Sections all information required for work to be provided under their respective Sections.

D. Wherever the DDC System Contract's work interconnects with work of other contractors, the DDC Contractor shall coordinate his work with these contractors to insure that all contractors have the information necessary so that they may properly install all the necessary connections and equipment. Identify all work items (valves, dampers, etc.) in an approved manner in order that the Ceiling Contractor may know where to install access doors and panels.

1.07 DDC SITE TESTING

A. General: Provide field testing and adjustment of the complete DDC system and an on-site operation acceptance test. The Owner shall be notified of all tests, to allow system verification.

B. Field Test: When installation of the DDC system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. **All** testing, calibrating, adjusting and final field tests shall be completed by the Contractor for all control and monitoring points and control algorithms. Verify that all systems are operable from local controls in the specified failure mode upon DDC system failure or loss of power. Submit the results of functional and diagnostic tests and calibrations.

C. Program loading/unloading capability shall be verified and tested to the Owner's Representative's satisfaction.

D. Upon completion of the project, the DDC Contractor shall:

1. Completely adjust and make ready for use all DDC panels, valves, damper operators, relays, etc. provided under this Section.
2. Furnish five instructive manuals covering the function and operation of the control systems on the project for the use *of* the Owner's operating personnel.

1.08 NOMENCLATURE

A. Nomenclature associated with control point identifiers, descriptions and object names shall be based on standard University equipment nomenclature. A copy of this nomenclature will be provided **by** the Owner upon request. Contractor shall request from

Owner, in writing, an update of final room numbers or other changes from Contract Documents to ensure proper notation on all control documents and programming.

1.09 WARRANTY

A. Provide all services, materials and equipment necessary for the successful operation of the entire **BAS** system for a period of one year after beneficial use.

B. Within this warranty provide for the adjustment, required testing, and repair of the system includes all computer equipment, transmission equipment and all sensors and control devices.

1.10 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).

a. Section 608, Shutoff for Smoke Control.
b. Section 403.3, Smoke Detection Group B Office Buildings and Group R, Division 1 Occupancies.
c. Section 710.5, Wiring in Plenums.
d. Section 713.10, Smoke Dampers.
e. Section 1106, Refrigeration Machinery Rooms.
f. Section 1107, Refrigeration Machinery Room Ventilation.
g. Section 1108, Refrigeration Machinery Room Equipment and Controls.
h. Section 1**120,** Detection and Alarm Systems.

3. Uniform Mechanical Code (UMC).
4. ASHRAE 135-1995.
5. FCC Regulation, Part 15-Governing Frequency Electromagnetic Interference.
6. Underwriters Laboratories.

a. UL 916.
b. UL 864.

PART 2 - PRODUCTS

2.01 BUILDING CONTROL SYSTEM

A. The building control system specified herein shall be a Direct Digital Control system which can perform all the control routines as required in this specification,

B. Performance capabilities, field programmability and operation of DDC system shall meet all the specified requirements. Actual system architecture may vary slightly between system manufacturers.

2.02 ACCEPTABLE MANUFACTURERS

A. Listing as an acceptable manufacturer does not relieve the Controls Contractor from meeting all requirements of the Specification. Manufacturer's standard equipment shall be upgraded as required to meet Project Specifications. Acceptable manufacturers are:

1. Johnson Controls, Inc.
2. Delta Controls.
3. Seimens.

2.03 SYSTEM PERFORMANCE

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

1. Graphic Display. The system shall display 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 60 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 5 seconds. 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 selectable 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. Stability of Control. Control loops shall maintain measured variable at setpoint within the tolerances listed in Table 2.

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)
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 (CO2)	+50 ppm

Note 1: 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	a50 Pa [±0.2" w.g.]	0-1.5 kPa [0-6" w.g.]
	±3 Pa [±0.01" w.g.]	-25 to 25 Pa [-0.1 to 0.1" w.g.]
Airflow	±100 cfm	
Temperature	±0.5ºC [±1.0ºF]	
Fluid Pressure	±10 kPa [±1.5 psi]	0-1 kPa [1-150 psi]
	±250 Pa [±1.0" w.g.]	0-12.5 kPa [0-50"w.g.] differential

2.04 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 interfaces) shall conform to ANSI/ASHRAE Standard 135-1995, 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, and routers necessary for the internetwork.

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

E. A device on the internetwork shall be provided with a minimum 28,800-baud modem that will allow for remote operator interface using the BACnet PTP Data Link/ Physical layer protocol. Remote operator interface via this modem shall allow for communication with any and all controllers on this network as described in Paragraph **F** below.

F. 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 interface 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 a 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.

G. The time clocks in all controllers shall be automatically synchronized daily via the internetwork. An operator change to the time clock in any controller shall be automatically broadcast to all controllers on the internetwork.

H. The internetwork shall have the following minimum capacity for future expansion:,

1. Each Building Controller shall have routing capacity for 150 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, Custom Application Controller, and Application Specific Controller input/output objects.

2.05 OPERATOR INTERFACE

A. Operator Interface. Furnish one PC-based workstation. The workstation shall be able to access all information in the system. The workstation 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.

C. Hardware. Each operator workstation and custom programming workstation shall consist of:

1. IBM Compatible with 256 MB Ram, 60 GB hard drive and controller, 40x EIDE CD-ROM, 3.5-inch diskette drive, 16MB AGP graphic card, mouse, 101-12ex enhanced keyboard, 750 **MHZ** Pentium processor, 19-inch diagonal monitor (resolution 640x480 pixels minimum with separate controls for color, contrast, and brightness, and a non-reflective screen), internal baud modem (56,000 speed and remote communication to network via dial-up telephone network and for automatic transmission of alarms to remote sites. Modem shall comply with Bell Standard 212A and 103 for both tone and pulse dialing networks).
2. Printer shall be Hewlett Packard ink jet. Provides 10 reams of auth *20* LBS xerographic quality letter size paper.
3. Operating system shall be Windows NT and provide all cables; connections, etc. for complete operating system.

4. BACnet Services, The workstation shall use the Read (Initiate) **and** Write (Execute) Services as defined in clauses 15.5 and 15.8, respectively, of ASHRAE Standard 135-95, to communicate with BACnet objects in the internetwork.

Operator Workstation BACnet Services	*Initiate*	*Execute*
Acknowledge Alarms	X	X
Confirmed COV Notification	X	X
Confirmed Event Notification	X	X
Get Alarm Summary	X	X
Get Enrollment Summary	X	X
Subscribe COV	X	X
Unconfirmed COV Notification	X	X
Unconfirmed Event Notification	X	X
Atomic Read File	X	X
Atomic Write File	X	X
Add List Element	--	X
Remove List Element	--	X
Create Object	X	X
Delete Object	X	X
Read Property	X	X
Read Property Multiple	X	X
Write Property	X	X
Read Range	X	X
Write Property Multiple	X	X
Device Communication Control	X	X
Confirmed Private Transfer	X	X
Unconfirmed Private Transfer	X	X

Reinitialize Device	X	--
Time Synchronization	X	--
Who-Has	--	X
I-Have	X	--
Who-Is	X	X

5. BACnet Functional Groups. The Operator Workstation shall support the following BACnet functional groups: Clock, Event Initiation, Event Response, COV Event Response, Files, Reinitialize, Device Communication, Time Master and Router.

6. The Operator Workstation shall have the capability to create, delete and support the following BACnet Objects:

   a. ANALOG INPUT, ANALOG OUTPUT AND ANALOG VALUE: These objects shall have the following writeable properties: Object Name; Object Value; Description; COV Increment; Out of Service and Units. In addition, these objects shall support the properties: Device type; Reliability; Min./Max. Values; Update Interval and Resolution.

   b. BINARY INPUT, BINARY OUTPUT AND BINARY VALUE: These objects shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Default Value; Min On/Off and Out of Service. In addition, these objects shall support the properties: Device Type; Reliability; Active/Inactive Texts; Update Interval; Resolution; Change-of-State Time; Count Times and Time Reset.

   c. CALENDAR: This object shall have the following writeable properties: Object Name; Object Value; Description; and Date List.

   d. DEVICE: This object shall have the following writeable properties: Object Name; Description; Location; and UTC Offset.

   e. EVENT ENROLMENT: This object shall have the following writeable properties: Object Name; Object Value; Description; Out-of-Service; Event & Notify Types; Paramenters; Property Ref; Enable; and Notification Class.

   f. FILE: This object shall have the following writeable properties: Object Name; Description; File Type; and File Access.

   g. LOOP (PID): This object shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Output and Input Refs.; Input Value & Units; Setpoint Value; PID Values; Bias; Write Priority and COV Increment. In addition, this object shall support the properties: Reliability; Update Interval; Proportional Constant & Units; Derivative Constant & Units and Min./Max. Outputs.

   h. NOTIFICATION CLASS: This object shall have the following writeable properties: Object Name; Object Value; Description; Priority and Ack Required.

   i. PROGRAM: This object shall have the following writeable properties: Object Name; Object Value and Description. In addition, this object shall support the property Reliability.

j. SCHEDULE: This object shall have the following writeable properties: Object Name; Object Value and Description; Effective period; Schedule; Exception; Controlled Properties and Write Properties.

k. TREND LOG: This object shall have the following writeable properties: Object Name; Description; Log Enable; Start/stop Times; Log Device Object Property; Log Interval; Stop When Full; Buffer Size; and Record Count.

D. 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 DOS or Microsoft Windows. Examples include Lotus 123, Microsoft Excel, WordPerfect, and Paradox. Acceptable operating systems are Windows 95, Windows *98* and Windows NT.

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 that are saved in industry standard formats such as PCX, TIFF, and GEM. The graphics generation package also shall provide the capability of capturing or converting graphics from other programs such as Designer 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 support on-line operating language selection with on the fly toggling capabilities between English, Spanish, French, German, Chinese, etc.

6. Dynamic Data Exchange (DDE). Software shall support dynamic data sharing with other Windows-based programs for third party add-on functionality e.g. preventative maintenance, tenant billing, etc.

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

1. Automatic 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 a change is made in any system panel. The storage of this data shall be automatic and not require operator intervention. In the event of a database loss in a building management panel, the first workstation to detect the loss shall automatically restore the database for that panel. The operator may disable this capability.

2. Manual 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 also shall be able to clear a panel database arid manually initiate a download of a specified database to any panel in the system.

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, editor, and object. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected. This auto logoff time shall be set per operator password. All system security data shall be stored in an encrypted format.

6. System Diagnostics. The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

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, or displaying specific system graphics. Each of these actions shall be configurable by workstation and time of day. An object in alarm that has not been acknowledged within an operator-specified time period shall be moved to a higher level of priority. The actions for that level will then be followed.

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 the

hard disk and be retrievable 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. All that have not been cleared by the operator shall be archived to the hard disk on the workstation.
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. Reports and Logs. Provide a reporting package that allows the operator to select, modify, or create reports. Each report shall be definable as to data content, format, interval, and date. Report data shall be archivable on the hard disk for historical reporting. Provide the ability for the operator to obtain real-time logs of all objects by type or status (e.g., alarm, lockout, normal). Reports and logs shall be stored on the PC hard disk in a format that is readily accessible by other standard software applications, including spreadsheets and word processing. Reports and logs shall be readily printed to the system printer and shall be set to be printed either on operator command or at a specific time each day.
15. Standard Reports. The following standard system reports shall be provided for this project. Provide ability for the Owner to readily customize these reports for this project.

    a. Electrical Meter Report: Provide a monthly report showing the daily electrical consumption and peak electrical demand for each building meter. Provide an annual (12-month) summary report showing the monthly electrical consumption and peak demand for each meter.
    b. Gas Meter Report: Provide a monthly report showing the daily natural gas consumption for each meter. Provide an annual (12-month) report that shows the monthly consumption for each meter.
    c. Weather Data Report: Provide a monthly report showing the daily minimum, maximum, and average outdoor air temperature - as well as the number of heating and cooling degree days for each day. Provide an annual (12-month) report showing the minimum, maximum, and average outdoor air temperature for the month - as well as the number of heating and cooling degree-days for the month.
    d. Tenant Override Reports: Provide a monthly report showing the daily total time in hours that each tenant has requested after-hours HVAC and lighting services. Provide an annual summary report that shows the override usage on a monthly basis.
    e. All Objects: **All** system (or sub-system) objects and their current values.
    f. Alarm Summary: **All** current alarms (except those in alarm lockout).
    g. Disabled Objects: All objects that are disabled.

h. Alarm Lockout Objects: All objects in alarm lockout (whether manual or automatic).

i. Alarm Lockout Objects in Alarm: All objects in alarm lockout that are currently in alarm.

j. Logs:

1) Alarm History
2) System Messages
3) System Events
4) Trends

k. Custom Reports: Provide the capability for the operator to easily define any system data into a daily, weekly, monthly, or annual report. These reports shall be time and date stamped, and shall contain a report title and the name of the facility.

F. 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. Schedules shall be easy to copy to other objects and/or dates.

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"). Alternatively, the programming language can be graphically-based using function blocks as long as blocks are available that directly provide the functions listed below, and that custom or compound function blocks can be created.

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 programming language shall have predefined variables representing the status and results of the System Software, and shall be able to enable, disable, and change the setpoints of the System Software described below.

G. Laptop Computer:

1. Windows 98/2000 or Windows NT 4.0 based, capable of accessing all system data. Laptop computer may be connected to any point on system LAN or may be connected directly to controllers for programming, setup and troubleshooting. Dedicated purpose interfaces are not acceptable. Laptop computer to contain the following as a minimum:

   a. 300 MHz Pentium Processor.
   b. 128 Meg RAM.
   c. 6 GB Hard File.
   d. 3.5-inch 1.44 Meg Floppy Disk Drive.
   e. 24x EIDE CD-ROM Drive.
   f. 8 MB AGP graphic card.

2. 25 line screen display with English language prompting for quick access to system information through pop-up menus.

3. When plugged into any multi-purpose controller on the DDC network, laptop computer to have same functionality as Operator Workstation with full editing, programming, display and command functions. Each laptop to allow access to entire control network.

H. Portable Operator's Terminal:

1. Provide 1 hand held Portable Operator's Terminal and controller interface software for communication with any DDC control panel. Portable Operator's Terminal capable of accessing all system data. Portable Operator's Terminal may be connected to any point on the system LAN, or may be connected directly to DDC panels of controllers for programming, setup, and troubleshooting. Dedicated purpose interfaces are not acceptable.
2. Portable Operator's Terminal to have English language prompting for quick access to system information.
3. When plugged into any multi-purpose controller on the DDC network, Portable Operator's Terminal to allow access to entire control network.

I. Pager's Software: Provide pager software to beep on selected alarms and notify paged individual to call for service.

2.06 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.
4. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.

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

1. Weekly Schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop, and night economizer. Each schedule may consist of up to 10 events. When a group of objects are scheduled together, provide the capability to adjust the start and stop times for each member.
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 *is* executed, it will be discarded and replaced by the standard schedule for that day of the week.

3. Holiday Schedules. Provide the capability for the operator to define up to 99 special or holiday 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. System Coordination. Provide a standard application for the proper coordination of equipment. This application shall provide the operator with a method of grouping together equipment based on function and location. This group may then be used for scheduling and other applications.

E. Binary Alarms. Each binary object shall be set 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. Alarming must be able to be automatically and manually disabled.

G. 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. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display graphics.

H. Remote Communication. The system shall have the ability to dial out in the event of an alarm using BACnet Point-To-Point at a minimum of 28,800 baud. Receivers shall be BACnet workstations.

I. Demand Limiting.

1. The demand limiting program shall monitor building power consumption from signals generated by a pulse generator (provided by others) mounted at the building power meter, or from a watt transducer or current transformer attached to the building feeder lines.
2. The demand-limiting program shall predict the probable power demand such that action can be taken to prevent exceeding the demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates the demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.
3. Demand reduction shall be accomplished by the following means:

   a. Reset air handling unit supply temperature setpoint up by 1ºC [2ºF].
   b. Reset space temperature setpoints up by 1ºC [2ºF].
   c. De-energize equipment based upon priority.

4. Demand limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which the local power company computes demand charges.
5. Provide demand-limiting prediction and control for any individual meter monitored by the system or for the total of any combination of meters.
6. Provide the means for an operator to make the following changes on-line:

a. Addition and deletion of loads controlled.
b. Changes in demand intervals.
c. Changes in demand limit for meter(s).
d. Maximum shutoff time for equipment.
e. Minimum shutoff time for equipment
f. Select rotational or sequential shedding and restoring.
g. Shed/restore priority.

7. Provide the following information and reports, to be available on an hourly, daily, and monthly basis:

a. Total electric consumption.
b. Peak demand.
c. Date and time of peak demand.
d. Daily peak demand.

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

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

L. 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.

M. Staggered Start. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started, along with the time delay between starts, shall be user-selectable.

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

O. 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.

P. 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.

Q. 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.

2.07 BUILDING CONTROLLERS

A. General. Provide an adequate number of Building Controllers to achieve the performance specified and shown on drawings. Each of these panels shall meet the following requirements.

1. The Building Automation 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 real-time clock.
6. The Building Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:

   a. Assume a predetermined failure mode.
   b. Generate an alarm notification.

7. The Building Controller shall communicate with other BACnet objects on the internetwork using the Read (Execute and Initiate) and Write (Execute and Initiate) Property services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE Standard 135-95.

Building Controller BACnet Services	*Initiate*	*Execute*
Acknowledge Alarms	--	X
Confirmed COV Notification	X	X
Confirmed Event Notification	X	X
Get Alarm Summary	X	X
Get Enrollment Summary	X	X
Subscribe COV	X	X
Unconfirmed COV Notification	X	X
Unconfirmed Event Notification	X	X
Atomic Read File	--	X
Atomic Write File	--	X
Add List Element	--	X
Remove List Element	--	X
Create Object	--	X
Delete Object	--	X
Read Property	X	X

Read Property Multiple	X	X
Write Property	X	X
Read Range	--	X
Write Property Multiple	X	X
Device Communication Control	--	X
Confirmed Private Transfer	X	X
Unconfirmed Private Transfer	X	X
Reinitialize Device	--	X
Time Synchronization	X	X
Who-Has	--	X
I-Have	X	X
Who-Is	X	X
I-Am	X	X

8. BACnet Functional Groups. The Building Controller shall support the following BACnet functional groups: Clock, Event Initiation, COV Event Response, Files, Device Communication, Time Master and Router.

B. Communication.

1. Each Building Controller shall support a communications card. The communications card shall be connected to the Building Controller by an industry stackable PC-104 bus connection. The communications card is connected to the BACnet network using the ISO 8802-3 (Ethernet) Data Link/ Physical layer protocol. The communications card shall provide for three diverse Ethernet installations; 10Base2, 10BASE5 and 10BaseT connections.
2. Each Building Controller with a communications card 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/or printer and/or modem.
4. The Building Controller secondary communication network shall support one LonWorks FTT port at 78 Kbits/s.
5. The Building Controller shall support non-proprietary open protocols, e.g. Modbus, CAB, etc. Interface to the Building Controller shall be through an EIA 232 Point-To-Point connection.

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 and dust proof enclosures, and shall be rated for operation at -29°C to 40°C (-20°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. 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 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. Memory shall be user extendible through RAM chip sockets and SIMMs for future memory expansion.

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. The Building Controller shall maintain all 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].

G. Inputs/Outputs. Controller shall support a directly connected inputloutput board with 16 universal inputs and 16 universal outputs. Inputloutput board to be expandable through individual I/O modules and up to 3 I/O expansion boards. A fully expanded controller shall support up to 145 connected inputs/outputs.

1. Inputs. Controller inputloutput 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 12-bit A to D.
2. Outputs. Controller input/output board shall support plug-and-play I/O modules configured with manual-auto-off override switch, potentiometer and input channel for feedback status or and unrelated analog or digital input. Output supported shall be 0-10 VDC-voltage and/or 4-20mA-current.
3. Diagnostics. Controller inputloutput board shall have red LEDs providing input status indication.
4. External Power. Controller inputloutput board shall have four on-board 24 VDC terminal for directly connected active transducers.
5. The Building Controller shall have the capability to create, delete and support the following BACnet Objects:

    a. ANALOG INPUT, ANALOG OUTPUT AND ANALOG VALUE: These objects shall have the following writeable properties: Object Name; Object Value; Description; COV Increment; Out of Service and Units. In addition, these objects shall support the properties: Device type; Reliability; Min./Max. Values; Update Interval and Resolution.
    b. BINARY INPUT, BINARY OUTPUT AND BINARY VALUE: These objects shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Default Value; Min On/Off and Out of Service. In addition, these objects shall support the properties: Device Type; Reliability;

Active/Inactive Texts; Update Interval; Resolution; Change-of-State Time; Count Times and Time Reset.

c. CALENDAR: This object shall have the following writeable properties: Object Name; Object Value; Description; and Date List.

d. DEVICE: This object shall have the following writeable properties: Object Name; Description; Location; and UTC Offset.

e. EVENT ENROLMENT: This object shall have the following writeable properties: Object Name; Object Value; Description; Out-of-Service; Event & Notify Types; Paramenters; Property Ref; Enable; and Notification Class.

f. FILE: This object shall have the following writeable properties: Object Name; Description; File Type; and File Access.

g. LOOP (PID): This object shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Output and Input Refs.; Input Value & Units; Setpoint Value; PID Values; Bias; Write Priority and COV Increment. In addition, this object shall support the properties: Reliability; Update Interval; Proportional Constant & Units; Derivative Constant & Units and Min./Max. Outputs.

h. NOTIFICATION CLASS: This object shall have the following writeable properties: Object Name; Object Value; Description; Priority and Ack Required.

i. PROGRAM: This object shall have the following writeable properties: Object Name; Object Value and Description. In addition, this object shall support the property Reliability.

j. SCHEDULE: This object shall have the following writeable properties: Object Name; Object Value and Description; Effective period; Schedule; Exception; Controlled Properties and Write Properties.

k. TREND LOG: This object shall have the following writeable properties: Object Name; Description; Log Enable; Start/stop Times; Log Device Object Property; Log Interval; Stop When **Full;** Buffer Size; and Record Count.

2.08 CUSTOM APPLICATION CONTROLLERS

A. General. Provide an adequate number of Custom 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 Custom Application Controller shall have sufficient memory to support its operating system, database, and programming requirements.
2. Data shall be shared between networked Custom Application Controllers.
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. Controllers that perform scheduling shall have a real-time clock.
5. The Custom Application Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:

   a. Assume a predetermined failure mode.
   b. Generate an alarm notification.

6. The Custom Application Controller shall communicate with other BACnet objects on the internetwork using the Read (Execute and Initiate) and Write (Execute and Initiate) Property services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE Standard 135-95.

B. Communication.

1. Each Custom Application Controller shall reside on a BACnet network using the MS/TP Data Link/ Physical layer protocol.
2. The controller shall provide a service communication port using BACnet Data LinW Physical layer protocol for connection to a hand-held workstation.

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 and dustproof enclosures, and shall be rated for operation at -29°C to 40°C [32˚F to 120˚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 Custom Application Controller shall be non-volatile FLASH memory.

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 to 120 Hz and from keyed radios up to 5 W at 1 m [3 ft].

2.09 APPLICATION SPECIFIC CONTROLLERS

A. General. Application Specific Controllers (ASCs) 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. Application Specific Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of ASHRAE Standard 135-95.

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.

B. Communication.

1. The controller shall reside on a BACnet network using the MS/TP Data Link/ Physical layer protocol. Each ASC shall be connected to one Building Controller. Each Building Controller shall support a network of 150 ASCs. Each ASC shall be optically isolated from the network.
2. Each controller shall have a BACnet Data LinW 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.

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 and dustproof enclosures, and shall be rated for operation at -28°C to 65°C (E-10°F to 150°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 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, four analog or digital inputs and two analog outputs and five digital outputs. ASC inputs shall support 0-5 VDC-voltage, 4-20mA-current, thermistor-resistance and dry contacts. ASC outputs shall support 0-10 VDC-voltage, 4-20 mA-current and digital triac rated at 0.5 amps at 24 VAC.

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.

2.10 INPUT/OUTPUT INTERFACE

A. Hardwired inputs and output points/objects may be wired into the system through Building, Custom Application, or Application Specific Controllers.

B. All input and output points shall be protected such that shorting of the point to itself, to another point, or to ground, will cause no damage tot he controller. All input and output points shall be protected from voltage up to 24 volts of any duration, such tat contact with this voltage will cause no damage to the controller. Inputs and outputs shall be arranged on interchangeable modules or circuit boards to allow the replacement of a damaged module or board without replacing the entire controller.

C. Digital inputs shall allow the monitoring of ON/OFF signals from remote devices. The digital inputs shall provide a current of at least 12 mA to be compatible with commonly available control devices, and shall be protected against the effects of contact bounce and noise. Digital inputs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.

D. Pulse accumulation inputs. This type of point/object shall conform to all requirements of a binary input point/object, and also accept up to **10** pulses per second for pulse accumulation.

E. Analog inputs shall allow the monitoring of 0-5 VDC, 0-10 VDC-voltage, 4-20 mA-current, or thermistors, RTD-resistance signals. Analog inputs shall be compatible, and be field configurable to commonly available sensing devices.

F. Digital outputs shall provide for ON/OFF operation, **or** a pulsed low-voltage signal for pulse width modulation control. Digital outputs on Building and Custom Application Controllers shall have three-position override switches, Hand-Off-Auto with status lights. Outputs shall be selectable for either normally open or normally closed operation.

G. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC or a **4** to 20 mA signal as required to provide proper control of the output device. Analog outputs on Building or Custom Application Controllers shall have status lights and a two-position (AUTO/MANUAL) switch and manually adjustable potentiometer for manual override. Analog outputs shall not exhibit a drift of greater than **0.4%** of range per year.

H. Tri-State Outputs. Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal unit control applications (VAV terminal units, duct mounted heating coils, zone dampers, radiation, etc.). Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

I. Input/Output points/objects shall be universal type, i.e., controller input or output may be designated (in software) as either a binary or analog type point/object with appropriate properties. Application Specific Controllers are exempted from this requirement.

J. 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. Control transformers shall be UL Listed. Furnish Class 2 current-limiting type, or furnish over-current protection in both primary and s'econdary circuits for Class *2* service per 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 a 150% current overload for at least **3** seconds without trip-out or failure.

a. Unit shall'operate between 0°C and 50°C [32°F and 120°F]. EM/RF shall meet FCC Class B and VDE 0871 for Class B, and MIL-STD **81**OC for shock and vibration.
b. Line voltage units shall be UL Recognized and CSA Approved.

B. Power line filtering.

1. Provide transient voltage and surge suppression for all workstations and controllers either internally or as an external component. Surge protection shall have the following at a minimum:

a. dielectric strength of 1,000 volts 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 better at **40** Hz to 100 Hz.

2.12 AUXILIARY CONTROL DEVICES

A. Motorized control dampers, unless otherwise specified elsewhere, shall be as follows:

1. Control dampers shall be parallel or opposed blade type as below or as scheduled on drawings.
2. Control dampers are specified in Division 15, Section "Duct Accessories."

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 rotary spring-return actuators shall be capable of both clockwise or counter-clockwise spring-return operation. Linear actuators shall spring-return to the retracted position.
4. Proportional actuators shall accept a 0 to 10 VDC or 0 to 20 mA control signal and provide a 2 to 10 VDC or 4 to 20 mA operating range.
5. All 24 VAC/DC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 W for DC applications. Actuators operating on 120 VAC or 230 VAC shall not require more than 11 VA.
6. 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.
7. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.
8. Actuators shall be provided with a raceway fitting and a minimum l m electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
9. Actuators shall be UL Standard 873 Listed and CSA Class 4813 02 Certified as meeting correct safety requirements and recognized industry standards.
10. Actuators shall be designed for a minimum of 60,000 full-stroke cycles at the actuator's rated torque.

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:

      1) Two-way: 150% of total system (pump) head.
      2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

3. Water Valves:

   a. 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.
   b. Sizing Criteria:

      1) Two-position service: Line size.
      2) Two-way modulating service: Pressure drop shall be equal to twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi, whichever is greater.

3) Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 35 kPa [5 psi] maximum.
4) Valves ½" through 2" shall be bronze body or cast brass ANSI Class 250, spring-loaded, Teflon packing, quick opening for two-position service. Two-way valves to have replaceable composition disc, or stainless steel ball.
5) 2%" valves and larger shall be cast iron ANSI Class 125 with guided plug and Teflon packing.
6) Water valves shall fail normally open or closed as scheduled on plans, or as follows:

a) Water zone valves - normally open preferred.
b) Heating coils in air handlers - normally open.
c) Chilled water control valves - normally closed.
d) Other applications - as scheduled or as required by sequences of 'operation.

D. Binary Temperature Devices

1. Low-voltage space thermostat shall be 24 V, bimetal-operated, mercury-switch type, with either adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C to 30°C [55°F to 85°F] setpoint range, 1°C [2°F] maximum differential, and vented ABS plastic cover.
2. Line-voltage space thermostat shall be bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch type, or equivalent solid-state type, with heat anticipator, UL listed for electrical rating, concealed setpoint adjustment, 13°C to 30°C [55°F to 85°F] setpoint range, 1°C [2°F] maximum differential, and vented ABS plastic cover.
3. 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.

E. Temperature sensors.

1. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistors.
2. Duct sensors shall be rigid or averaging as shown. Averaging sensors shall be a minimum of 1.5 m [5 feet] in length.
3. Immersion sensors shall be provided with a separable stainless steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.
4. Space sensors shall be equipped with setpoint adjustment, override switch, display, and/or communication port as shown.
5. Provide matched temperature sensors for differential temperature measurement.

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 1% of full scale per year.

G. Carbon Dioxide Sensors

1. Duct and room sensors shall have a nominal range of 0 PPM to 2000 PPM of carbon dioxide with recalibration ability to adjust range to 0 PPM to 5000 PPM.
2. Duct sensors shall have sampling tube and an operating flow rate from 0 FPM to 1950 **FPM.**
3. Outside air carbon dioxide sensors shall have a range of 0 PPM to 1000 PPM with an accuracy of 20 ppm +-% of reading.
4. Indoor carbon dioxide sensors shall have operating temperature of -5° C to 45°C and a humidity range of 0%RH to 85%RH (non condensing).
5. Outdoor carbon dioxide sensors shall have an operating temperature range of -30" C to 60" C and a humidity range of 0%RH to 100%RH.
6. Outdoor carbon dioxide sensor shall have a PC plastic probe tube. Sensor shall be suitable for outside operation.
7. Carbon dioxide sensors control housing shall be NEMA **4** Enclosures.

H. Flow switches.

1. Flow-provingswitches shall be either paddle or differential pressure type, as shown.
2. Paddletype switches (water service only) shall be UL Listed, SPDT snap-acting with pilot duty rating (125 VA minimum). Adjustable sensitivity with NEMA **1** enclosure unless otherwise specified.
3. 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 specified.

I. Relays..

1. Control relays shall be UL Listed plug-in type with dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage suitable for application.
2. Time delay relays shall be UL Listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable ±200% (minimum) from setpoint shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.

J. Override timers.

1. Override timers shall be spring-wound line voltage UL Listed, contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless

otherwise specified; suitable for flush mounting on control panel face, located on local control panels or where shown.

K. Current transmitters.

1. AC current transmitters shall be self-powered combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4 to 20 Ma two-wire output. Unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A full scale, internal zero and span adjustment, and ±1% full scale accuracy at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UUCSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

L. Current transformers.

1. AC current transformers shall be UUCSA recognized and completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full scale output.
3. Transformers shall be fixed-core or split-core type for installation on new or existing wiring, respectively.

M. Voltage transmitters.

1. AC voltage transmitters shall be self-powered single loop (two-wire) type, 4 to 20 mA output with zero and span adjustment.
2. Ranges shall include 100 to 130 VAC, 200 to 250 VAC, 250 to 330 VAC, and 400 to 600 VAC full-scale, adjustable, with ±1% full-scale accuracy with 500 ohm maximum burden.
3. Transmitters shall be UUCSA recognized at 600 VAC rating and meet or exceed ANSI/ISA S50.1 requirements.

N. Voltage transformers.

1. AC voltage transformers shall be UUCSA recognized, 600 VAC rated, complete with built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4 to 55°C [40 to 130°F] and shall provide ±0.5% accuracy at 24 VAC and a 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic material.

O. Power monitors.

1. Power monitors shall be three-phase type furnished with three-phase disconnect/shorting switch assembly, UL Listed voltage transformers and UL Listed split-core current transformers.

2. Shall provide a selectable rate pulse output for kWh reading and a 4 to 20 mA output for kW reading. Shall operate with 5 A current inputs with a maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

P. Current switches.

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system.

Q. 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.

R. Local control panels.

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction. All outdoor control cabinets shall be NEMA 4 construction. All cabinets shall have 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. 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 over-current 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 the applicable sections of Division 16.

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

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that conditioned power supply is available to control units and operator workstation.

B. Verify that duct-, pipe-, and equipment-mounted devices and wiring are installed before proceeding with installation.

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

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

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

3.02 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.

3.03 INSTALLATION

A. Install equipment level and plumb.

B. Install software in control units and operator workstation. Implement all features of programs to specified requirements and as appropriate to sequence of operation.

C. Connect and configure equipment and software to achieve sequence of operation as specified on drawings.

D. Install automatic dampers according to Division 15 Section "Duct Accessories."

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

F. Install labels and nameplates to identify control components according to Division 15 Section "Mechanical Identification."

G. Install hydronic instrument wells, valves, and other accessories according to Division 15 Section "Duct Accessories."

H. install all equipment in accordance with equipment manufacturer's published instructions.

I. Review the project design drawings to become thoroughly familiar with all details of the work and working conditions. The DDC contractor shall be responsible for the coordination of the control work with the work of all trades.

J. Where installation procedures, or any part there of, are required to be in accordance with the recommendations of the manufacturer of the material being installed, furnish printed copies of these recommendations to the Owner's Representative prior to installation.

K. All control wiring shall be installed in electrical conduit when being routed exposed within the space, mechanical rooms, exterior locations, etc. Control wiring installed within a concealed location, such as above a ceiling, may be neatly bundled and routed in a logical and organized manner. Bundle shall be sheathed and supported by zinc plated steel hangers **4** feet on center maximum. In all cases, exposed control wiring to be plenum rated.

L. Conduit and boxes associated with new sensors in space below ceiling shall be ran inside of existing walls whenever possible. When it is not possible to do so, conduit and boxes shall be a decorative type selected to match surroundings on which they are being installed and approved by owner.

M. All system control points and devices shall be clearly labeled using engraved plastic laminate tags. Nomenclature for system labeling shall be consistent with that used on system shop drawings.

N. **All** control and interlock wiring shall comply with national and local electrical codes and Division 16 of this specification. Where the requirements of this section differ with those in Division 16, the requirements of this section shall take precedence.

O. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway per NEC and Division 16 requirements.

P. 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.)

Q. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations including ceiling return air plenum, approved cables not in raceway may be used, provided that cables are UL Listed for the intended application. For example, cables used in ceiling plenum shall be UL Listed specifically for that purpose.

R. All wiring in mechanical, electrical, or service rooms - or where subject to mechanical damage - shall be installed in raceway at levels below 3m [10ft].

S. Do not install Class 2 wiring in raceway 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).

T. Do not install wiring in raceway containing tubing.

U. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it, and neatly tied at 3m [10ft] intervals.

V. 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.

W. 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.

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

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

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

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

BB. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendation and NEC requirements, except as noted elsewhere.

CC. Include one pull string in each raceway 2.5 cm [1"] or larger

DD. Use coded conductors throughout with different colored conductors.

EE. 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.

FF. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15cm [6"] from high-temperature equipment (e.g., steam pipes or flues).

GG. 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.

HH. Adhere to Division 16 requirements where raceway crosses building expansion joints.

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

JJ. 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.

KK. 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 " 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.

LL. 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 (per code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

MM. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.

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

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

PP. When a cable enters or exits a building, a lightning arrester must be installed between the lines and ground. The lighting arrester shall be installed according to the manufacturer's instructions. All runs of communication wiring shall be unspliced length when that length is commercially available.

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

RR. Grounding of coaxial cable shall be in accordance with NEC regulations Article on Communications Circuits, Cable and Protector Grounding.

3.04 PROJECT MANAGEMENT

A. Provide a designated project manager who will be responsible for the following:

1. Construct and maintain project schedule
2. On-site coordination with all applicable trades, subcontractors, and other integration vendors
3. Authorized to accept and execute orders or instructions from owner/engineer
4. Attend project meetings as necessary to avoid conflicts and delays
5. Make necessary field decisions relating to this scope of work
6. Coordination/Single point of contact

3.05 START-UP

A. When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. The manufacturer shall complete all testing, calibrating, adjusting and final field tests. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power.

B. Provide any recommendation for system modification in writing to owner. Do not make any system modification, including operating parameters and control settings, without prior approval of owner.

C. After manufacturer has completed system start-up and commissioning. Joint commissioning of integrated system segments shall be completed.

3.06 ELECTRICAL WIRING AND MATERIALS

A. Install, connect and wire the items included under this Section. This work includes providing required conduit, wire, fittings, and related wiring accessories. All wiring shall be installed in conduit.

B. Provide wiring between thermostats, aquastats and unit heater motors, all control and alarm wiring for all control and alarm devices for all Sections of Specifications

C. Provide 120 volt, single phase, 60 hertz emergency power to every BAS DDC Controller panel, HVAC/Mechanical Equipment Controller, PC console, power supply, transformer, annunciator, modems, printers and to other devices as required. It is the intent that the entire building management system except terminal equipment shall be operative under emergency power conditions in the building. The power supplies are to be extended in conduit and wire from emergency circuit breakers.

D. Provide status function conduit and wiring for equipment covered under this Section.

E. Provide conduit and wiring between the BAS panels and the temperature, humidity, or pressure sensing elements, including low voltage control wiring in conduit.

F. Provide conduit and control wiring for devices specified in this Section

G. Provide conduit and signal wiring between motor starters in motor control centers and high and/or low temperature relay contacts and remote relays in **BAS** panels located in the vicinity of motor control centers.

H. Provide conduit and wiring between the PC workstation, electrical panels, metering instrumentation, indicating devices, miscellaneous alarm points, remotely operated contractors, and BAS panels, as shown on the drawings or as specified

I. All wiring to be compliant to local building code and the NEC.

J. Provide electrical wall box and conduit sleeve for all wall mounted

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

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

3.07 INSTALLATION OF SENSORS

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

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

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

D. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas 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 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 3 m of sensing element for each 1 m^2 [1 ft of sensing element for each 1 ft^2] of coil area

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

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

I. Differential air static pressure.

1. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pivot tube. Pipe the low-pressure port to a tee in the high-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 the high-pressure tap to the duct using a pivot 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 shutoff valves installed before the tee.

3.08 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch in accordance with manufacturer's instructions.

3.09 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.

3.10 WARNING LABELS

A. Permanent warning labels shall be affixed to all equipment which can be automatically started by the DDC system.

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows:

C A U T I O N
This equipment is operating under automatic control
and may start or stop at any time without warning.
Switch disconnect to "Off" position before servicing.

B. Permanentwarning labels shall be affixedto all motor starters and all control panels which 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.

3.11 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. Permanentlylabel 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 componentswith 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

F. Manufacturers' nameplatesand UL or CSA labelsto be visible and legible after equipment is installed.

G. Identifiers shall match record documents.

3.12 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/objects associated with the system are assigned to the same DDC controller. Points/objects 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 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 pointlobject used.

1. Future use of spare capacity shall require providing the field device, field wiring, pointlobject database definition, and custom software. No additional controller

boards or point/object modules shall be required to implement use of these spare points.

3.13 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 pointlobject index. Use the following naming convention:

AAABBBCCCDDDEEE where:

AAA is used to designate the location of the pointlobject within the building such as mechanical room, wing, or level, or the building itself in a multi-building environment.

BBB is used to designate the mechanical system with which the point/object is associated (e.g., A01, HTG, CLG, LTG).

CCC represents the equipment or material referenced (e.g., SAF for supply air fan , EXF for exhaust fan, RAF for return air fan).

D or DD or DDD may be used for clarification or for identification if more than one of CCC exists (e.g., SAF10, EXF121).

EE represents the action or state of the equipment or medium (e.g., T for temperature, RH for humidity, CO for control, S for status, D for damper control, I for current).

C. Software Programming

1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the Contractor. Embed 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:

1) must provide actions for all possible situations
2) must be modular and structured
3) must be commented

b. Graphic-based:

1) must provide actions for all possible situations
2) must be documented

c. Parameter-based:

1) must provide actions for all possible situations
2) 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 shown.

3. The Contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and their 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.

3.14 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.

3.15 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 Sequences of Operation through all modes of operation.
7. Demonstrate complete operation of Operator Interface.
8. 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 sheddable equipment outputs.

c. Optimum Start/Stop. 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."

3.16 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.

3.17 TRAINING

A. Provide a minimum of four on-site or classroom training sessions, three days each, throughout the contract period for personnel designated by the Owner.

B. Provide two additional training sessions at 6 and 12 months following building's turnover. Each session shall be three days in length and must be coordinated with the building Owner.

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

1. Day-to-day Operators:

a. Proficiently operate the system
b. Understand control system architecture and
c. Understand DDC system components
d. Understand system operation, including DDC system control and optimizing routines (algorithms
e. Operate the workstation and peripherals
f. Log on and off the system
g. Access graphics, point/object reports, and logs
h. 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
i. Understand system drawings, and Operation and Maintenance manual
j. Understand the job layout and location of control components
k. Access data from DDC controllers and ASCs
l. 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 pointlobject trend logs, and graph or print these both on an ad-hoc basis and at user-definable time
d. Create, delete, and modify
e. Add, remove, and modify system's physical points/objects
f. Create, modify, and delete programming
g. Add panels when required
h. Add operator interface
i. Create, delete, and modify system displays - both graphical and
j. Perform DDC system field checkout
k. Perform DDC controller unit operation and maintenance
l. Perform workstation and peripheral operation and maintenance procedures

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

3. System Managers/Administrators:

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

D. These objectives will be divided into three logical groupings. Participants may attend one or more of these, depending on level of knowledge required:

1. Day-to-day Operators: parts 1-13
2. Advanced Operators: parts 1-29
3. System Managers/Administrators: parts 1-13, and 30-32

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.

3.18 SEQUENCES OF OPERATION

A. Provide operation as shown on drawings.

3.19 OBJECT LIST

A. Provide complete device list as part of the submittal. Use the following form type to describe devices (see next page):

(3.19 OBJECT LIST)

Object Name	BACnet Object Types									Graphic Display	Notes
	AI	AO	AV	BI	BO	BV	Alarm	Trend	Sched.		

NOTES:

1.

2.

Instructions to Other Contractors

3.20 CONTROL VALVE INSTALLATION

A. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.

B. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball type control valves shall be installed with the stem in the horizontal position.

C. Valves shall be installed in accordance with the manufacturer's recommendations.

D. Control valves shall be installed so that they are accessible and serviceable, and such that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.

E. Isolation valves shall be installed such that the control valve body may be serviced without draining the supply/return side piping system. Unions shall be installed at all connections to screw-type control valves.

F. Provide tags for all control valves indicating service and number. Tags shall be in accordance with Division 15 Section "Mechanical Identification."

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 " 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"] of each other.

D. Follow 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 per manufacturer'sinstructions. (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 assure 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 assure 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.

C. This Contractor shall interlock wire duct smoke detector for fan/system shutdown.

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 points/object list, 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 ASHRAE Standard 135-1995 (BACnet). Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of ASHRAE Standard 135-95.

B. Distributed Processing. The Controller shall be capable of standalone operation and shall continue to provide control functions without being connected to the network.

C. I/O Capacity. The Controller shall contain sufficient I/O capacity to control and monitor the target system with a minimum of 16 universal inputs and 16 universal outputs.

D. Communication. The Controller shall reside on a BACnet network using the MS/TP Data LinW Physical layer protocol. Each network of controllers shall be connected to one Building Controller.

E. The Controller shall have a BACnet Data Link/ Physical layer compatible connection for a laptop computer or a portable operator's tool.

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

G. 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].

H. 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]

I. 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.

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

K. 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%. 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].

L. 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.

M. Protocol Implementation Conformance Statement (PICS). Supplier of the electronic controls packaged with this equipment shall provide to the controls contractor a PICS list, complete with object list and wiring diagrams for proper and complete interface.

3.25 STARTUP AND CHECKOUT PROCEDURES

A. Start up, check out, and test all hardware and software, and verify communication between all components.

1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
2. Verify that all analog and binary input/output points/objects read properly.
3. Verify alarms and interlocks.
4. Verify operation of the integrated system.

END OF SECTION 15975