## 1. General

### 1.1 INTENT

.1 This Section specifies general requirements common to all energy management and control system (EMCS) work. Read this Section in conjunction with all Sections that specify EMCS work.

## 2. Products

2.1 All BMS work is to be performed by ESC Automation to match & integrate with the existing base building BMS in the Pê Sâkâstêw Centre, Maskwacis, Alberta facilities. Contact Curtis Shenher at ESC Automation - cshenher@escautomation.com.

2.2 Once the new equipment, plumbing & ventilation is in place, a new Delta Controls BMS shall be installed to serve the new systems and points list noted below. This includes all software, controllers, sensors, conduit / wire, programming, commission, and graphics typical of the building owner's standards. Any required VFD's shall be supplied, mounted & commissioned by ESC with the line & load wiring to be done by the electrical contractor. All required control valves & dampers are to be supplied this trade and turned over to the mechanical contractor for installation.

## 3. MATERIALS

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

## 4. COMMUNICATION

4.1 All control products provided for this project shall comprise a BACnet internetwork. Communication involving control components (i.e., all types of controllers and Operator Workstations) shall conform to ANSI/ASHRAE Standard 135-2001, BACnet.

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

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

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

4.5 A device on the internetwork shall be provided with a 56k-baud modem that will allow for remote Operator Workstation using the BACnet PTP Data Link/ Physical layer protocol. Remote Operator Workstation via this modem shall allow for communication with any and all controllers on this network as described in Paragraph F below.

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

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

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

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

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

## 5. OPERATOR WORKSTATION

5.1 Operator Workstation. Furnish one PC-based workstations as shown on the system drawings. Each of these workstations shall be able to access all information in the system. These workstations shall reside on the same Ethernet protocol network as the Building Controllers.

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

5.3 Hardware. Each operator workstation and custom programming workstation shall consist of the following:

1. Personal Computer. Furnish IBM compatible PCs as shown. The CPU shall be a minimum of an Intel Pentium and operate at a minimum of 1,800 MHz. A minimum of 1 gigabyte of RAM, one CD readable/writeable drive and a 80GB hard disk with a minimum access time of 12 milliseconds shall be provided. A two-button mouse also will be provided. Furnish all required serial (USB), and network communication ports, and all cables for proper system operation. The PC shall have a minimum of a 20" SVGA LCD monitor (1024 x 768 resolution, 32 Bit color).
2. Network.
3. Printers.
4. BACnet Interoperability Building Blocks. The workstation shall support the following BIBBs:

| Data Sharing | Alarm & Event | Scheduling | Trending | Device & Network Mgmt. |
|---|---|---|---|---|
| DS-RP-A,B | AE-N-A | SCHED-A | T-VMT-A | DM-DDB-A,B |
| DS-RPM-A | AE-ACK-A | | T-ATR-A | DM-DOB-A,B |
| DS-WP-A | AE-ASUM-A | | | DM-DCC-A |
| DS-WPM-A | AE-ESUM-A | | | DM-TS-A |
| | | | | DM-UTC-A |
| | | | | DM-RD-A |
| | | | | DM-BR-A |
| | | | | NM-CE-A |

5.4 System Software

1. Operating System. Furnish a concurrent multi-tasking operating system. The operating system also shall support the use of other common software applications that operate under Microsoft Windows. Examples include Microsoft Excel, Microsoft Word, Microsoft Access. Acceptable operating systems are Windows 2000 Professional, Windows XP Pro and Windows 2003 Server.

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

static text, and animation files. Graphics shall have the ability to show animation by shifting image files based on the status of the object.

3. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics. The graphics generation package also shall provide the capability of capturing or converting graphics from other programs such as Visio or AutoCad

4. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program. Graphics shall be created by drag-and-drop selection of graphic symbols and drag-and-link with BACnet objects with dynamic and interactive display fields.

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

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.

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

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

2. 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 shall be able to clear a panel database via the network and may initiate a download of a specified database to any panel in the system from the network.

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.

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

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

8. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm, in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying upon acronyms or other mnemonics.

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

10. Trend Logs. The operator shall be able to define a custom trend log for any data object in the system. This definition shall include change-of-value digital, change-of-value analog, time interval, start time, and stop time. Trend data shall be sampled and stored on the Building Controller panel, and be archivable on 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.

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.

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

1. Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and setpoints for all controllers.

2. Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and month. This shall consist of a monthly calendar for each schedule. Exception schedules and holidays shall be shown clearly on the calendar. Provide a method for allowing several related objects to follow a schedule. The start and stop times for each object shall be adjustable from this master schedule.

3. Custom Application Programming. Provide the tools to create, modify, and debug custom application programming. The operator shall be able to create, edit, and download custom programs at the same time that all other system applications are operating. *The system shall be fully operable while custom routines are edited, compiled, and downloaded.* The programming language shall have the following features:
   a. The language shall be English language oriented, be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and allow for free-form programming (i.e., not column-oriented or "fill in the blanks").
   b. A full-screen character editor/programming environment shall be provided. The editor shall be cursor/mouse-driven and allow the user to insert, add, modify, and delete custom programming code. It also shall incorporate word processing features such as cut/paste and find/replace.
   c. The programming language shall allow independently executing program modules to be developed. Each module shall be able to independently enable and disable other modules.
   d. The editor/programming environment shall have a debugging/simulation capability that allows the user to step through the program and observe any intermediate values and/or results. The debugger also shall provide error messages for syntax and execution errors.
   e. The programming language shall support conditional statements (IF/THEN/ELSE/ELSE-IF) using compound Boolean (AND, OR, and NOT)

and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

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

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

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

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

5.7 Portable Operator's Terminal. Furnish a Portable Operator's Terminal that shall be capable of accessing all system data. This device may be connected to any point/object on the system network or may be connected directly to any controller for programming, setup, and troubleshooting. This device may be connected to any point/object on the system network or it may be connected directly to controllers using the BACnet PTP (Point-To-Point) Data Link/ Physical layer protocol. The terminal shall use the Read (Initiate) and Write (Execute) Services as defined in Clauses 15.5 and 15.8, respectively, of ASHRAE Standard 135-2001, to communicate with BACnet objects in the internetwork. The Portable Operator's Terminal shall be an IBM compatible notebook-style PC including all software and hardware required. The PC shall contain at minimum:

1. 1,800 MHz Pentium Processor
2. 1 Gigabytes of RAM
3. 60GB Hard Drive
4. CD R-W Disk Drive
5. Touch-pad or Other Internal Pointing Device

5.8 REPORT MANAGEMENT

1. The following reporting capability shall be provided at the operator workstation.

2. Reporting:

   a. Internal reports built into operator workstation software
   b. External reporting via ODBC

3. Internal Reports
   a. User definable query reports (support advanced multiple property, multiple object).
   b. Reports shall be scheduled for automatic generation by schedule or event.
   c. Manual execution to printing/file.
   d. Ability to save report in system report folder.
   e. Query controller hierarchy.
   f. Report to multiple destinations
      i. Email
      ii. Print
      iii. File (text, csv, xml)
      iv. Terminal

4. Enterprise Interface
   a. ODBC driver supporting common SQL statements (select, update, insert, where, order by, group by, etc.)
   b. Allow integration to Enterprise software
   c. Shall be capable of being used with third party software that supports ODBC connection such as: Microsoft Access, Excel, Crystal Reports, etc.
   d. All queries shall be real time into live controller network.
   e. Shall be able to both read and write using SQL.

5.9 Web Browser Interface

1. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Internet Explorer™ or Netscape Navigator™.

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

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

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

    a. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.

5. Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the GUI shall be supported by the Web browser interface.

6. HTML editing of the Web page shall be allowed if the user desires a specific look or format.

7. Storage of the graphical screens shall be in the Server, without requiring any graphics to be stored on the client machine.

8. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.

9. User’s shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
    a. Modify common application objects, such as schedules, calendars, and set points in a graphical manner.

10. Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.

11. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.

12. The system shall provide the capability to specify a user’s (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.

13. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

## 5.10 SERVER FUNCTIONS AND HARDWARE

1. A central server (location TBD) shall be provided. The server shall support all Network Area Controllers connected to the customer’s network whether local or

remote.
Local connections shall be via an Ethernet LAN. Remote connections can be via ISDN, ADSL, T1 or dial-up connection.

2. The server shall provide scheduling for all Area Controllers and their underlying field control devices.

3. The server shall implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of all commands issued to Network Area Controllers. Systems not employing this prioritization shall not be accepted.

4. The server shall provide central management of alarm data for all Network Area controllers supported by the server inclusive of the following:
   a. View and acknowledge alarms

5. Server Hardware Requirements: The server hardware platform shall have the following requirements:
   a. The computer shall be an Intel Pentium P4 based computer (minimum processing speed of 1.8 GHz with 1 GB RAM and a 100-gigabyte minimum hard drive). It shall include a 32x CD RW Drive, 2 10/100 Ethernet cards, 1024x768 True Color Video Card
   b. The server operating system shall be Microsoft XP Professional or Microsoft Windows Server 2003.

## 6. CONTROLLER SOFTWARE

6.1 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

6.2 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.

6.3 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 and optimal start. 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. 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.

6.4 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.

6.5 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 56K baud. Receivers shall be BACnet workstations.

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

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

6.8 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.

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

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

6.11 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.

6.12 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.

6.13 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.

6.14 Lighting Control system shall be manufactured by Delta Controls / supplied by ESC Automation and installed by the electrical contractor. Provide software to allow lighting control functions to be executed by field panels. Features shall include:

1. Flash before off. A flash before going off feature shall be available at each controller to flash the lights on/off an adjustable amount of time before the unoccupied period begins.
2. After hours sweep off. A programmable sweep-off function shall be provided which will shut-off the lighting outputs as scheduled or commanded from local override switch. A time delay shall be provided between each off command. Multiple controllers at the same location shall be cascaded together with a local interlock.
3. Local override switches with remote monitoring of status of switch.
4. True feedback of lighting relays.
5. Interlocks to any system event (scheduling, alarms, card access reads, fan status) for control of lighting zone(s).
6. Web-based override features. An Internet enabled, web-based override feature shall be provided to allow remote after-hours lighting requests via PC's running standard web browsers similar to Microsoft Internet Explorer. The system shall log all after hours requests, allow unique accounts and passwords for each user and provide for an afterhours request totalizer and billing package. The system administrator shall be able to view when an after-hours override request was made, by whom it was made (account or user name) and for how long the override lasted. Provide a means to set individual override time limits. An after-hours totalizer shall be provided for each account/user. Provide a reporting feature that shows the runtime (in hours) for each account and a cost center accounting report that allows each account to be costed/billed for their after hours usage at an adjustable and individually assignable rate (in dollars/hour).
7. Ambient Lighting Control. System shall monitor the ambient lighting effect for perimeter zones using a photovoltaic technology. Dimmable ballasts shall be modulated as required to compensate for the varying ambient lighting intensity. Where 1/3 2/3 lighting fixtures are indicated, system shall control lighting level in perimeter zones to compensate for the ambient lighting effect.

6.15 Access Control system shall be manufactured by Delta Controls / supplied by ESC Automation and installed by the electrical contractor. Access Control. Provide software to allow access control functions to be executed by appropriate field panels. Features shall include:

1. Card Holders.
    a. The system shall handle a minimum of 500 unique card holders.
    b. The system shall support the following information for each card holder:
        i. Full Name.
        ii. Contact information.

iii. Employee ID number.
iv. Email address.
v. Photo ID.
vi. Access Groups that user belongs to (minimum of 4 separate access groups per card user).
vii. Expiration Date of card.

2. Access Groups.
   i. Access rights to specific doors and/or door groups shall be available – provide a minimum of 500 access groups.
   ii. Weekly schedules may be assigned to each access group to allow or exclude access based upon that schedule.
3. Door Groups.
   i. Multiple door strikes shall be assignable to door groups allowing one reader to control multiple doors across the network. One reader may be used for entrance to unlock 2 separate doors.
   ii. Door groups may also be associated with a schedule for convenient locking/unlocking of common functions. For example, all exterior doors.
4. Transaction Logging.
   i. The operator may select which types of transactions to log at each controller.
   ii. Transaction logs are stored at the nearest access control panel in a transaction buffer, and at the central Operator Workstation(s) for remote, long-term transaction storage.
   iii. In the event of a communication outage between the local access controller and the remote Operator Workstation, the local controller will continue to store transaction data for later retrieval by the system.
5. Scheduling.
   i. Weekly schedules (7 day plus 2 separate holiday schedules per weekly schedule) shall be available in the system for assignment to access functions (locking/unlocking doors, allowing access by individuals or groups etc.)
   *ii. The number of schedules available shall not be limited. Provide for at least 12 schedules.*
6. Access Events/Alarms.
   i. Individual Card Users may be flagged for "tracing" all access activity. Every time the flagged user's card is used, an alarm event will be generated alerting the operator (and transaction log) to the event.
   ii. Invalid Card Access attempts may be flagged to generate alarms at any/all readers.
   iii. Use of an unrecognized card (wrong facility code or not in the database) may be flagged to generate an alarm.

iv. Auxiliary input points (motion detectors, etc.) may generate alarm events when in the "off normal" mode.
v. Supervisory messages including battery voltage advisories, doors left open, tamper etc. shall also generate alarm events.

7. Door Handling.
   i. Door strikes shall be controlled by a local door controller. Provide battery backup for the door controller and door strike to ensure security in the event of a power failure. Battery charging circuit and battery status are to be supervised by the system to generate remote alarms in the event of low voltage, or charging problems.
   ii. A push to exit function must be provided for each door strike to allow for supervised overrides of the door strike (unless an exit reader is provided).
8. Auxiliary Point Monitoring.
   i. Each door controller or local area panel, shall be able to monitor the auxiliary points shown on the drawings and/or point list.
9. Sharing Data with The Network.
   i. Card user information shall be passed to the rest of the BAS for use in HVAC and lighting control sequences. If this is not possible, furnish dry contact outputs at the nearest BAS HVAC control panel, fully programmed to pass information regarding valid reads for each card user in the system.

## 7.0 BUILDING CONTROLLERS

7.1 General. Provide an adequate number of Building 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 Energy Management and Control System shall be comprised of one or more independent, standalone, microprocessor-based Building Controllers to manage the global strategies described in the System Software section.

2. The Building Controller shall have sufficient memory to support its operating system, database, and programming requirements.

3. Data shall be shared between networked Building Controllers.

4. The operating system of the Building Controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information, and allow central monitoring and alarms.

5. Controllers that perform scheduling shall have a real-time clock.

6. 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 135-2001.

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

7.2 Communication

1. Each Building Controller shall support BACnet™ over Ethernet and BACnet™ over IP. The Building Controller shall be connected to the BACnet network using the ISO 8802-3 (Ethernet) Data L/ Physical layer protocol.

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/ and/or modem.

4. The Building Controller secondary communication network shall support BACnet MS/TP.

7.3 Environment. Controller hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at 0°C to 40°C [32°F to 100°F] and 10 to 90% RH.

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

7.4 Building Controllers shall be fully peer to peer.

7.5 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.

7.6 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.

7.7 Immunity to power and noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. The Building Controller shall maintain all database information including BIOS and programming information in the event of a power loss for at least 72 hours. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m [3 ft].

7.8 Inputs/Outputs.

1. Inputs. Controller input/output board shall support dry contact, 0-5 VDC and 0-10 VDC- voltage, 4-20 mA- current and thermistor-resistive signal types on an individual basis for connecting any status or sensing device. Analog resolution shall be 10-bit A to D.

2. Outputs. Controller input/output board shall support built in HOA modules configured with manual-auto-off override switch. Output supported shall be 0-10 VDC. All HOA's shall be supervised.

3. Diagnostics. Controller input/output board shall have red LEDs providing input status indication.

4. Building Controller shall have the capability to create, delete and support the following BACnet Objects:
    1. 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.
    2. 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.
    3. CALENDAR: This object shall have the following writeable properties: Object Name; Object Value; Description; and Date List.
    4. DEVICE: This object shall have the following writeable properties: Object Name; Description; Location; and UTC Offset.
    5. EVENT ENROLMENT: This object shall have the following writeable properties: Object Name; Object Value; Description; Out-of-Service; Event & Notify Types; Parameters; Property Ref; Enable; and Notification Class.
    6. FILE: This object shall have the following writeable properties: Object Name; Description; File Type; and File Access.
    7. 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.

8. NOTIFICATION CLASS: This object shall have the following writeable properties: Object Name; Object Value; Description; Priority and Ack Required.
9. PROGRAM: This object shall have the following writeable properties: Object Name; Object Value and Description. In addition, this object shall support the property Reliability.
10. SCHEDULE: This object shall have the following writeable properties: Object Name; Object Value and Description; Effective period; Schedule; Exception; Controlled Properties and Write Properties.

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.

## 8. ADVANCED APPLICATION CONTROLLERS

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

1. The Advanced Application Controller shall have sufficient memory to support its operating system, database, and programming requirements.

2. Advanced Application Controllers shall be fully peer to peer.

3. The operating system of the Controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information, and allow central monitoring and alarms.

4. All equipment that requires scheduling shall be scheduled in that equipments controller.

5. Both firmware and controller database shall be loadable over the network.

6. Advanced Application Controllers shall support the following BACnet Interoperability Building Blocks (BIBBs):

| Data Sharing | Alarm & Event | Scheduling | Trending | Device & Network Mgmt. |
|---|---|---|---|---|
| DS-RP-B | AE-N-B | SCHED-B | | DM-DDB-B |
| DS-RPM-B | AE-ACK-B | | | DM-DOB-B |
| DS-WP-B | AE-ASUM-B | | | DM-DCC-B |
| DS-WPM-B | | | | DM-TS-B |

| | | | | |
|---|---|---|---|---|
| | | | | DM-UTC-B |
| | | | | DM-RD-B |
| | | | | |
| | | | | |

8.2 Communication.

1. Each Advanced Application Controller shall reside on a BACnet network using the MS/TP or Ethernet Data Link/ Physical layer protocol.

2. The controller shall provide a service communication port using BACnet Data Link/ Physical layer protocol for connection to portable operators' workstation and allow access to the entire network.

8.3 Environment. Controller hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at 0°C to 40°C.

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.

8.4 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.

8.5 Memory. The Advanced Application Controller shall be non-volatile FLASH memory.

8.6 Immunity to power and noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to120 Hz and from keyed radios up to 5 W at 1 m.

9. APPLICATION SPECIFIC CONTROLLERS

9.1 General. Application Specific Controllers (ASCs) are microprocessor-based DDC controllers which through hardware or firmware design are able to control a wide variety of equipment. They are fully user-programmable, and are not restricted to any one type of equipment.

1. Each ASC shall be capable of standalone operation and shall continue to provide control functions without being connected to the network

2. Each ASC will contain sufficient I/O capacity to control the target system.

3. Both firmware and controller database shall be loadable over the network

4. Application Specific Controllers shall be fully peer to peer

5. ASC's shall come with an integrated housing to allow for easy mounting and protection of the circuit board. Only wiring terminals shall be exposed.

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

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

9.2 Communication

1. The controller shall reside on a BACnet network using the MS/TP Data Link/ Physical layer protocol.

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

3. Each controller shall have a secondary sub network for communicating sensors or I/O expansion modules

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

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at -40°C to 65°C [-40°F to 150°F] and/or suitably installed in a heated or fan cooled enclosure

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

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

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

9.6 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].

9.7 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.

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

9.9 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 Workstations installed for this project shall not require any hardware additions or software revisions in order to expand the system.

## 10. AUXILIARY CONTROL DEVICES

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

10.2 Electric damper/valve actuators.

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

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

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

10.3 Control valves.

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

2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
   a. Water Valves:
      i. Two-way: 150% of total system (pump) head.
      ii. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
   b. Steam Valves: 150% of operating (inlet) pressure.

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.

4 Steam Valves:

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

10.4 Binary Temperature Devices

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

10.5 Temperature sensors.

1. Temperature sensors shall be thermistors.

2. Space sensors shall be equipped with the following:

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

3. Provide matched temperature sensors for differential temperature measurement.

10.6 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 .

4. Humidity sensor's drift shall not exceed 3% of full scale per year.

10.7 Flow switches.

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

10.8 Pressure transducers

1. Transducer shall have linear output signal. Zero and span shall be field-adjustable.

2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage

3. Water pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Transducer shall be complete with 1 - 5vdc or 4 to 20 mA output, required mounting brackets, and block and bleed valves.

4. Water differential pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall be complete with 1 – 5vdc or 4 to 20 mA output, required mounting brackets, and five-valve manifold.

10.9 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.

10.10 Pressure-Electric (PE) Switches

1. Shall be metal or neoprene diaphragm actuated, operating pressure rated 0–175 kPa [0–25 psig], with calibrated scale setpoint range of 14–125 kPa [2–18 psig] minimum, UL listed

2. Provide one- or two-stage switch action SPDT, DPST, or DPDT, as required by application.

3. Shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified

4. Shall have a permanent indicating gauge on each pneumatic signal line to PE switches.

10.11 Electro-pneumatic (E/P) transducers

1. Electronic/pneumatic transducer shall provide a proportional 20 to 100 kPa [3 to 15 psig] output signal from a 0 to 10 VDC analog control input.

10.12 Local control panels

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with [hinged door], key-lock latch, removable sub-panels. A single key shall be common to all field panels and sub-panels

2. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. 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 120v receptacle at each local panel location.

## 11 WIRING AND RACEWAYS

11.1 General: Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 16.

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

## 12 LIGHTING CONTROL HARDWARE

12.1 Lighting controllers shall directly communicate with the rest of the EMCS network via BACnet MSTP at 76,800 baud.

12.2 The lighting controllers shall have independent time of day schedules and annual holiday schedules which run independent of the rest of the network. If the controller looses communication with the network, it shall continue to execute its on/off schedule and lighting interlocks.

12.3 Each lighting controller shall have sufficient capacity to switch the scheduled circuits and provide 10% capacity for future expansion. No additional control hardware other than lighting relays shall be necessary to add the 10% capacity in the future.

12.4 Provide the low voltage lighting control switches shown on the drawings. Each override switch shall be a separately recognized binary input to the controller. The controller shall be fully programmable to allow any override switch to be associated with any output zone or multiple zones.

12.5 All of the lighting controllers shall communicate with each other as peers. They will not be dependent upon passing data to a PC or another "master panel." Inputs to one lighting controller will be passed to any other controller on the network for interlocking or auxiliary control functions.

12.6. Standard lighting control relays similar to the GE RR7/RR9 series shall be used for reliability, ease of serviceability and availability of replacement parts. Use of proprietary printed circuit board style relays is not acceptable. Feedback from the lighting control relays will indicate the current status of the lighting control relay. If the relay does not respond to the commanded condition from the controller, an alarm event shall be generated and broadcast to the network.

## 13. ACCESS CONTROL HARDWARE

13.1 Provide ACS card readers at locations shown on drawings. Card readers shall, at a minimum:

1. Use proximity technology.
2. Have a multicolor LED displaying green upon a valid read (and door unlocked), red upon invalid read (and door locked), amber upon startup and standby.
3. Be AWID SR-2400 Sentinel Prox or approved equal for indoor & outdoor installations and AWID MR-1824 Sentinel Prox for garage installations.

13.2 Provide access cards. The cards shall at minimum be:

1. Credit card sized ISO standard, white in color.
2. Slot punched on the short side and fitted with detachable clips.
3. Passive proximity cards – no battery.
4. Encoded with unique ID code.
5. Capable of direct printing of video image, both sides.
6. AWID ProxLinc-GR or approved equal.

13.3 Keypads. The system shall support single and combo keypads.

1. Keypads can be used in combination with a card reader, or on their own.
2. When used in combination with a card reader, a valid card swipe must be accompanied by a valid PIN entry.
3. When used standalone, the keypad essentially takes place of the card reader, and the user need only enter a valid PIN code to gain access. These options are selected from within the Door Controller object.

## 14. Execution

SECTION INCLUDES

1. Examination
2. Protection
3. Coordination
4. General Workmanship
5. Field Quality Control
6. Existing Equipment
7. Wiring
8. Communication Wiring
9. Fiber Optic Cable
10. Control Air Tubing
11. Installation of Sensors
12. Flow Switch Installation
13. Actuators
14. Warning Labels
15. Identification of Hardware and Wiring
16. Controllers
17. Programming
18. Control System Checkout and Testing
19. Control System Demonstration and Acceptance
20. Cleaning
21. Training
22. Sequences of Operation

### 14.1 EXAMINATION

1. 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

2. 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

3. 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.

14.2 PROTECTION

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

2. 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

14.3 COORDINATION

1. Site

    1. Where the mechanical work will be installed in close proximity to, or will interfere with work of other trades, the Contractor shall assist in working out space conditions to make a satisfactory adjustment. If the Contractor installs its work before coordinating with other trades, so as to cause any interference with work of other trades, the Contractor shall make the necessary changes in its work to correct the condition without extra charge

    2. Coordinate and schedule work with all other work in the same area, or with work which is dependent upon other work, to facilitate mutual progress.

2. Submittals. Refer to the “Submittals” Article in Part 1 of this specification for requirements

3. Test and Balance

    1. The Contractor shall furnish all tools necessary to interface to the control system for test and balance purposes

    2. The Contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours

    3. In addition, the Contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.

    4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

4. Life Safety

1. Duct smoke detectors required for air handler shutdown are supplied and installed under Division 16. The Division 16 Contractor shall interlock smoke detectors to air handlers for shutdown as described in Part 3: “Sequences of Operation”.

2. Smoke dampers and actuators required for duct smoke isolation are provided under another Division 15 Section

3. Fire/smoke dampers and actuators required for fire rated walls are provided under another Division 15 Section. Control of these dampers shall be by Division 16.

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

1. All communication media and equipment shall be provided as specified in Part 2: “Communication” of this specification.

2. Each supplier of controls product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequences of operation described in this section.

3. The Contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this Section and those provided under other sections or divisions of this specification.

14.4 GENERAL WORKMANSHIP

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

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

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

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

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

## 14.5 FIELD QUALITY CONTROL

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

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

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

## 14.6 EXISTING EQUIPMENT

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

2. Pneumatic Tubing: The Contractor may reuse any redundant pneumatic tubing. The integrity of the tubing and its proper application to the installation is the responsibility of the Contractor. The tubing shall be properly identified and tested as per this specification. Unused or redundant tubing must be removed, or where this is not possible, properly identified

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

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

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

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

7. Room Thermostats: Unless specifically noted otherwise, shall become the property of the Contractor.

8. Electronic Sensors and Transmitters: Unless specifically noted otherwise, shall become the property of the Contractor.

9. Controllers and Auxiliary Electronic Devices: Unless specifically noted otherwise, shall become the property of the Contractor.

10. Pneumatic Controllers, Relays and Gauges: Unless specifically noted otherwise, shall become the property of the Contractor.

11. Damper Actuators, Linkages and Appurtenances: Unless specifically noted otherwise, shall become the property of the Contractor.

12. Control Valves: Unless specifically noted otherwise, shall become the property of the Contractor.

13. Control Compressed Air System: Unless specifically noted otherwise, shall become the property of the Contractor.

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

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

16. Install control panels where shown

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

18. Patch holes and finish to match existing

14.7 WIRING

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

2. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway per NEC and Division 26 requirement.

3. 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.)

## 14.8 ACTUATORS

1. 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.

2. 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.

## 14.9 IDENTIFICATION OF HARDWARE AND WIRING

1. All wiring and cabling, including that within factory-fabricated panels, shall be labelled at each end within 5 cm of termination with the DDC address or termination number.

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

3. Identify control panels with minimum 1 cm letters on laminated plastic nameplates.

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

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

## 14.10 CONTROLLERS

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

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

required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point/object used.

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

14.11 PROGRAMMING

1. 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.

2. Point/object Naming: System point/object names shall be modular in design, allowing easy operator interface without the use of a written point/object index. Use the following naming convention:

AAABBBCCCDDDEEE where:

AAA is used to designate the location of the point/object 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).

*CC*C 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).

3. Software Programming

1. Provide programming for the system and adhere to the sequences of operation provided. The Contractor also shall provide all other system programming necessary for the operation of the system, but not specified in this document. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:
   a. Text-based:
      i. must provide actions for all possible situations
      ii. must be modular and structured

iii. must be commented

b. Graphic-based
   i. must provide actions for all possible situations
   ii. must be documented

c. Parameter-based
   i. must provide actions for all possible situations
   ii. must be documented

4. 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 Sow terminal equipment information on a "graphic" summary table. Provide dynamic information for each point/object show

3 The Contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all Operator Workstation software and their functions as described in this section. This includes any operating system software, the Operator Workstation database, and any third-party software installation and integration required for successful operation of the operator interface

## 14.12 CONTROL SYSTEM CHECKOUT AND TESTING

1. 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

## 14.13 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

1. Demonstration
    1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed its own tests

    2. The tests described in this section are to be performed in addition to the tests that the Contractor performs as a necessary part of the installation, startup, and debugging process and as specified in the “Control System Checkout and Testing” Article in Part 3 of this specification. The Engineer will be present to observe and review these tests. The Engineer shall be notified at least 10 days in advance of the start of the testing procedures.

    3. The demonstration process shall follow that approved in Part 1: “Submittals.” The approved checklists and forms shall be completed for all systems as part of the demonstration

    4. The Contractor shall provide at least two persons equipped with two-way communication, and shall demonstrate actual field operation of each control and

sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point/object and system. Any test equipment required to prove the proper operation shall be provided by and operated by the Contractor.

5. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.

6. Demonstrate compliance with Part 1: “System Performance

7. Demonstrate compliance with Sequences of Operation through all modes of operation

8. Demonstrate complete operation of Operator Workstation

9. Additionally, the following items shall be demonstrated:

    a) DDC Loop Response. The Contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in setpoint, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the setpoint, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
    b) Demand limiting. The Contractor shall supply a trend data output showing the action of the demand-limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting setpoint, and the status of shed-able equipment outputs.
    c) Optimum Start/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.

2. 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."

14.14 CLEANING

1. 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.

2. 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.

3. 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.

14.15 TRAINING

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

2. Train the designated staff of Owner's Representative and Owner to enable Day-to-day Operators to:
   1. Proficiently operate the system.
   2. Understand control system architecture and configuration.
   3. Understand DDC system components.

4. Understand system operation, including DDC system control and optimizing routines (algorithms).
5. Operate the workstation and peripherals.
6. Log on and off the system.
7. Access graphics, point/object reports, and logs.
8. Adjust and change system setpoints, time schedules, and holiday schedules.
9. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals.
10. Understand system drawings, and Operation and Maintenance manual.
11. Understand the job layout and location of control components.
12. Access data from DDC controllers and ASC.
13. Operate portable operator's terminals.

3. Train the designated staff of Owner’s Representative and Owner to enable Advanced Operators to:

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

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

    8. Maintain software and prepare backups
    9. Interface with job-specific, third-party operator software
    10. Add new users and understand password security procedures
    11.
5. 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.

6. The instructor(s) shall be factory-trained instructors experienced in presenting this material.
7. Classroom training shall be done using a network of working controllers representative of the installed hardware.

14.16 SEQUENCES OF OPERATION

1. As required to provide a fully functioning system.

14.17 POINTS LIST

1. As required to provide a fully functioning system.