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.
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. Video Training. Provide on-line video support to supplement on-line help assistance. Video content shall be relevant and support existing system documentation.
6. Security. Each operator shall be required to log on to the system with user name and password in order to view, edit, add, or delete data.
    a. Operator Access. The user name and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.
    b. Password Policy Rules. System administrator shall invoke policies for minimum password strength, including number of characters, special characters and numbers, upper and lower case, etc.
    c. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time period shall be user-adjustable.
    d. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.
7. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.
8. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as required by sequences of operation. Alarms shall be BACnet alarm objects and shall use BACnet alarm services. BMS system shall be capable of assigning alarm sources to categories such as HVAC Critical, or HVAC General. The BMS shall include at a minimum HVAC and FDD categories. BMS system shall allow user to create custom alarm categories.
9. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms or mnemonics.
10. Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send SMS text, and audibly annunciate.

11. Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms, and archive closed alarms to the workstation or web server hard disk.
12. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified by the sequences of operation. Trends shall be BACnet trend objects.
13. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.
14. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
15. Audit and Security Detail. All users accessing the system shall have their actions recorded. Information recorded shall include:
    a. Login/logout time and date
    b. System modifications - with before and after values
    c. Ability to report user activity based on individual and/or date and time.
16. Standard Reports. Furnish the following standard system reports:
    a. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
    b. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    c. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:
        i. Alarm History.
        ii. Trend Data. Operator shall be able to select trends to be logged.
17. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface. Operator shall be able to schedule reports to automatically run and be emailed to recipients on a recurring basis from the BMS system.
18. Logic Page. System shall allow operator to view all application software in real time for all controllers furnished and installed by BMS manufacturer.
19. Environmental Index. System shall monitor all occupied zones and compile an index that provides a numerical indication of the environmental comfort within the zone. As a minimum, this indication shall be based upon the deviation of the zone temperature from the heating or cooling setpoint. If humidity is being measured within the zone then the environmental index shall be adjusted to reflect a lower comfort level for high or low humidity levels. Similarly, if carbon dioxide levels are being measured as an indication of ventilation effectiveness then the environmental index shall be adjusted to indicate degraded comfort at high carbon dioxide levels.

Other adjustments may be made to the environmental index based upon additional measurements. The system shall maintain a trend of the environmental index for each zone in the trend log. The system shall also compute an average comfort index for every building included in this contract and maintain trendlogs of these building environmental indices. Similarly, the system shall compute the percentage of occupied time that comfortable conditions were maintained within the zones. Through the UI the user shall be able to add a weighting factor to adjust the contribution of each zone to the average index based upon the floor area of the zone, importance of the zone, or other static criteria.

20. Time Span Graphic Replay. Operator shall be able to "replay" any graphic in the system to see how key values changed over an operator-selected period of time. Operator shall be able to select the starting date/time for this display and the end date/time or the display period. System shall then display the graphic as it would have looked at the beginning of that period, displaying key data, dynamic colors, etc. based upon values recorded at the start time. When the operator starts the replay the graphics and key values shall dynamically change to produce the effect of "fast forwarding" through the designated period of time. Once the system has been operational for at least 30 days, the contractor shall demonstrate that up to 24 hours of data from within the last 30 days can be replayed on any graphic page. Owner's representative shall choose the graphic pages for this demonstration at the time of the demonstration.
21. Semantic Tagging. The BMS system shall include a semantic tagging engine that uses the Project Haystack library of descriptive tagging for building equipment and systems used in the BMS. The Project Haystack naming tags used by the BMS shall be a library that includes a comprehensive list of standard tag names to address common equipment, building systems, and device types. The library of tag names shall include at a minimum the tag names listed in ASHRAE Standard 223P.

F. Workstation Application Editors. Each PC or browser workstation shall support editing of all system applications. 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 set points 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 schedule type. Exception schedules and holidays shall be shown clearly on the calendar. The start and stop times for each object shall be adjustable from this interface.
   3. Custom Application Programming. Provide the tools to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:
      a. Language. Language shall be graphically based or English oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall

allow for free-form programming that is not column-oriented or "fill-in-the-blanks."

b. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
c. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
d. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
e. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
f. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.
g. Variables. Operator shall be able to use variable values in program conditional statements and mathematical functions.
    i. Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.
    ii. System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

2.4 Controller Software

A. All controller software applications shall reside and operate in the system controllers.
B. All application software in controllers furnished by BMS manufacturer shall be editable through operator workstation, web browser interface, or workstation.
C. Each controller furnished by BMS manufacturer shall have all of its local on board software applications backed up and saved to the BMS web server. In the event of a controller failure, the BMS server shall download backed up software applications to replacement controller. Controllers furnished by others and integrated into the BMS are not required to be backed up to BMS server.
D. Furnish the following applications for building and energy management:
    1. System Security.

2. Scheduling. Provide the capability to execute control functions according to a user created or edited schedule. Each schedule shall provide the following schedule options as a minimum:
    a. Weekly Schedule. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
    b. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule has executed, the system shall discard and replace the exception schedule with the standard schedule for that day of the week.
    c. Holiday Schedules. Provide the capability for the operator to define up to 24 special or holiday schedules. These schedules will be repeated each year. The operator shall be able to define the length of each holiday period.
3. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.
4. Binary Alarms. Each binary object shall have the capability to be configured to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
5. Analog Alarms. Each analog object shall have both high and low alarm limits. The operator shall be able to enable or disable these alarms.
6. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display on graphics.
7. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.
8. Demand Limiting.
    a. The demand-limiting program shall monitor building power consumption from a building power meter (provided by others) which generates pulse signals or a BACnet communications interface. An acceptable alternative is for the system to monitor a watt transducer or current transformer attached to the building feeder lines.
    b. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified in in sequences of operation. When demand drops below adjustable levels, system shall restore loads as specified.
9. Maintenance Management. The system shall be capable of generating maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in sequences of operation.
10. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in sequences of operation.
11. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-

varying analog value that can be used to position an output or to stage a series of outputs. The calculation interval, PID gains, and other tuning parameters shall be adjustable by a user with the correct security level.

12. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.
13. Energy Calculations.
    a. The system shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
    b. The system shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.
14. Anti-Short Cycling. All binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.
15. On and Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and a setpoint. The algorithm shall be direct-acting or reverse-acting.
16. Runtime Totalization. Provide software to totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as required by sequences of operation.

2.5 Controllers

A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified by system performance. Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of communicating actuators, communicating sensors, BACnet Smart Actuators and BACnet Smart Sensors.

B. BACnet.
    1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
    2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
    3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
    4. Smart Actuators (SAs). An actuator which is controlled by a network connection rather than a binary or analog signal (0-10v, 4-20mA, relay, etc.). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in

ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.

5. Smart Sensors (SSs). A sensor which provides information to the BAS via network connection rather than a binary or analog signal (0-10000 ohm, 4-20mA, dry contact, etc.). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
6. BACnet Communication.
    a. Building Controllers (BC). Each BC shall connect to a network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol using BACnet/IP or BACnet/SC.
    b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
    c. Each AAC shall connect to a network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol using BACnet/IP or BACnet/SC.
    d. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    e. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

C. Security.
    1. Provide BACnet firewall capability, as defined in the BACnet standard.
D. Building Controllers (BC)
    1. Communication
        a. Network Connection. Controller shall support a single point ethernet connection.
        b. Ethernet Port. Provide one (1) Gig-E port capable of full duplex communication up to 1000 Mbps
        c. Service Port. Provide one (1) ethernet port for connection to a Portable Operator's Terminal.
        d. Serial Port. Provide two (2) serial ports for communication to serial BACnet or serial Modbus networks.
        e. Signal Management. BC shall have the ability to manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
        f. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
        g. Stand-Alone Operation. Each piece of equipment shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

2. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
    a. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
    b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory
    a. Controller memory shall support operating system, database, and programming requirements.
    b. Each BC shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

E. Advanced Application/Specific Controllers (AAC/ASC)
1. Communication
    a. Network Connection. Controller shall support a single point ethernet connection or a daisy-chained ethernet connection using the Spanning Tree Protocol (STP).
    b. Ethernet Port. Provide two (2) 10/100 Base T ethernet ports with ethernet switching capability.
    c. Service Port. Provide one (1) USB port for connection to a Portable Operator's Terminal or a display.
    d. Serial Port. Provide two (2) serial ports for communication to serial BACnet or serial Modbus networks.
    e. Stand-Alone Operation. Each piece of equipment shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.
2. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
    a. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
    b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory
    a. Controller memory shall support operating system, database, and programming requirements.
    b. Each AAC shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

F. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
G. Transformer. Power supply shall be fused or current limiting and shall be rated at a minimum of 125% of controller power consumption.

2.6 Input and Output Interface

A. General. Hard-wire input and output points to BCs, AACs, or ASCs.
B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.
C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. Binary inputs shall sense dry contact closure without application of power external to the controller.
D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.
E. Analog Inputs. Analog inputs shall monitor low-voltage (0–10 Vdc), current (4–20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.
F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on Building Controllers shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.
G. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0–10 Vdc or a 4–20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.
H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

J. Communicating Sensors. Controller shall be capable of using hardwired sensors or an option of using communicating sensors connected to a dedicated sensor network port. The dedicated sen-sor network shall be capable of monitoring the following communicating sensors:
   1. Temperature
   2. Humidity
   3. CO2
   4. VOC
   5. Occupancy
   6. Motion

2.7 Power Supplies and Line Filtering

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
   1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
      a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
      b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.
   1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
      a. Dielectric strength of 1000 V minimum
      b. Response time of 10 nanoseconds or less
      c. Transverse mode noise attenuation of 65 dB or greater
      d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

2.8 Auxiliary Control Devices

A. Motorized Control Dampers, unless otherwise specified elsewhere, shall be as follows:
   1. Type. Control dampers shall be the parallel- or opposed-blade type as specified below or as scheduled on drawings.
      a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
      b. Other modulating dampers shall be opposed-blade.
      c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.

2. Frame. Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (⅛ in.) extruded aluminum with reinforced corner bracing.
3. Blades. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).
4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 50 L/s·m^2 (10 cfm per ft^2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).
6. Sections. Individual damper sections shall not exceed 125 cm × 150 cm (48 in. × 60 in.). Each section shall have at least one damper actuator.
7. Modulating dampers shall provide a linear flow characteristic where possible.
8. Linkages. Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators.
1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range. Proportional actuators shall accept a 0–10 Vdc or a 0–20 mA control signal and shall have a 2–10 Vdc or 4–20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)
4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.

C. Control Valves.
1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.
2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
    a. Water Valves:
        i. Two-way: 150% of total system (pump) head.
        ii. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
    b. Steam Valves: 150% of operating (inlet) pressure.
3. Water Valves.
    a. Body and trim style and materials shall be in accordance with manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.
    b. Sizing Criteria:
        i. Two-position service: Line size.

ii. 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.
iii. Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 35 kPa (5 psi) maximum.

c. Valves ½ in. through 2 in. shall be bronze body or cast brass ANSI Class 250, spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or stainless steel ball.
d. Valves 2½ in. and larger shall be cast iron ANSI Class 125 with guided plug and PTFE packing.
e. Water valves shall fail normally open or closed, as scheduled on plans, or as follows:
i. Water zone valves—normally open preferred.
ii. Heating coils in air handlers—normally open.
iii. Chilled water control valves—normally closed.
iv. Other applications—as scheduled or as required by sequences of operation.

4. Steam Valves.
a. Body and trim materials shall be in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service.
b. Sizing Criteria:
i. Two-position service: pressure drop 10% to 20% of inlet psig.
ii. Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig.
iii. Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig.
iv. Modulating service: over 350 kPa (50 psig); pressure drop as scheduled on plans.

D. Temperature Sensors.
1. Type. Temperature sensors shall be thermistor (10k Type2).
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2(10 ft^2) of duct cross-section.
3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.

E. Humidity Sensors.
1. Duct and room sensors shall have a sensing range of 20%–80%.
2. Duct sensors shall have a sampling chamber.

3. Outdoor air humidity sensors shall have a sensing range of 20%–95% RH and shall be suitable for ambient conditions of -40°C–75°C (-40°F–170°F).
4. Humidity sensors shall not drift more than 1% of full scale annually.

F. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

G. Relays.
1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED “energized” indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

H. Override Timers.
1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0–6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

I. 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 4–20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

J. Current Transformers.
1. AC current transformers shall be UL/CSA recognized and shall be 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. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

K. Voltage Transmitters.
1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4–20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100–130 Vac, 200–250 Vac, 250–330 Vac, and 400–600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

L. Voltage Transformers.
   1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
   2. Transformers shall be suitable for ambient temperatures of 4°C–55°C (40°F–130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
   3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

M. Power Monitors.
   1. Selectable rate pulse output for kWh reading, 4–20 mA output for kW reading, N.O. alarm contact, and ability to operate with 5.0 amp current inputs or 0–0.33 volt inputs.
   2. 1.0% full-scale true RMS power accuracy, +0.5 Hz, voltage input range 120–600 V, and auto range select.
   3. Under voltage/phase monitor circuitry.
   4. NEMA 1 enclosure.
   5. Current transformers having a 0.5% FS accuracy, 600 VAC isolation voltage with 0–0.33 V output. If 0–5 A current transformers are provided, a three-phase disconnect/shorting switch assembly is required.

N. Hydronic Flowmeters
   1. Insertion-Type Turbine Meter
      a. Dual counter-rotating axial turbine elements, each with its own rotational sensing system, and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion. Single turbine for piping 2 inches and smaller. Flow sensing turbine rotors shall be non-metallic and not impaired by magnetic drag.
      b. Insertion type complete with 'hot-tap' isolation valves to enable sensor removal without water supply system shutdown.
      c. Sensing method shall be impedance sensing (non magnetic and non photoelectric)
      d. Volumetric accuracy
         i. ± 0.5% of reading at calibrated velocity
         ii. ± 1% of reading from 3 to 30 ft/s (10:1 range)
         iii. ± 2% of reading from 0.4 to 20 ft/s (50:1 range)
      e. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer's primary standards which must be accurate to within 0.1% of flow rate and traceable to the National Institute of Standards and Technology (NIST).
      f. Maximum operating pressure of 400 psi and maximum operating temperature of 95°C (200°F) continuous or 105°C (220°F) peak.
      g. All wetted metal parts shall be constructed of 316 stainless steel.
      h. Analog outputs shall consist of non interactive zero and span adjustments, a DC linearly of 0.1% of span, voltage output of 0-10 Vdc, and current output of 4-20 mA.
   2. Magnetic Flow-Tube Type Flowmeter
      a. Sensor shall be a magnetic flowmeter, which utilizes Faraday's Law to measure volumetric fluid flow through a pipe. The flowmeter shall consist of two elements, the sensor and the electronics. The sensor shall generate a

measuring signal proportional to the flow velocity in the pipe. The electronics shall convert this EMF into a standard current output.

b. Electronic replacement shall not affect meter accuracy (electronic units are not matched with specific sensors).
c. Four-wire, externally powered, magnetic type flow transmitter with adjustable span and zero, integrally mounted to flow tube. Output signal shall be a digital pulse proportional to the flow rate (to provide maximum accuracy and to handle abrupt changes in flow). Standard 4-20 mA or 0-10 Vdc outputs may be used provided accuracy is as specified.
d. Flow Tube:
    i. ANSI class 150 psig steel
    ii. ANSI flanges
    iii. Protected with PTFE, PFA, or ETFE liner rated for 102°C (245°F) minimum fluid temperature
e. Electrode and grounding material
    i. 316L Stainless steel or Hastelloy C
    ii. Electrodes shall be fused to ceramic liner and not require o-rings.
f. Electrical Enclosure: NEMA 4, 7
g. Approvals:
    i. UL or CSA
    ii. NSF Drinking Water approval for domestic water applications
h. Performance
    i. Accuracy shall be ±0.5% of actual reading from 3 to 30 ft/s flow velocities, and 0.015 ft/s from 0.04 to 3 ft/s.
    ii. Stability: 0.1% of rate over six months.
    iii. Meter repeatability shall be ±0.1% of rate at velocities > 3 ft/s.

3. Magnetic Insertion-Type Flowmeter
    a. Magnetic Faraday point velocity measuring device.
    b. Insertion type complete with “hot-tap” isolation valves to enable sensor removal without water supply system shutdown.
    c. 4-20 mA transmitter proportional to flow or velocity.
    d. Accuracy: larger of 1% of reading and 0.2 ft/s.
    e. Flow range: 0.2 to 20 ft/s, bidirectional.
    f. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer’s primary standards which must be accurate to within 0.1% of flow rate and traceable to the National Institute of Standards and Technology (NIST).
4. Vortex Shedding Flowmeter
    a. Output: 4-20 mA, 0-10 Vdc, 0-5 Vdc.
    b. Maximum Fluid Temperature: 427 °C (800ºF).
    c. Wetted Parts: Stainless Steel.
    d. Housing: NEMA 4X.
    e. Turndown: 25:1 minimum.
    f. Accuracy: 0.5% of calibrated span for liquids, 1% of calibrated span for steam and gases.
    g. Body: Wafer style or ANSI flanged to match piping specification.
5. Transit-Time Ultrasonic Flowmeter

a. Clamp-On transit-time ultrasonic flowmeter
b. Wide-Beam transducer technology
c. 4-20 mA transmitter proportional to flow or velocity.
d. Accuracy: 0.5% of reading in range 1 to 30 ft/s, 0.001 ft/s sensitivity.

O. Thermal Energy Meters
1. Matched RTD, solid state, or thermistor temperature sensors with a differential temperature accuracy of ±0.08°C (±0.15°F).
2. Flow meter: See "Hydronic Flowmeters" section.
3. Unit accuracy of ±1% factory calibrated, traceable to NIST with certification.
4. NEMA 1 enclosure.
5. Panel mounted display.
6. UL listed.
7. Isolated 4–20 ma signals for energy rate and supply and return temperatures and flow.

P. Current Switches.
1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

Q. Pressure Transducers.
1. Transducers shall have linear output signal and field-adjustable zero and span.
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 diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4–20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300psi.) Transducer shall have 4–20 mA output, suitable mounting provisions, and 5-valve manifold.

R. Differential Pressure Switches.
1. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

S. Pressure-Electric (PE) Switches.
1. Shall be metal or neoprene diaphragm actuated, operating pressure rated for 0–175 kPa (0–25 psig), with calibrated scale minimum 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. Electrically rated for pilot duty service (125 VA minimum) and/or for motor control.
3. Switches shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
4. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

T. Occupancy Sensors.
1. Occupancy sensors shall utilize Passive Infrared (PIR) and/or Microphonic Passive technology to detect the presence of people within a room. Sensors shall be

mounted as indicated on the approved drawings. The sensor output shall be accessible by any lighting and/or HVAC controller in the system. Occupancy sensors shall be capable of being powered from the lighting or HVAC control panel, as shown on the drawings. Occupancy sensor delay shall be software adjustable through the user interface and shall not require manual adjustment at the sensor.

U. Communicating Sensors
   1. General
      a. Sensors shall communicate with DDC controller via sensor network rather than connect via standard controller input.
      b. Provide communicating sensors where required per the plans or spec. Communicating sensors may be submitted as a voluntary value engineering substitute if appropriate for the application.
      c. Combination temperature and humidity shall be provided where all conditions are required to be sensed.
      d. Duct temperature sensors shall be used where not affected by temperature stratification or where ducts are smaller than 9 sq ft. (1 sq m). The length of the sensor shall be a minimum of one-third of the width of the duct with a maximum length of 8".
      e. Averaging temperature sensors shall be used where prone to temperature stratification or where ducts are larger than 9 sq ft (1 sq m); length as required. The length of the sensor shall be 8' minimum or 1 linear foot per every 1 sq ft of cut cross section, whichever is greater.
      f. All sensor housings, other than space sensors, shall be provided with threaded conduit entrance.
      g. All sensors shall include the following:
         i. Power Requirements: 12 Vdc @ 210 mA unless otherwise indicated, power to be supplied by controller via communication cable
         ii. Communication speed: 115 kbps minimum
         iii. Sensor shall be equipped with a local communication port that allows plug in to a laptop for maintenance and commissioning
         iv. Compliance United States of America: FCC Part 15-Subpart B-Class B, CE
   2. Outside Air Sensors
      a. Outside Air Temperature Sensors
         i. Sensor: Thermistor type
         ii. Range: -40°F to 158°F (-40°C to 70°C)
         iii. Accuracy: ±1.3°F (0.72°C)
         iv. Enclosure: Designed to protect sensors from elements while providing air circulation, made of UV-resistant Polycarbonate with NEMA 4, IP66 rating and UL94V-0 flammability rating
         v. Provide Automated Logic ZSO-S-2-6-B or approved equal
      b. Outside Air Humidity Sensors
         i. Sensor shall be integral to outside air temperature sensor housing
         ii. Range: 10 to 90% RH
         iii. Accuracy: ±2% at less than 0.5% drift per year
         iv. Provide Automated Logic ZSO-SH-2-6-B or approved equal
   3. Space Sensors

a. Space Temperature Sensors
   i. Sensor shall be thermistor type
   ii. Range: -4°F to 122°F (-20°C to 50°C)
   iii. Accuracy: ±0.35°F
   iv. Environmental Operating Range: 32°F to 122°F (0° to 50°C), 10% to 90% RH, non-condensing
   v. Options for LCD display, alarm indicator, setpoint adjustment and fan override shall be provided for where called for on the plan or in the sequence of operation
   vi. Mounting via standard 4" x 2" electrical box
b. Space Humidity Sensors
   i. Sensor shall be integral to space temperature sensor housing
   ii. Range: 10 to 90% RH
   iii. Accuracy: ±1.8%
   iv. Environmental Operating Range: 32°F to 122°F (0°C to 50°C), 10% to 90% RH, non-condensing
c. Space Carbon Dioxide Sensors
   i. Sensor shall be integral to space temperature sensor housing
   ii. Range: 400 to 2000 ppm
   iii. Accuracy: greater of ±30 ppm or ±3% from 400 to 1250 ppm and ±5% from 1250 to 2000 ppm
   iv. Power Requirements: 12 Vdc @ 190 mA
   v. Environmental Operating Range: 32°F to 122°F (0° to 50°C), 10% to 90% RH, non-condensing
d. Space VOC Sensors
   i. Sensor shall be integral to space temperature sensor housing
   ii. Range: 0 to 2000 ppm
   iii. Accuracy: ±100 ppm
   iv. Power Requirements: 12 Vdc @ 60 mA
   v. Environmental Operating Range: 32°F to 122°F (0° to 50°C), 10% to 90% RH, non-condensing
e. Space Motion Sensor
   i. Sensor shall be integral to space temperature sensor housing
   ii. Passive infrared (PIR) type with effective range of 16.4 ft (5 m)
   iii. Motion effective detection angle: 102° x 82°
f. Provide the following Automated Logic models with features as required or approved equal:

Features	Model				
	ZS Standard	ZS Plus	ZS Pro	ZS Pro-M	ZS Pro-F
Temp	×	×	×	×	×
RH Available		×	×	×	×
CO2 Available		×	×	×	×
VOC Available		×	×		×

Motion Sensing				×	
Fan Speed Control					×
Clg/Htg/Fan Only Mode Control					×
°F to °C Conversion Button					×
Push Button Override		×	×	×	×
Setpoint Adjust		×	×	×	×
LCD Display			×	×	×
Alarm Indicator			×	×	×

4. Duct Sensors
    a. Duct Point Temperature Sensors
        i. Sensor: Thermistor type
        ii. Range: 20°F to 120°F (-5°C to 50°C)
        iii. Environmental Operating Range: -40° to 158°F (-40°C to 70°C), 0-100% RH, non-condensing
        iv. Accuracy: ±0.36°F (0.5°C)
        v. Enclosure: Polycarbonate with NEMA 4, IP66 rating and UL94V-0 flammability rating, closed cell foam shall be utilized to seal the insertion hole and absorb vibration
        vi. Probe: Stainless steel of sufficient length (4" or 8") for size of duct.
        vii. Provide Automated Logic ZSD-B-X-6-B or approved equal
    b. Duct Humidity Sensors
        i. Sensor shall be integral to duct temperature sensor housing
        ii. Range: 10 to 90% RH
        iii. Environmental Operating Range: -40°F to 158°F (-40°C to 70°C), 0-100% RH, non-condensing
        iv. Accuracy: ±2% at less than 0.5% drift per year
        v. Provide Automated Logic ZSD-BH-6-6-B or approved equal
    c. Averaging Temperature Sensors
        i. Sensor: Thermistor type
        ii. Range: 20°F to 120°F (-5°C to 50°C)
        iii. Environmental Operating Range: -40°F to 158°F (-40°C to 70°C), 0-100% RH, non-condensing
        iv. Accuracy: ±0.36°F (0.5°C)
        v. Enclosure: Polycarbonate with NEMA 4, IP66 rating and UL94V-0 flammability rating, closed cell foam shall be utilized to seal the insertion hole and absorb vibration
        vi. Probe: Stainless steel of sufficient length (8', 12' or 24') for size of duct.
        vii. Provide Automated Logic ZSA-B-X-6-B or approved equal
5. Pipe Sensors
    a. Immersion Temperature Sensors
        i. Sensor: Thermistor type, double encapsulated to be watertight

ii. Range: -40°F to 212°F (-40°C to 100°C)
iii. Accuracy: ±1.3°F (0.5°C)
iv. Enclosure: Polycarbonate with NEMA 4, IP66 rating and UL94V-0 flammability rating, closed cell foam shall be utilized to seal the insertion hole and absorb vibration
v. Probe: Stainless steel of sufficient length (2" or 4") for size of pipe. Install in stainless steel or brass thermowell to accommodate pipe material.
vi. Provide Automated Logic ZSI-B-X-6-B with thermowell ZSI-T-2-X-B or approved equal.

b. Pipe Clamp-On Temperature Sensors
i. Sensor: Thermistor type with bendable copper sensing plate that forms to the curvature of the pipe along with an adjustable hose clamp that holds the unit in place around the pipe
ii. Range: -40°F to 212°F (-40°C to 100°C)
iii. Accuracy: ±1.3°F (0.5°C)
iv. Enclosure: Polycarbonate with NEMA 4, IP66 rating and UL94V-0 flammability rating, closed cell foam shall be utilized to seal the insertion hole and absorb vibration
v. For pipe sizes from 2" to 4 ½"
vi. Provide Automated Logic ZSS-B-2-6-B or approved equal.

2.9 Local Control Panels

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

2.10Wiring and Raceways

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.
B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

PART 3: EXECUTION

3.0 Duct Smoke Detection

3.1 Start-Up and Checkout Procedures

3.1 Examination

A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.
B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.
C. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

3.2 Protection

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

3.3 Coordination

A. Site
    1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
    2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.
B. Test and Balance.
    1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
    2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
    3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
    4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

C. Life Safety.
   1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in sequences of operation.
   2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23. Interlock smoke dampers to air handlers as specified in sequences of operation.
   3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.

D. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
   1. All communication media and equipment shall be provided as specified in Section 23 09 23 Article 2.2 (Communication).
   2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Section 23 09 93.
   3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
   4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
   5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4 General Workmanship

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.
B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).
D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 Field Quality Control

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 23 09 23 Article 1.8 (Codes and Standards).
B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

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

3.6 Wiring

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.
B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.
C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.
D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.
E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway at levels below 3 m (10ft).
F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).
G. Do not install wiring in raceway containing tubing.
H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.
I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.
K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
L. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
O. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
P. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
Q. Use color-coded conductors throughout with conductors of different colors.
R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).

T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
U. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.
V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.
W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

3.7 Communication Wiring

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.
B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling
C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.
D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.
F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer's instructions.
G. All runs of communication wiring shall be unspliced length when that length is commercially available.
H. All communication wiring shall be labeled to indicate origination and destination data.
I. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."
J. BACnet IP, Arcnet, or MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:
    1. IP
        a. The network shall use Cat5e or greater cabling for connections.
        b. Custom made patch cables must use either the T568A or T568 wiring standard and must use the same standard on both ends of the cable.
    2. Arcnet
        a. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 nominal. Distributed capacitance between conductors shall be less than 12.5 pF per foot (41 pF per meter.)

b. The maximum length of an Arcnet segment is 610 meters (2000 ft) with AWG 22 cable.
c. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
d. An Arcnet network shall have no T connections

3. MS/TP
a. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
b. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
c. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
d. An MS/TP EIA-485 network shall have no T connections.

3.8 Fiber Optic Cable

A. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within cable manufacturer's specifications.
B. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

3.9 Installation of Sensors

A. Install sensors in accordance with the manufacturer's recommendations.
B. Mount sensors rigidly and adequately for environment within which the sensor operates.
C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.
D. All wires attached to sensors shall be sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.
E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (10 ft) of sensing element for each 1 m^2 (1 ft^2) of coil area.
G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.
H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
J. Differential Air Static Pressure.

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

K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.
L. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.10Flow Switch Installation

A. Use correct paddle for pipe diameter.
B. Adjust flow switch according to manufacturer's instructions.

3.11Actuators

A. General. Mount and link control damper actuators according to manufacturer's instructions.
   1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
   2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
   3. Provide all mounting hardware and linkages for actuator installation.
B. Electric/Electronic
   1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall be mounted following manufacturer's recommendations.
   2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.12Warning Labels

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

B. Permanent warning labels shall be affixed to all motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
   1. Labels shall use white lettering (12-point type or larger) on a red background.
   2. Warning labels shall read as follows.
      a. 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.

3.13Identification 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 in.) of termination with control system address or termination number.
B. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.
C. Permanently label or code each point of field terminal strips to show the instrument or item served.
D. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.
E. Identify all other control components with permanent labels. All plug-in components shall be labeled such that label removal of the component does not remove the label.
F. Identify room sensors related to terminal boxes or valves with nameplates.
G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.
H. Identifiers shall match record documents.

3.14Controllers

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.
B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in sequences of operation.

3.15Programming

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.
B. Point Naming. Coordinate with owner for point naming conventions. Name points as shown on the equipment points list provided with each sequence of operation or as directed by owner. If character limitations or space restrictions make it advisable to shorten the name,

abbreviations as coordinated with owner may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, “Zone Temp 1” for Zone 1, “Zone Temp 2” for Zone 2.

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:
         i. Must provide actions for all possible situations
         ii. Must be modular and structured
         iii. Must be commented
      b. Graphic-based:
         i. Must provide actions for all possible situations
         ii. Must be documented
      c. Parameter-based:
         i. Must provide actions for all possible situations
         ii. Must be documented.

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

3.16Control System Checkout and Testing

A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner’s representative is notified of the system demonstration.
   1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
   2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.

3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
7. Alarms and Interlocks:
    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

3.17Control System Demonstration and Acceptance

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

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

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

3.18Cleaning

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.
B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

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

3.19Training

A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.
B. Training shall enable students to accomplish the following objectives.
    1. Day-to-day Operators:
        a. Proficiently operate the system
        b. Understand control system architecture and configuration
        c. Understand DDC system components
        d. Understand system operation, including DDC system control and optimizing routines (algorithms)
        e. Operate the workstation and peripherals
        f. Log on and off the system
        g. Access graphics, point reports, and logs
        h. Adjust and change system set points, time schedules, and holiday schedules
        i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
        j. Understand system drawings and Operation and Maintenance manual
        k. Understand the job layout and location of control components
        l. Access data from DDC controllers and ASCs
        m. Operate portable operator's terminals
    2. Advanced Operators:
        a. Make and change graphics on the workstation
        b. Create, delete, and modify alarms, including annunciation and routing of these
        c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
        d. Create, delete, and modify reports
        e. Add, remove, and modify system's physical points
        f. Create, modify, and delete programming
        g. Add panels when required
        h. Add operator interface stations
        i. Create, delete, and modify system displays, both graphical and others
        j. Perform DDC system field checkout procedures
        k. Perform DDC controller unit operation and maintenance procedures
        l. Perform 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
        o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
        p. Adjust, calibrate, and replace system components
    3. System Managers/Administrators:

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

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.
D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.
E. The instructor(s) shall be factory-trained and experienced in presenting this material.
F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.20 Sequences of Operation

A. See Section 23 Sequences of Operation

3.21 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 so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.
E. Isolation valves shall be installed so 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 brass, 1.5 inch in diameter, with ¼ inch high letters. Securely fasten with chain and hook. Match identification numbers as shown on approved controls shop drawings.

3.22 Control Damper Installation

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.
B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure ¼ in. larger than damper dimensions and shall be square, straight, and level.
C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8 in.) of each other.
D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

E. Install extended shaft or jackshaft according to manufacturer's instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)
F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.
G. Provide a visible and accessible indication of damper position on the drive shaft end.
H. Support ductwork in area of damper when required to prevent sagging due to damper weight.
I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.23Smoke Damper Installation

A. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the engineer no less than two weeks prior to inspection by the code authority having jurisdiction.
B. Provide complete submittal data to controls system subcontractor for coordination of duct smoke detector interface to HVAC systems.

3.24Duct Smoke Detection

A. Submit data for coordination of duct smoke detector interface to HVAC systems as required in Part 1, "Submittals."
B. This Contractor shall provide a dry-contact alarm output in the same room as the HVAC equipment to be controlled.

3.25Start-Up 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 read properly.
    3. Verify alarms and interlocks.
    4. Verify operation of the integrated system.

23 09 93 SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1: GENERAL

1.0 Section Includes
1.1 Pkgd RTU- Air Cooled Heat Pump
1.2 **Exhaust Fan - On/Off and IDF Room temp monitoring**

1.1 Pkgd RTU- Air Cooled Heat Pump (typical of 17)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 75°F (adj.) cooling setpoint
  - A 70°F (adj.) heating setpoint
- Unoccupied Mode (night setback): The unit shall maintain
  - A 85°F (adj.) cooling setpoint.
  - A 55°F (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a smoke detector status.

Fan:
The fan shall run anytime the unit is commanded to run, unless shutdown on safeties.

Heating and Cooling - 2 Compressor Stages:
The controller shall measure the zone temperature and stage the compressors to maintain its setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime. The compressor shall run subject to its own internal safeties and controls.

The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the fan status is on.
- AND the reversing valve is in heat mode.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the fan status is on.
- AND the reversing valve is in cool mode.

On mode change, the compressor shall be disabled and remain off until after the reversing valve has changed position.

Alarms shall be provided as follows:

- Compressor 1 Runtime Exceeded: Compressor 1 runtime exceeds a user definable limit (adj.).
- Compressor 2 Runtime Exceeded: Compressor 2 runtime exceeds a user definable limit (adj.).

Economizer:
The controller shall measure the zone temperature and modulate the mixed air dampers in sequence to maintain the zone cooling setpoint. The outside air damper shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is at least 3°F (adj.) less than the zone temperature.
- AND the outside air temperature is less than 75°F (adj.)

The economizer shall close whenever the freezestat (if present) is on.

The outside air damper shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:
When in the occupied mode, the controller shall measure the zone CO2 concentration and open the outside air dampers on rising CO2 concentrations, overriding normal damper operation as CO2 concentrations rise above 750ppm (adj.).

Supplemental Electric Heating Stages:

The controller shall measure the zone temperature and stage the heating to maintain its heating setpoint should the compressors not meet the heating demand. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- The heat pump is in heating mode.
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

Zone Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the zone CO2 concentration.

Alarms shall be provided as follows:

- High Zone Carbon Dioxide Concentration: If the zone CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

Environmental Index:
When the zone is occupied, the controller will monitor the deviation of the zone temperature from the heating or cooling setpoint. The controller will also monitor the carbon dioxide concentration and compare it to comfort conditions. This data will be used to calculate a 0 - 100% Environmental Index

which gives an indication of how well the zone is maintaining comfort. The controller will also calculate the percentage of time since occupancy began that the Environmental Index is 70% or higher. Optionally, a weighting factor can be configured to adjust the contribution of the zone to the rollup average index based upon the floor area of the zone, importance of the zone, or other static criteria.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Discharge Temp	x								x		x
Zone Carbon Dioxide PPM	x								x		x
Zone Setpoint Adjust	x										x
Zone Temp	x								x		x
Mixed Air Dampers		x							x		x
Fan Status			x						x		x
Smoke Detector			x						x	x	x
Zone Override			x						x		x
Cooling Stage 1				x					x		x
Cooling Stage 2				x					x		x
Heating Stage 1				x					x		x
Heating Stage 2				x					x		x
Electric Heat Stage 1				x					x		x
Electric Heat Stage 2 (if applicable)				x					x		x
Fan Start/Stop				x					x		x
Reversing Valve				x					x		x
Cooling Setpoint					x				x		x
Environmental Index					x				x		
Heating Setpoint					x				x		x
Percent of Time Satisfied					x				x		
Zone Carbon Dioxide PPM Setpoint					x				x		x
Schedule								x			
Compressor 1 Runtime Exceeded										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Compressor 2 Runtime Exceeded										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
High Discharge Air Temp										x	
High Zone Carbon Dioxide Concentration										x	
High Zone Temp										x	
Low Discharge Air Temp										x	
Low Zone Temp										x	
Totals	**4**	**1**	**3**	**5**	**5**	**0**	**0**	**1**	**17**	**12**	**15**

Total Hardware (13) **Total Software (35)**

Exhaust Fan - On/Off (typical of 1)

Run Conditions - Interlocked:
The fan(s) EF --- shall be interlocked to run whenever Air Handling Unit or based on user defined time schedule.

Fan:
The fan shall have a user definable (adj.) minimum runtime.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Fan Status			x						x		x
Fan Start/Stop				x					x		x
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**2**	**3**	**2**

Total Hardware (2) **Total Software (5)**

IDF Room Temperature Monitoring

The BAS shall monitor the IDF room temperature and alarm when above alarm trip setpoint.

APPENDIX A: Definitions

Terms used within the Specification Text:

- **Adjustable (adj.):**

Adjustable by the end user, through the supplied user interface.

- **Advanced Application Controller (AAC):**

A fully programmable control module. This control module may be capable of some of the advanced features found in Building Controllers (storing trends, initiating read and write requests, etc.) but it does not serve as a master controller. Advanced Application Controllers may reside on either the Ethernet/IP backbone or on a subnet.

- **Alarm:**

The control system shall be configured to generate an alarm when this object exceeds user definable limits, as described in the Sequence of Controls.

- **Analog Value:**

An intermediate (software) point that may be editable or read-only. Editable AVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only AVs are typically used to display the status of a control operation.

- **Application Specific Controller (ASC):**

A pre-programmed control module which is intended for use in a specific application. ASCs may be configurable, in that the user can choose between various pre-programmed options, but it does not support full custom programming. ASCs are often used on terminal equipment such as VAV boxes or fan coil units. In many vendors' architectures ASCs do not store trends or schedules but instead rely upon a Building Controller to provide those functions.

- **BACnet Interoperability Building Blocks (BIBB):**

A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.

- **BACnet/BACnet Standard:**

  BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.

- **Binary Value:**

  An intermediate (software) point that may be editable or read-only. Editable BVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only BVs are typically used to display the status of a control operation.

- **Building Controller (BC):**

  A fully programmable control module which is capable of storing trends and schedules, serving as a router to devices on a subnet, and initiating read and write requests to other controllers. Typically this controller is located on the Ethernet/IP backbone of the BAS. In many vendors' architectures a Building Controller will serve as a master controller, storing schedules and trends for controllers on a subnet underneath the Building Controller.

- **Control Systems Server:**

  A computer(s) that maintain(s) the systems configuration and programming database.

- **Controller:**

  Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.

- **Direct Digital Control (DDC):**

  Microprocessor-based control including Analog/Digital conversion and program logic.

- **Furnished or Provided:**

  The act of supplying a device or piece of equipment as required meeting the scope of work specified and making that device or equipment operational. All costs required to furnish the specified device or equipment and make it operational are borne by the division specified to be responsible for providing the device or equipment.

- **Gateway:**

  Bi-directional protocol translator connecting control systems that use different communication protocols.

- **Install or Installed:**

  The physical act of mounting, piping or wiring a device or piece of equipment in accordance with

the manufacturer's instructions and the scope of work as specified. All costs required to complete the installation are borne by the division specified to include labor and any ancillary materials.

- **Integrate:**

  The physical connections from a control system to all specified equipment through an interface as required to allow the specified control and monitoring functions of the equipment to be performed via the control system.

- **Interface:**

  The physical device required to provide integration capabilities from an equipment vendor's product to the control system. The equipment vendor most normally furnishes the interface device. An example of an interface is the chilled water temperature reset interface card provided by the chiller manufacturer in order to allow the control system to integrate the chilled water temperature reset function into the control system.

- **Local Area Network:**

  Computer or control system communications network limited to local building or campus.

- **Loop or control loop:**

  Most commonly a PID control loop. Typically a control loop will include a setpoint, an input which is compared to the setpoint, and an output which controls some action based upon the difference between the input and the setpoint. A PID control loop will also include gains for the proportional, integral, and derivative response as well as an interval which controls how frequently the control loop updates its output. These gains may be adjustable by the end user for control loop “tuning,” but in self-tuning control loops or loops which have been optimized for a specific application the gains may not be adjustable.

- **Master-Slave/Token Passing (MS/TP):**

  Data link protocol as defined by the BACnet standard.

- **Point-to-Point:**

  Serial communication as defined in the BACnet standard.

- **Primary Controlling LAN:**

  High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.

- **Protocol Implementation Conformance Statement (PICS):**

A written document that identifies the particular options specified by BACnet that are implemented in a device.

- **Router:**

  A device that connects two or more networks at the network layer.

- **Schedule:**

  The control algorithm for this equipment shall include a user editable schedule.

- **Trend:**

  The control system shall be configured to collect and display a trend log of this object. The trending interval shall be no less than one sample every 5 minutes. (Change of Value trending, where a sample is taken every time the value changes by more than a user-defined minimum, is an acceptable alternative.)

- **Web services:**

  Web services are a standard method of exchanging data between computer systems using the XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services can be used at any level within a Building Automation System (BAS), but most commonly they are used to transfer data between BAS using different protocols or between a BAS and a non-BAS system such as a tenant billing system or a utility management system.

- **Wiring:**

  Raceway, fittings, wire, boxes and related items.

- **APPENDIX B: Abbreviations**

The following abbreviations are utilized within this section and the sequences of operations. Refer to mechanical drawings for additional abbreviations.

AC – Air Conditioning
ACU – Air Conditioning Unit
AHU – Air Handling Unit
AI – Analog Input
AO – Analog Output
ATC – Automatic Temperature Control
AUTO – Automatic
AUX – Auxiliary
AV – Analog Value

BAS – Building Automation System
BI – Binary Input
BO – Binary Output
BV – Binary Value
C – Common
CFM – Cubic Feet per Minute
CHW – Chilled Water
CHWP – Chilled Water Pump
CHWR – Chilled Water Return
CHWS – Chilled Water Supply
COND – Condenser
CV – Constant Volume
CW – Condenser Water
CWP – Condenser Water Pump
CWR – Condenser Water Return
CWS – Condenser Water Supply
DA – Discharge Air
DDC – Direct Digital Control
DI – Digital Input
DO – Digital Output
EA – Exhaust Air
EF – Exhaust Fan
EVAP – Evaporators
FAS – Fire Alarm System
FCU – Fan Coil Unit
HOA – Hand / Off / Auto
HP – Heat Pump
HRU – Heat Recovery Unit
HVAC – Heating, Ventilating, and Air Conditioning
HW – Hot Water
HWP – Hot Water Pump
HWR – Hot Water Return
HWS – Hot Water Supply
HX – Heat Exchanger
IU – Induction Unit
LAN – Local Area Network
MER – Mechanical Equipment Room
NC – Normally Closed
NO – Normally Open
OA – Outdoor Air
PID – Proportional Integral Derivative
POT – Portable Operators Terminal
RA – Return Air
RF – Return Fan
RH – Relative Humidity
RTU – Roof-top Unit
SA – Supply Air

SF – Supply Fan
SP – Static Pressure
TEMP – Temperature
UH – Unit Heater
UV – Unit Ventilator
VAV – Variable Air Volume
VFD – Variable Frequency Drive
VRF – Variable Refrigerant Flow
VRV – Variable Refrigerant Volume
WSHP – Water Source Heat Pump

SECTION 26 0500 - BASIC ELECTRICAL REQUIREMENTS

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Requirements applicable to all Division 26 Sections. Also refer to Division 1 - General Requirements. This section is also applicable to Interior Communications Pathways Section 27 0528. This section is also applicable to Fire Alarm and Detection Systems Section 28 3100.

B. All materials and installation methods shall conform to the applicable standards, guidelines and codes referenced herein and within each specification section.

1.02 REFERENCES

A. CEC California Electrical Code

B. CCR California Code of Regulation

C. CBC California Building Code

D. CFC California Fire Code

E. CMC California Mechanical Code

F. CPC California Plumbing Code

G. California Title 24 - Building Energy Efficiency Standards

1.03 SCOPE OF WORK

A. This Specification and the associated drawings govern furnishing, installing, testing and placing into satisfactory operation the Electrical Systems.

B. The Contractor shall furnish and install all new materials as indicated on the drawings, and/or in these specifications, and all items required to make the portion of the Electrical Work a finished and working system.

C. Separate contracts will be awarded for the following work.

D. All work will be awarded under a single General Contract. The division of work listed below is for the Contractor's convenience and lists normal breakdown of the work.

E. Separate contracts will be awarded for the following work. The division of work listed below is for the contractors' convenience and lists a normal breakdown of the work. Please refer to the Construction Manager's scope statements for complete scope of work description.

F. Description of Systems shall be as follows:

1. Electrical power system to and including luminaires, equipment, motors, devices, etc.
2. Electrical power service system from the Utility Company to and including service entrance equipment, distribution and metering.
3. Grounding system.
4. Wiring system for temperature control system as shown on the drawings.
5. Wiring of equipment furnished by others.
6. Removal work and/or relocation and reuse of existing systems and equipment.
7. Furnish and install firestopping systems for penetrations of fire-rated construction associated with this Contractor's work.

G. Work Not Included:

1. Telecommunications cabling will be by others, in raceways and conduits furnished and installed as part of the Electrical work.
2. Temperature control wiring for plumbing and HVAC equipment (unless otherwise indicated) will be by other Contractors.

1.04 OWNER FURNISHED PRODUCTS

A. The Owner will supply manufacturer's installation data for Owner-purchased equipment for this project.

B. This Contractor shall make all electrical system connections shown on the drawings **or** required for fully functional units.

C. This Contractor is responsible for all damage to Owner furnished equipment caused during installation.

1.05 WORK SEQUENCE

A. All work that will produce excessive noise or interference with normal building operations, as determined by the Owner, shall be scheduled with the Owner. It may be necessary to schedule such work during unoccupied hours. The Owner reserves the right to determine when restricted construction hours are required.

1.06 DIVISION OF WORK BETWEEN MECHANICAL, ELECTRICAL, and CONTROL CONTRACTORS

A. Division of work is the responsibility of the Prime Contractor. Any scope of work described at any location on the contract document shall be sufficient for including said requirement in the project. The Prime Contractor shall be solely responsible for determining the appropriate subcontractor for the described scope. In no case shall the project be assessed an additional cost for scope that is described on the contract documents on bid day. The following division of responsibility is a guideline based on typical industry practice.

B. Definitions:

1. "Mechanical Contractors" refers to the Contractors listed in Division 21/22/23 of this Specification.
2. "Technology Contractors" refers to the Contractors furnishing and installing systems listed in Division 27/28 of this Specification.
3. Motor Power Wiring: The single phase or 3 phase wiring extending from the power source (transformer, panelboard, feeder circuits, etc.) through disconnect switches and motor controllers to, and including the connections to the terminals of the motor.
4. Motor Control Wiring: The wiring associated with the remote operation of the magnetic coils of magnetic motor starters or relays, or the wiring that permits direct cycling of motors by means of devices in series with the motor power wiring. In the latter case, the devices are usually single phase, have "Manual-Off-Auto" provisions, and are usually connected into the motor power wiring through a manual motor starter.
5. Control devices such as start-stop push buttons, thermostats, pressure switches, flow switches, relays, etc., generally represent the types of equipment associated with motor control wiring.
6. Motor control wiring is single phase and usually 120 volts. In some instances, the voltage will be the same as the motor power wiring. When the motor power wiring exceeds 120 volts, a control transformer is usually used to give a control voltage of 120 volts.
7. Temperature Control Wiring: The wiring associated with the operation of a motorized damper, solenoid valve or motorized valve, etc., either modulating or two-position, as opposed to wiring that directly powers or controls a motor used to drive equipment such as fans, pumps, etc. This wiring will be from a 120-volt source and may continue as 120 volt, or be reduced in voltage (24 volt), in which case a control transformer shall be furnished as part of the temperature control wiring.
8. Control Motor: An electric device used to operate dampers, valves, etc. It may be two-position or modulating. Conventional characteristics of such a motor are 24 volts, 60 cycles, 1 phase, although other voltages may be encountered.
9. Low Voltage Technology Wiring: The wiring associated with the technology systems, used for analog or digital signals between equipment.

10. Telecommunications/Technology Rough-in: Relates specifically to the backboxes, necessary plaster rings and other miscellaneous hardware required for the installation or mounting of telecommunications/technology information outlets.

C. General:

1. The purpose of these Specifications is to outline the Electrical and Mechanical Contractors' responsibilities related to electrical work required for items such as temperature controls, mechanical equipment, fans, chillers, compressors, etc. The exact wiring requirements for much of the equipment cannot be determined until the systems have been selected and submittals approved. Therefore, the electrical drawings show only known wiring related to such items. All wiring not shown on the electrical drawings, but required for mechanical systems, is the responsibility of the Mechanical Contractor.
2. Where the drawings require the Electrical Contractor to wire between equipment furnished by the Mechanical Contractor, such wiring shall terminate at terminals provided in the equipment. The Mechanical Contractor shall furnish complete wiring diagrams and supervision to the Electrical Contractor and designate the terminal numbers for correct wiring.
3. Control low (24V) and control line (120V) voltage wiring, conduit, and related switches and relays required for the automatic control and/or interlock of motors and equipment, including final connection, are to be furnished and installed under Divisions 21, 22 and 23. Materials and installation to conform to Class 1 or 2 requirements, California Electrical Code Article 725.
4. The Electrical Contractor shall establish electrical utility elevations prior to fabrication and installation. The Electrical Contractor shall coordinate utility elevations with other trades. When a conflict arises, priority shall be as follows:

    a. Luminaires.
    b. Gravity flow piping, including steam and condensate.
    c. Electrical bus duct.
    d. Sheet metal.
    e. Cable trays, including access space.
    f. Other piping.
    g. Conduits and wireway.

D. Mechanical Contractor's Responsibility:

1. Assumes responsibility for internal wiring of all equipment furnished by the Mechanical Contractor.