1. CONTROLS 25 09 10

Part 1 General

1.1 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

1. Section 23 00 10 - Heating and cooling:
    1. Control valves
    2. Press and temp sensor wells & sockets

2. Section 23 30 10 - Ventilation:
    1. Airflow stations
    2. Automated dampers

3. Section 26 00 00 - Electric Specifications:
    1. Variable Frequency Drives

1.2 PRODUCTS NOT FURNISHED OR INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION

1. Section 23 00 10- Air handling or evaporative cooling unit:
    1. Packaged Fan coil controls: Unit shall be furnished configured to accept control inputs from an external building automation system controller as specified in Section 25 09 10, Appendix A. Factory mounted safeties and other controls shall not interfere with this controller.

2. Communications with Third Party Equipment:
    1. Any additional integral control systems included with the products integrated with the Work of this section shall be furnished with a BACnet interface for integration into the Direct Digital Control System described in this section.

1.3 RELATED SECTIONS

1. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this Specification and shall be used in conjunction with this section as part of the Contract Documents.

2. The following sections constitute related Work:
    1. Section 21 00 05 – General Requirements
    2. Section 21 00 07 – Mechanical Definitions
    3. Section 22 08 10 – Testing and Balancing
    4. Section 23 00 10 - Heating & Cooling
    5. Section 23 30 10 - Ventilation
    6. Section 26 00 00 - Basic Electrical Materials and Methods
    7. Section 26 00 00 - Mechanical Equipment Wiring

1.4 DESCRIPTION

1. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphic. Provide a web server with a network interface card to gather data from this system and generate web pages accessible through a conventional web by PC via internet connection. Operators shall be able to perform all normal operator functions through the web browser interface. This system shall be capable of connection to The City's current remote building management system.

2. The system shall directly control HVAC equipment as specified in Section 25 09 10 Appendix A (Sequences of Operation). Each zone controller shall provide occupied and unoccupied modes

of operation by individual zone. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified in Appendix A.

3. Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

4. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. Schedules, setpoints, trends, and alarms specified in Section 25 09 10 Appendix A (Sequences of Operation) shall be BACnet objects.

1.5 APPROVED CONTROL SYSTEMS

1. The new Control system shall be compatible with The City's existing remote building management systems.
2. The following is a list of approved DDC suppliers:

Supplier	Manufacturer	Product Line
Johnson Controls	Johnson Controls	METASYS

3. The above list is alphabetical and does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this Specification.
4.
    1. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless The City approves use of multiple manufacturers.
    2. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.6 QUALITY ASSURANCE

1. Installer and Manufacturer Qualifications:
    1. Installer shall have an established working relationship with Control System Manufacturer.
    2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.

1.7 CODES AND STANDARDS

1. Work, Materials, and equipment shall comply with the most restrictive of local, provincial, and federal authorities' codes and ordinances or these plans and Specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of Bids of the following codes:
    1. Canadian Electric Code (CEC), to the satisfaction of the Authority having Jurisdiction.
    2. National Building Code (NBC), to the satisfaction of the Authority having Jurisdiction.
    3. ASHRAE/ANSI 135: Data Communication Protocol for Building Automation and Control Systems (BACnet)
    4. Manitoba Energy Code for Buildings (MECB), to the satisfaction of the Authority having Jurisdiction and the Contract Administrator.

1.8 SYSTEM PERFORMANCE

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

Table 1
Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±25 ppm duct, ±50 ppm space applications

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

Table 2
Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.9 SUBMITTALS

1. Product Submittal Requirements: Meet requirements of Section 01600 on Shop Drawings, Product Data, and Samples. Provide six copies of Shop Drawings and other submittals on hardware, software, and equipment to be installed or furnished. Begin no Work until submittals have been approved for conformity with design intent. Provide Drawings as AutoCAD 2006 (or newer) or MS VISIO compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and 6 prints of each Drawing on 11" x 17" paper. When manufacturer's cutsheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered Specification and Drawing on each submittal. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of Work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete Work. Provide submittals within 6 weeks of Contract award on the following:
    1. Direct Digital Control System Hardware
        1. Complete bill of Materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
        2. Manufacturer's description and technical data such as performance curves, product Specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
            1. Direct digital controllers (controller panels)
            2. Transducers and transmitters
            3. Sensors (include accuracy data)
            4. Actuators
            5. Valves
            6. Relays and switches
            7. Control panels
            8. Power supplies
            9. Batteries
            10. Operator interface equipment
            11. Wiring
        3. Wiring diagrams and layouts for each control panel. Show termination numbers.
        4. Floor plan schematic diagrams indicating field sensor and controller locations.
        5. Riser diagrams showing control network layout, communication protocol, and wire types.
    2. Central System Hardware and Software
        1. Complete bill of Material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
        2. Manufacturer's description and technical data such as product Specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this Contract not listed below:
            1. Central Processing Unit (CPU) and web server
            2. Monitors
            3. Keyboards

4. Power supplies
5. Battery backups
6. Interface equipment between CPU or server and control panels
7. Operating System software
8. Operator interface software
9. Color graphic software
10. Third-party software

3. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
4. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems
   1. Riser diagrams showing control network layout, communication protocol, and wire types.
   2. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
   3. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
   4. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
   5. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified in Section 25 09 10 Appendix A. Indicate alarmed and trended points.
4. Description of process, report formats, and checklists to be used in Section 25 09 10 Article 3.17 (Control System Demonstration and Acceptance).
5. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

2. Schedules
   1. Schedule of Work provided within one month of Contract award, indicating:
      1. Intended sequence of Work items
      2. Start date of each Work item
      3. Duration of each Work item
      4. Planned delivery dates for ordered Material and equipment and expected lead times
      5. Milestones indicating possible restraints on Work by other trades or situations
   2. Monthly written status reports indicating Work completed and revisions to expected delivery dates. Include updated schedule of Work.

3. Project Record Documents. Submit three copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:
   1. Project Record Drawings. As-built versions of submittal Shop Drawings provided as AutoCAD 2006 (or newer) or MS VISIO compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and 6 prints of each Drawing on 11" x 17" paper.
   2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 25 09 10 Article 3.17 (Control System Demonstration and Acceptance).
   3. Operation and Maintenance (O&M) Manual. Printed, electronic, or online help documentation of the following:
      1. As-built versions of submittal product data.
      2. Names, addresses, and telephone numbers of installing Contractors and service representatives for equipment and control systems.
      3. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.

4. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
5. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
6. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
7. Graphic files, programs, and database on magnetic or optical media.
8. List of recommended spare parts with part numbers and suppliers.
9. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
10. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
11. Licenses, guarantees, and warranty documents for equipment and systems.
12. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
13. Copies of Training records, signed by end user attendees.

4. Training Materials: Provide course outline and Materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Contract Administrator will modify course outlines and Materials if necessary to meet The City's needs. Contract Administrator will review and approve course outlines and Materials at least three weeks before first class.

1.10 WARRANTY

1. Warrant Work as follows:
    1. Warrant labor and Materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to The City. Respond during normal business hours within 24 hours of The City's warranty service request.
    2. Work shall have a single warranty date, even if The City receives beneficial use due to early system start-up.
    3. If Contract Administrator determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Contract Administrator will certify in writing that control system operation has been tested and accepted in accordance with the terms of this Specification. Date of acceptance shall begin warranty period.
    4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, The City can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without The City’s written authorization.
    5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and Materials shall be warranted. Demonstrate operable condition of reused devices at time of Contract Administrator's acceptance.

1.11 OWNERSHIP OF PROPRIETARY MATERIAL

1. Project-specific software and documentation shall become The City's property. This includes, but is not limited to:
    1. Graphics
    2. Record Drawings
    3. Database
    4. Application programming code
    5. Documentation

Part 2 Products

2.1 MATERIALS

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

2.2 COMMUNICATION

1. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.

2. Install new wiring and network devices as required to provide a complete and Workable control network. Use existing Ethernet backbone for network segments marked "existing" on project Drawings.

3. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

4. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
    1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
    2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 25 09 10 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

5. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

6. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.3 CONTROLLER SOFTWARE

1. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

2. System Security. See Paragraph 2.3.6.5 (Security) and Paragraph 2.3.6.14.3 (Operator Activity).

3. Scheduling. See Paragraph 2.3.4.4 (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:

1. Weekly. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

4. 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.

5. Binary and Analog Alarms. See Paragraph 2.3.6.7 (Alarm Processing).

6. Alarm Reporting. See Paragraph 2.3.6.9 (Alarm Reactions).

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. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Section 25 09 10 Appendix A (Sequences of Operation).

9. Sequencing. Application software shall sequence, boilers, and pumps as specified in Section 25 09 10 Appendix A (Sequences of Operation).

10. 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.

11. 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.

12. Energy Calculations.
    1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
    2. 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.

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

14. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

15. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Section 25 09 10 Appendix A (Sequence of Operations).

2.4 CONTROLLERS

1. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 25 09 10 Article 1.9 (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 BACnet Smart Actuators and Smart Sensors.

2. 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). 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). 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.
        1. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
        2. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
        3. Each AAC 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 the ARCNET or MS/TP Data Link/Physical layer protocol.
        4. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
        5. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
        6. 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.

3. Communication.
    1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on Drawings.
    2. Signal Management. BC and ASC operating systems shall 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.
    3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
    4. Stand-Alone Operation. Each piece of equipment specified in Section 25 09 10 Appendix A 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.

4. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
    1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -35°C to 60°C (-31°F to 140°F).

2. 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).

5. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide a laptop computer (DELL with 13.3 inch display) and the software and any interface cabling needed to use the laptop computer as a Portable Operator's Terminal for the system.

6. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

7. Serviceability.
   1. Controllers shall have diagnostic LEDs for power, communication, and processor.
   2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
   3. 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.

8. Memory.
   1. Controller memory shall support operating system, database, and programming requirements.
   2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
   3. Each ASC and SA 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.

9. 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. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

10. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.5 INPUT AND OUTPUT INTERFACE

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

2. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

3. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.
4. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

5. 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.

6. Binary Outputs. Binary outputs shall send an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

7. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 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.

8. 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 and zone dampers.

9. 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.

2.6 POWER SUPPLIES AND LINE FILTERING

1. Power Supplies. Control transformers shall be CSA approved. 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.
        1. 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.
        2. Line voltage units shall be UL recognized and CSA listed.

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

2.7 AUXILIARY CONTROL DEVICES

1. Motorized Control Dampers.
    1. Type. Control dampers shall have linear flow characteristics and shall be parallel- or opposed-blade type as specified below or as scheduled on Drawings.
        1. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
        2. Other modulating dampers shall be opposed-blade.
        3. Two-position shutoff dampers shall be parallel-blade with blade and side seals.
    2. Extruded aluminum (6063T5) damper frame shall not be less than .080" (2.03mm) in thickness. Damper frame to be 4" (101.6mm) deep and shall be insulated with polystyrofoam on four sides.
    3. Entire frame shall be thermally broken by means of polyurethane resin pockets, complete with thermal cuts.

4. Blades to be extruded aluminum (6063T5) profiles, internally insulated with expanded polyurethane foam and shall be thermally broken. Complete blade shall have an insulating factor of R-2.29 and a temperature index of 55.
5. Blade and frame seals shall be of extruded silicone and be secured in an integral slot within the aluminum extrusions.
6. Bearings are to be composed of a Celcon inner bearing fixed to a 7/16" (11.11mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
7. Linkage hardware shall be installed in the frame side and constructed of aluminum and corrosion-resistant, zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip.
8. Dampers are to be designed for operation in temperatures ranging between -40°F (-40°C) and 185°F (85°C).
9. Dampers shall be available with either opposed blade action or parallel blade action.
10. Leakage shall not exceed 3 cfm/ft² (15.2 l/s/m²) against 1" (.25 kPa) w.g. differential static pressure.
11. Leakage shall not exceed 4.9 cfm/ft.² (25 l/s/m²) against 4" (1kPa) w.g. differential static pressure at -40°F (-40°C).
12. Pressure drop of a fully open 48" x 48" (1220mm x 1220mm) damper shall not exceed .03" (.007kPa) w.g. at 1000 fpm (5.08 m/s).
13. Dampers shall be made to size required without blanking off free area.
14. Dampers shall be available as "Flanged to Duct" mounting type.
15. Installation of dampers must be in accordance with current manufacturer's installation guidelines provided with each shipment of TAMCO dampers.
16. Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See TAMCO Aluminum Damper Installation Guidelines.)
17. Acceptable product shall be TAMCO Series 9000 BF Thermally Insulated Damper with Thermally Broken Frame for outdoor air and exhaust air applications and TAMCO Series 1000 for return air applications.

2. 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 2.6.8)
   4. 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.

3. Control Valves.
   1. General. Select body and trim Materials in accordance with manufacturer's recommendations for design conditions and service shown.
   2. Type. Provide two- or three-way control valves for two-position or modulating service as shown.
   3. Valves up to 1.5 inch (38 mm) size may be Ball type with stainless steel balls; larger sizes shall be Globe type. Modulating valves for air handling unit coils, heat exchangers and similar fan and pumping systems shall be Globe type.
   4. Valves up to and including 2 inch (50 mm) size shall have screwed connections; valves 2.5 inch (63 mm) and larger sizes shall have flanged connections.
   5. Water Valves.

1. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball.
2. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.
    1. Two-way: 150% of total system (pump) head.
    2. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
3. Ports. Valves providing modulating service shall have equal percentage ports.
4. Sizing.
    1. Two-position service: line size.
    2. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 21 kPa (3 psi).
    3. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 21 kPa (3 psi).
5. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.
    1. Water zone valves: normally open.
    2. Heating coils in air handlers: normally open.
    3. Chilled water control valves: normally closed.
    4. Other applications: as scheduled or as required by sequences of operation.

4. Binary Temperature Devices.
    1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
    2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL/CSA listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
    3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

5. Temperature Sensors.
    1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
    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. Generally, space sensors in public areas shall have blank covers. Where noted on the control schematics or in the sequence of operation the space sensors shall have LEXAN or steel guards.
    5. Differential Sensors. Provide matched sensors for differential temperature measurement.

6. 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.

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

8. Relays.
   1. Control Relays. Control relays shall be plug-in type, UL/CSA 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/CSA 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.

9. 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. Timers shall be without a Hold position.

10. 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.

11. 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.

12. 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.
13. 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.

14. Power Monitors.
    1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
    2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

15. 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.

16. Pressure Transducers.
    1. Transducers shall have linear output signal and field-adjustable zero and span.
    2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
    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 (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

17. Differential Pressure Switches.
    1. Differential pressure switches (air or water service) shall be UL/CSA 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.

18. Local Control Panels.
    1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
    2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL/CSA listed for 600 V service, individually identified per control and interlock Drawings, with adequate clearance for field wiring.
    3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

19. Air Quality Sensors (CO2).
    1. Microprocessor controlled, fully digital, non-dispersive, dual wavelength infrared, temperature compensated.
    2. Sensor shall be equipped with the following features:
    3. 0-2000 PPM
    4. Accuracy ± 25 PPM in 15 to 30C range for duct mounted applications
    5. Accuracy ± 40 PPM in 15 to 30C range for space mounted applications
    6. Outputs: 4-20mA, 0-10V, 0-5VDC
    7. Supply Voltage 12VDC or 24VAC/DC
    8. Digital Display of PPM
    9. Wall or duct mounting
    10. 5 Year Warranty on duct sensors, 3 year warranty on space sensors
    11. Approved Product: VULCAIN 90DM3 for space mounted applications and COMAG IR PPM 4022H for all duct mounted applications

2.8 WIRING AND RACEWAYS

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

2. Where the requirements of Section 25 09 10 differ from Division 26, Section 25 09 10 shall take precedence.

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

2.9 FIBER OPTIC CABLE SYSTEM

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

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

Part 3 Execution

3.1 EXAMINATION

1. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Contract Administrator for resolution before starting rough-in Work.

2. Inspect Site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Contract Administrator for resolution before starting rough-in Work.

3. Examine Drawings and Specifications for Work of others. Report inadequate headroom or space conditions or other discrepancies to Contract Administrator and obtain written instructions for changes necessary to accommodate Section 25 09 10 Work with Work of others. Subcontractor shall perform at his expense necessary changes in specified Work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

1. Subcontractor shall protect against and be liable for damage to Work and to Material caused by Contractor's Work or employees.
2. Subcontractor shall be responsible for Work and equipment until inspected, tested, and accepted. Protect Material not immediately installed. Close open ends of Work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

1. Site.
    1. Assist in coordinating space conditions to accommodate the Work of each trade where Work will be installed near or will interfere with Work of other trades. If installation without coordination causes interference with Work of other trades, Contractor shall correct conditions 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.

2. Submittals. See Section 25 09 10 Article 1.10 (Submittals).

3. Test and Balance.
   1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
   2. Train Test and Balance Contractor to use control system interface tools.
   3. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
   4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

4. Life Safety.
   1. Duct smoke detectors required for air handler shutdown are provided, installed and wired under Division 26.
   2. Smoke dampers and actuators required for duct smoke isolation are provided, installed and wired under Division 23.
   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 26.

5. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows.
   1. Communication media and equipment shall be provided as specified in Section 25 09 10 Article 2.2 (Communication).
   2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described in Section 25 09 10 Appendix A regardless of where within the Contract Documents those products are described.
   3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this Specification.
   4. Subcontractor shall be responsible for integration of control products (as noted in the control system architecture Drawing) provided by multiple suppliers regardless of where integration is described within the Contract documents.

3.4 GENERAL WORKMANSHIP

1. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

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

3. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

4. Equipment, installation, and wiring shall comply with industry Specifications and standards and local codes for performance, reliability, and compatibility.

3.5 FIELD QUALITY CONTROL

1. Work, Materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 25 09 10 Article 1.8 (Codes and Standards).

2. Continually monitor field installation for code compliance and Workmanship quality.

3. Contractor shall arrange for Work inspection by local or state authorities having jurisdiction over the Work.

3.6 WIRING

1. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26, and manufacturer's recommendations. Where the requirements of Section 25 09 10 differ from Division 26, Section 25 09 10 shall take precedence.

2. NEC Class 1 (line voltage) wiring shall be UL/CSA listed in approved raceway as specified by NEC and Division 26.

3. Low-voltage wiring shall meet NEC Class 2 requirements. Subfuse low-voltage power circuits as required to meet Class 2 current limit.

4. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL/CSA listed for the intended application.

5. Install wiring in raceway where subject to mechanical damage and at levels below 3 m (10ft) in mechanical, electrical, or service rooms.

6. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.

7. Do not install wiring in raceway containing tubing.

8. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 3 m (10 ft) intervals.

9. Use structural members to support or anchor plenum cables without raceway. Do not use ductWork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

10. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductWork, electrical raceways, piping, or ceiling suspension systems.

11. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

12. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

13. Use color-coded conductors throughout.

14. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.

15. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment such as steam pipes or flues.

16. Adhere to requirements in Division 26 where raceway crosses building expansion joints.

17. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.

18. Terminate control and interlock wiring related to the Work of this section. Maintain at the job Site updated (as-built) wiring diagrams that identify terminations.
19. 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. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.

20. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.7 COMMUNICATION WIRING

1. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).

2. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.

3. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

4. Verify entire network's integrity following cable installation using appropriate tests for each cable.

5. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.

6. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.

7. Label communication wiring to indicate origination and destination.

8. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.8 INSTALLATION OF SENSORS

1. Install sensors according to manufacturer's recommendations.

2. Mount sensors rigidly and adequately for operating environment.

3. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

4. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.

5. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

6. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2 (1 ft^2) of coil area.

7. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

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

9. Differential Air Static Pressure.
    1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
    4. Where an Air Monitor S.O.A.P. outdoor static reference is specified on the control schematics or in Appendix A, adhere to the manufacturer’s installation guide lines.
    5. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
    6. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductWork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
    7. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

10. 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.

3.9 ACTUATORS

1. General. Mount actuators and adapters according to manufacturer's recommendations.

2. Electric and Electronic Damper Actuators. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.
    1. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
    2. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, then tighten linkage.
    3. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
    4. Provide necessary mounting hardware and linkages for actuator installation.

3. Valve Actuators. Connect actuators to valves with adapters approved by actuator manufacturer.

3.10 WARNING LABELS

1. Affix permanent warning labels to equipment that can be automatically started by the control system.
    1. Labels shall use white lettering (12-point type or larger) on a red background.
    2. Warning labels shall read as follows.

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

2. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
    1. Labels shall use white lettering (12-point type or larger) on a red background.

2. Warning labels shall read as follows.

C A U T I O N
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.11 IDENTIFICATION OF HARDWARE AND WIRING

1. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.

2. Label pneumatic tubing at each end within 5 cm (2 in.) of termination with a descriptive identifier.
3. Permanently label or code each point of field terminal strips to show instrument or item served.

4. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

5. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.

6. Label room sensors related to terminal boxes or valves with nameplates.

7. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

8. Label identifiers shall match record documents.

3.12 PROGRAMMING

1. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 25 09 10 Appendix A (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix C 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.

2. Software Programming. Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.
    1. Application Programming. Provide application programming that adheres to sequences of operation specified in Section 25 09 10 Appendix A. Program documentation or comment statements shall reflect language used in sequences of operation.
    2. System Programming. Provide system programming necessary for system operation.

3. Operator Interface.
    1. Standard Graphics. Provide graphics as specified in Section 25 09 10 Article 2.3 Paragraph 5.2 (System Graphics). Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List in Section 25 09 10 Appendix A. Point information on graphics shall dynamically update.
    2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation) as described in Section 25 09 10.

3.13 CONTROL SYSTEM CHECKOUT AND TESTING

1. Startup Testing. Complete startup testing to verify operational control system before notifying The City of system demonstration. Provide The City with schedule for startup testing. The City may have representative present during any or all startup testing.
    1. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 25 09 10.
    2. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
    3. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
    4. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
    5. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
    6. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated. The log shall be included in the O&M manuals.
    7. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
    8. Alarms and Interlocks.
        1. Check each alarm with an appropriate signal at a value that will trip the alarm.
        2. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
        3. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.14 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

1. Demonstration. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with Specification after and in addition to tests specified in Article 3.16 (Control System Checkout and Testing). Provide Contract Administrator with log documenting completion of startup tests.
    1. Contract Administrator will be present to observe and review system demonstration. Notify Contract Administrator at least 10 days before system demonstration begins.
    2. Demonstration shall follow process submitted and approved under Section 25 09 10 Article 1.10 (Submittals). Complete approved checklists and forms for each system as part of system demonstration.
    3. Demonstrate actual field operation of each sequence of operation as specified in Section 25 09 10 Appendix A. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Contract Administrator. Provide and operate test equipment required to prove proper system operation.
    4. Demonstrate compliance with Section 25 09 10 Part 1 (System Performance).
    5. Demonstrate compliance with sequences of operation through each operational mode.
    6. Demonstrate complete operation of operator interface.
    7. Demonstrate each of the following.
        1. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Contract Administrator will require further tuning of each loop that displays unreasonably under- or over-damped control.

2. Demand limiting. Supply trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
3. Building fire alarm system interface.
4. Trend logs for each system. Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list (or as noted on the control schematics and the sequence of operation) provided with each sequence of operation in Section 25 09 10 Appendix A. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified in Section 25 09 10 Article 2.3 Paragraph 6.11 (Trend Configuration). Note that the long term trending, specified in the above article shall also be provided (all points, 30 minute interval, one year).

8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

2. Acceptance.
   1. After tests described in this Specification are performed to the satisfaction of both Contract Administrator and The City, Contract Administrator will accept control system as meeting completion requirements. Contract Administrator may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Contract Administrator will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
   2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 25 09 10 Article 1.10 (Submittals).

3.15 CLEANING

1. Each day clean up debris resulting from Work. Remove packaging Material as soon as its contents have been removed. Collect waste and place in designated location.

2. On completion of Work in each area, clean Work debris and equipment. Keep areas free from dust, dirt, and debris.

3. On completion of Work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new Material and repaint to match adjacent areas.

3.16 TRAINING

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

2. Training shall enable students to accomplish the following objectives.
   1. Proficiently operate system
   2. Understand control system architecture and configuration
   3. Understand DDC system components
   4. Understand system operation, including DDC system control and optimizing routines (algorithms)
   5. Operate workstation and peripherals
   6. Log on and off system
   7. Access graphics, point reports, and logs

8. Adjust and change system setpoints, time schedules, and holiday schedules
9. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
10. Understand system Drawings and Operation and Maintenance manual
11. Understand job layout and location of control components
12. Access data from DDC controllers
13. Operate portable operator's terminals
14. Create and change system graphics
15. Create, delete, and modify alarms, including configuring alarm reactions
16. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs
17. Configure and run reports
18. Maintain software and prepare backups

3. Divide presentation of objectives into two sessions (1-13, 14-18). Participants will attend one or more of sessions, depending on knowledge level required.
   1. Day-to-day Operators (objectives 1-13)
   2. Advanced Operators (objectives 1-13 and 14-18)

4. Provide course outline and Materials according to Section 25 09 10 Article 1.10 (Submittals). Provide one copy of training Material per student.

5. Instructors shall be factory-trained and experienced in presenting this material.

6. Perform classroom training using a network of working controllers, representative of installed hardware.

7. Use sign-in sheets for all training sessions, recording attendees and time (number of hours) of training and subjects covered (per list 3.19.2 above)

3.17 SEQUENCE OF OPERATION

See Section 25 09 10 Appendix A (Sequences of Operation).

APPENDIX A: Sequences of Operation

1. General

.1 The building is to operate on a summer/winter schedule and occupied and unoccupied mode. The winter operation schedule shall be enabled when the outdoor temperature drops below 60°F (15°C) (adj).
Summer operation (occupied) setpoint of 75°F (24°C) and night (unoccupied) setpoint of 82°F (28°C)
Winter operation (occupied) setpoint of 72°F (22°C) (adj.) and night (unoccupied) setpoint of 61°F (16°C) (adj.)

Occupied Mode:

In occupied mode all fan coil blowers and ERV fans shall run continuously.

Unoccupied Mode:

In unoccupied mode the fan coil blowers shall be off, and the ERV shall be disabled. Fan coils shall turn on and operate to heat or cool a space in which the temperature drops below the night setpoint.

A. Building Warm-up Mode:

- When the building is in the warm-up mode the fan coils shall operate in occupied mode. When the warm-up temperature has been reached the systems shall revert to normal operation.

2. Heat Recovery Ventilator

.1 The unit shall run in occupied mode. The fans shall be disabled in unoccupied mode. Both motorized dampers located in ERV ductwork shall remain open in occupied mode, and shall remain closed in unoccupied mode.

.2 When the outside conditions are appropriate for free cooling, and the VRF system has more than three (3) zones calling for cooling, the ERV shall operate in economizing mode, whereby the supply fan and exhaust fan continue to operate, but the air-stream will not reverse flow direction for heat recovery.

3. Fan Coil with Variable Refrigerant System and Electric Heating Coils (9 fan coils, 9 electric coils)

.1 The system shall come complete with factory controller with BACnet communication interface for integration with DDC.

.2 The system shall operate in heating and cooling modes utilizing its integral control system linked to outdoor unit, indoor VRF indoor units, and branch selectors.

.3 The system shall operate based on an occupied and unoccupied schedule. This schedule shall be determined by the DDC system.

.4 In heating mode, and while outdoor conditions are suitable for the VRF system, the VRF system shall maintain space temperature setpoint. The electric heating coils and electric heaters shall be enabled as the second stage of heating to supplement the VRF system heating. Refer to mechanical Drawings for locations of electric heaters. The system shall operate to maintain minimum supply air temperature of 60°F (adj.) in heating mode.

.5 The system shall not allow electric heating and VRF cooling simultaneously.

4. Electric Heating Mat

.1 The electric heating mat shall modulate to maintain floor temperature. The slab temperature shall be reset based on the outdoor air temperature. The reset schedule shall be adjustable, and initially set as follows:

Outdoor Air Temperature	Slab Set-point
41°F or above	Electric mat off
40°F	75°F
-35°F or below	85°F

The temperature shall reset linearly between the points above.

Points List

The below points list is intended to be an accurate representation. If extra points are required to meet the sequence of operation Specifications, they shall not be an extra to the Contract.

1. HRV - On/Off

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Fan Status (x2)			x						x		x
Fan Start/Stop (x2)				x					x		x
Fan Failure (x2)										x	x
Fan Runtime Exceeded					x					x	x
Motorized Damper 1				x							x
Motorized Damper 2				x							x
Outside Air Wetbulb Temperature	x								x		x
Outside Air drybulb Temperature	x								x		x

2. Fan Coil Units and Electric Coils (x number of points)

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp (typ. x9)	x								x		x
Zone Setpoint Adjust (x9)	x										x
Zone Override (x9)			x						x		x
Fan Status (x9)			x								x
Fan Start/Stop (x9)				x					x		x
Heating Setpoint (x9)					x				x		x
Cooling Setpoint (x9)					x				x		x
High Zone Temp (x9)										x	x
Low Zone Temp (x9)										x	x
Fan Failure (x9)										x	x
Fan in Hand (x9)										x	x

4. Miscellaneous

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Room Temperature (x Refer to plans for locations of sensors)	x										x
Room Low Temp. (x Refer to plans for locations of sensors)					x					x	x
Reading Room Slab Temp. and Set-point	x				x					x	x

APPENDIX B: Glossary of Terms
Terms used within the Specification Text:

- **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.
- **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/IP:**
  An approved BACnet network type which uses an Ethernet carrier and IP addressing.
- **BACnet MS/TP:**
  An approved BACnet network type which uses a Master-Slave Token Passing configuration. MS/TP networks are unique to BACnet and utilize EIA485 twisted pair topology running at 9600 to 76,800 bps.
- **BACnet over ARCNET:**
  An approved BACnet network type which uses an ARCNET (attached resource computer network) carrier. ARCNET is an industry standard that can utilize several speeds and wiring standards. The most common configuration used by BACnet controllers is an EIA485 twisted pair topology running at 156,000 bps.
- **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.
- **Direct Digital Control (DDC):**
  A control system in which a digital computer or microprocessor is directly connected to the valves, dampers, and other actuators which control the system, as opposed to indirectly controlling a system by resetting setpoints on an analog pneumatic or electronic controller.
- **PICS - Protocol Implementation Conformance Statement:**
  A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.
- **Smart Actuator (SA):**
  An actuator which is controlled by a network connection rather than a binary or analog signal. (0-10v, 4-20mA, relay, etc.)

- **Smart Sensor (SS):**
  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.)
- **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.

Terms used within the Sequences of Operation:

- **adj.**
  Adjustable by the end user, through the supplied user interface.
- **AI, AO, etc. (Column Headings on Points List)**
  AI = Analog Input. A physical input to the control module.
  AO = Analog Output. A physical output from the control module.
  AV = 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.
  BI = Binary Input. A physical input to the control module.
  BO = Binary Output. A physical output from the control module.
  BV = 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.
  Sched = 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.)
  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.

  Note: If the Specifications require use of the BACnet protocol, all of the above shall be provided as BACnet objects.
- **KW Demand Limiting:**
  An energy management strategy that reduces energy consumption when a system's electric power meter exceeds an operator-defined threshold.
  When power consumption exceeds defined levels, the system automatically adjust setpoints, de-energizes low priority equipment, and takes other pre-programmed actions to avoid peak demand charges. As the demand drops, the system restores loads in a predetermined manner.
- **Occupant Override Switch, or Timed Local Override:**
  A control option that allows building occupants to override the programmed HVAC schedule for a limited period of time.
  When the override time expires, the zone returns to its unoccupied state.
- **Occupant Setpoint Adjustment:**
  A control option that allows building occupants to adjust - within limits set by the HVAC control system - the heating and cooling setpoints of selected zones. Typically the user interface for this function is built into the zone sensor.
- **Optimal Start-Up:**
  A control strategy that automatically starts an HVAC system at the latest possible time yet ensures comfort conditions by the time the building becomes occupied.
  In a typical implementation, a controller measures the temperature of the zone and the outside air. Then, using design heating or cooling capacity at the design outside air temperature, the system computes how long a unit must run at maximum capacity to bring the zone temperature to its occupied setpoint.
  The optimal start algorithm often includes a self-learning feature to adjust for variations from design capacity.
  A distributed system must use Run on Request with Optimal Start. (See below.)

- **Requested, or Run on Request:**
  A control strategy that optimizes the runtime of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service. Source equipment runs only when needed, not on a fixed schedule.
  The source equipment runs when one or more receiving units request its services. An operator determines how many requests are required to start the source equipment.
  For example, if all the zones in a building are unoccupied and the zone terminal units do not need heating or cooling, the AHU will shut down. However, if a zone becomes occupied or needs cooling, the terminal unit will send a run request to the AHU to initiate the start-up sequence. If this AHU depends on a central chiller, it can send a run request to the chiller.
  The run on request algorithm also allows an operator to schedule occupancy for individual zones based on the needs of the occupants without having to adjust the schedules of related AHUs and chillers.
- **Trim and Respond, or Setpoint Optimization:**
  A control strategy that optimizes the setpoint of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service.
  The source unit communicates with receiving units to determine heating, cooling, and other requirements, and then adjusts its setpoint.
  For example, if all zones are comfortable and do not request cooling, the AHU will gradually increase (trim) its supply air setpoint. When a zone requests cooling, the AHU responds by dropping its setpoint. The more zones that request cooling, the more it drops the setpoint. The AHU repeats this process throughout the day to keep zones cool, but with a supply air setpoint that is no cooler than necessary.

Contracting Terms:

- **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.
- **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.
- **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.
- **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.

APPENDIX C: Abbreviations

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

AC - Air Conditioning
ACU - Air Conditioning Unit
AHU - Air Handling Unit
AI - Analog Input
AO - Analog Output
AUTO - Automatic
AUX - Auxiliary
BI - Binary Input
BO - Binary Output
C - Common

CHW - Chilled Water
CHWP - Chilled Water Pump
CHWR - Chilled Water Return
CHWS - Chilled Water Supply
COND - Condenser
CW - Condenser Water
CWP - Condenser Water Pump
CWR - Condenser Water Return
CWS - Condenser Water Supply
DA - Discharge Air
EA - Exhaust Air
EF - Exhaust Fan
EVAP - Evaporators
FCU - Fan Coil Unit
HOA - Hand / Off / Auto
HP - Heat Pump
HRU - Heat Recovery Unit
HTEX - Heat Exchanger
HW - Hot Water
HWP - Hot Water Pump
HWR - Hot Water Return
HWS - Hot Water Supply
MAX - Maximum
MIN - Minimum
MISC - Miscellaneous
NC - Normally Closed
NO - Normally Open
OA - Outdoor Air
PIU - Powered Induction Unit
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
VVTU - Variable Volume Terminal Unit
W/ - with
W/O - without
WSHP - Water Source Heat Pump

END OF SECTION