1.0 PART 1 - GENERAL

1.1 GENERAL SCOPE

A. Building Management System (BMS), utilizing direct digital controls.

B. Furnish all labor, materials, equipment, and service necessary for a complete and operating Building Control System (BCS), utilizing Direct Digital Controls (DDC) as shown on the drawings and described herein.

C. The BCS shall perform control algorithms, calculations and all monitoring functions. The BCS shall provide operator interaction and dynamic process manipulation, including overall system supervision, coordination and control.

D. This shall include HVAC control, metering, energy management, alarm monitoring, and all trending, reporting and maintenance management functions related to normal building operations all as indicated on the drawings or elsewhere in this specification.

1.2 RELATED WORK SPECIFIED ELSEWHERE

A. Products Supplied But Not Installed Under This Section:
1. Control valves.
2. Flow switches.
3. Wells, sockets and other inline hardware for water sensors (temperature, pressure, flow).
4. Automatic control dampers, where not supplied with equipment.
5. Airflow measuring stations.
6. Terminal unit controllers and actuators, when installed by terminal unit manufacturer.
7. Variable frequency drives. (This does not include VFDs integral to machinery such as chillers or boilers).

B. Products Supplied But Not Installed Under This Section:
1. Section – Hydronic Piping
   a. Control valves.
   b. Flow switches.
   c. Flow meters.
   d. Wells, sockets and other inline hardware for water sensors (temperature, pressure, flow).
2. Section – Ductwork Accessories
   a. Automatic control dampers, where not supplied with equipment.
   b. Airflow measuring stations.
   c. Terminal unit controllers and actuators, when installed by terminal unit manufacturer.

C. Products Installed But Not Supplied Under This Section:
1. None.

D. Products Not Furnished or Installed But Integrated with the Work of This Section:
1. Major Items
   a. Chiller control systems.
   b. Boiler control systems.
   c. Pump control packages.
   d. In-line meters (gas, water, power).
   e. Refrigerant monitors.
   f. Chemical water treatment.
   g. Smoke detectors (through alarm relay contacts).

E. Work Required Under Other Divisions Related to This Section:
1. Power wiring to line side of motor starters, disconnects or variable frequency drives.
2. Wiring of power feeds through all disconnects, starters, and variable speed controllers to electric motors.
3. Wiring and conduit required for dedicated 115 VAC outlets at the Operator Interfaces and accessories.
4. Provision and wiring of smoke detectors and other devices relating to fire alarm system.
5. Campus LAN (Ethernet) connection adjacent to network management controller.

1.3 RELATED SECTIONS

A. 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.

B. Section 23 05 00 - Basic Mechanical Materials and Methods: Performance and reference standards for products and materials required for the Project.

1.4 SYSTEM DESCRIPTION

A. Scope: Provide and install a dedicated, stand-alone automatic Direct Digital Control system complete with all required software and hardware. This system will directly control all specified mechanical equipment, including VAV boxes, heat pumps, fans, duct coils, heat recovery units, pumps, cooling towers, central chiller plant machinery, etc.
1. The operator workstation shall run on a personal computer (PC) with a color monitor, mouse, keyboard, and printer. The operator workstation will allow a user to interface with the network via graphic and/or text format as described in the Product section Part 2.
2. The controls contractor shall assume complete responsibility for the entire controls system as a single source. He shall certify that he has on staff under his direct employ on a daily basis, factory trained technical personnel. These employees shall be qualified to project manage, engineer, commission, and service all portions of the control system.
3. The control system shall be designed such that each mechanical system will be able to operate under stand-alone control. As such, in the event of a network communication failure, or the loss of any other controller, the control system shall continue to independently operate.

B. Basic System Features:
1. Zone by zone direct digital logic control of space temperature, scheduling, optimum starting, equipment alarm reporting, and override timers for after-hours usage. A zone is the area served by one VAV box, heat pump, unit ventilator, fan coil, etc.
2. Operator Interface software shall be a web-browser application. The server software shall be multi-tasking, capable of executing and displaying multiple instances in individual windows while running concurrently with other Windows programs such as word processors or database programs. Operation of the terminal software shall be simple and intuitive.
3. Complete energy management firmware, including self-adjusting optimum start, power demand limiting, global control strategies and logging routines for use with total control systems. All energy management firmware shall be resident in field hardware and not dependent on the Operators Terminal for operation. Operators terminal software is to be used for access to field based energy management control firmware only.
4. Priority password security systems to prevent unauthorized use. Each user shall have an individual password, or users can be assigned to a group password. Each user shall be assigned which control functions they have access to.

5. Equipment monitoring and alarm function including information for diagnosing equipment problems and alarm dial out to remote sites or pagers.
6. The complete system, including, but not limited to zone controllers, field installed controllers and operator's terminals shall auto-restart, without operator intervention, on resumption of power after a power failure. Database stored in field installed controller memory shall be battery backed up for a minimum of 1 year. Batteries on unitary controllers shall not be allowed.
7. Modular system design of proven reliability.
8. Each field panel capable of independent control.
9. All software and/or firmware interface equipment for connection to remote monitoring station from field hardware or the operator's terminal.
10. The system shall be capable of recording equipment runtime totalization of fans, heaters, boilers, etc., and also capable of alarm generation and alarm dial out to remote sites.
11. Communication wiring for field controllers shall not be run in star patterns.
12. All DDC hardware and software shall be designed and manufactured by U.S. corporations. All hardware shall be Listed Underwriters Laboratory for Open Energy Management Equipment (PAZX) under the U.L. standard for safety 916, with integral labels showing rating.

C. Reference Standards.
1. The latest edition of the following standards and codes in effect and amended as of date of supplier's purchase order, and any subsections thereof as applicable, shall govern design and selection of equipment and material supplied:
2. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) Standards 135 (BACnet), 90.1 and 62.99,
3. Directive 89/336/EEC (European CE Mark).
4. City, county, state, and federal regulations and codes in effect as of date of purchase order.
5. Except as otherwise indicated, the system supplier shall secure and pay for all permits, inspections, and certifications required for his work and arrange for necessary approvals by the governing authorities.

1.5 QUALITY ASSURANCE

A. The Control System Contractor shall have a full service DDC office within 50 miles of the job site. This office shall be staffed with applications engineers, software engineers and field technicians. This office shall maintain parts inventory and shall have all testing and diagnostic equipment necessary to support this work, as well as staff trained in the use of this equipment.

B. The installer shall be certified as a trained, approved installer by the Building Controls Systems Manufacturer. The certification shall be for the type and version of the product to be installed in this project.

C. The installer shall have completed the Building Control Systems Manufacturer's classes on the control system. The installer shall present for review the certification of completed training, including the hours of instruction and course outlines upon request.

D. Single Source Responsibility of Supplier: The Control System Contractor shall be responsible for the complete installation and proper operation of the control system. The Control System Contractor shall exclusively be in the regular and customary business of design, installation and service of computerized building management systems similar in size and complexity to the system specified. The Control System Contractor shall be the manufacturer of the primary DDC system components or shall have been the authorized representative for the primary DDC components manufacturer for at least 5 years.

E. Product Qualification:
1. All products used in this installation shall be new, currently under manufacture, and shall not be used as a test site for any new products unless explicitly approved by the Engineer in writing. Spare parts shall be available for at least 5 years after completion of this contract.
2. All controllers shall be capable of containing and executing factory designed and tested, pre-engineered control algorithms. Factory tested algorithms shall be utilized to meet the sequence of operation (except as noted).
3. All products shall be available to multiple installers. The manufacturer shall have at least 3 installation and service providers within 100 mile radius.

1.6 SUBMITTALS

A. Submit under provisions of Section 01 30 00.

B. Drawings:
1. The system supplier shall submit engineered drawings, control sequences, bill of materials, bus riser diagrams, hardware/software product data sheets, and applicable valve and damper schedules for approval.
2. Drawings shall be submitted in the following standard sizes: 11” x 17” or 8 ½” x 11”
3. Six complete sets of submittal drawings shall be provided.
4. Drawings shall be available on CD-ROM.

C. Operation and Maintenance Manuals:
1. Manuals will be provided prior to final acceptance and shall include:
2. Installation instructions.
3. Principles of operation and a detailed system description.
4. Startup and operating instructions.
5. System layout and interconnection schematic diagrams.
6. Routine preventive maintenance procedures and corrective diagnostic troubleshooting procedures.
7. Name, address and telephone number of the DDC Systems field representative.
8. Complete recommended spare parts list.

1.7 WARRANTY

A. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one year from completion and acceptance by the owner, except for damages from other causes.

B. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours during normal business hours.

C. This warranty shall apply equally to both hardware and software and be at no cost to the owner.

1.8 APPROVED CONTROL SYSTEM PRIMARY MANUFACTURERS

A. The following are approved BAS manufacturers and product lines:
1. Carrier Corporation: i-Vu Building Automation

B. Owner reserves the right to reject, at his option, any and all bids that do not meet the specified requirements stated.

1.9

2.0 MANUFACTURERS INSTALLER REQUIREMENTS

A. Manufacturers Authorized Installer Requirements
   1. The contractor must be regularly engaged in the service and installation of BACnet and i-Vu as specified herein.
      a. The Contractor shall have a minimum of 5 years' experience in the sales, installation, engineering, programming, servicing and commissioning of i-Vu.
   2. The contractor shall submit a list of no less than three (3) similar (in function, application and design) projects, which have similar Building Automation Systems as specified herein installed by the Contractor.
      a. These projects must be on-line and functional such that the Owner's/User's representative can observe the system in full operation.
   3. The Contractor's capabilities shall include engineering and design of control systems, programming, electrical installation of control systems, troubling shooting and service.

B. BAS Contractor Certification
   1. The Contractor shall have a minimum of three (3) technicians who have successfully completed the factory authorized training of the proposed manufactures hardware and software components and have successfully completed i-Vu Control Expert certification course(s).
      a. Contractor must provide proof of required training.
      b. Contractor must provide proof of completing annual product update training, offered by the manufacturer.
   2. Bidder for Carrier systems shall provide documentation showing them as a currently authorized Carrier Controls Expert.
      a. The contractor shall be listed accordingly on the www.carrier.com/controls-experts geographical locator, and provide factory certificates upon request.
      b. All technicians utilized shall also provide the appropriate exam certificates upon request.
   3. Certification must include one of the following
      a. Comfort System provider (CS)
      b. I-vu System provider (IS)
      c. Encompass System provider (ES).

2.0 <u>PART 2 - PRODUCTS</u>

2.1 MATERIALS

2.1.1 BAS PC HARDWARE

2.1.1.1 OPERATOR INTERFACE: CLIENT PC

A. Each standard client browser connected to the server shall be able to access all system information.

B. Hardware: Each client computer shall consist of the following:
   1. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document.
   2. Provide
      a. Dual core processor,
      b. 1.5 GB RAM,
      c. 10Mbps or higher LAN communications,
      d. Serial, parallel, cables as required for proper DDC system operation.

e. The client PC shall support a minimum screen resolution of 1024 x 768 32-bit color.
f. The BCS shall perform control algorithms, calculations and all monitoring functions.
g. The BCS shall provide operator interaction and dynamic process manipulation, including overall system supervision, coordination and control.

C. Browser Software
1. Client computer shall have an industry-standard professional-grade operating system. Operating system shall support Google™ Chrome™, Internet Explorer, Mozilla Firefox, and Safari web browsers with Java and ActiveX plugins enabled.

D. Communication
1. Each client shall be able to communicate to the server over a Local Area Network (LAN) or Wide Area Network (WAN) using industry standard Internet Protocols.

2.1.2 BUILDING CONTROLLERS

2.1.2.1 BACNET CONTROLLERS: GENERAL PURPOSE

A. Advanced Application Controllers (AAC) shall be a solid state micro-controller with configurable control module with pre-tested and factory configured software specifically designed for regulating building equipment using closed-loop Direct Digital Control and facility management routines. Controllers shall be capable operating in a stand-alone or networked manner, and shall be located where shown on the plans. The controller shall be powered from standard, off-the-shelf, Class II, 24-volt transformers. The controller shall be easily mounted in a standard NEMA 1 type enclosure without special rails or mounting hardware and as local and national code dictates. The controller shall be capable of operating in either a stand-alone mode or as part of a network with an EMS operator's station and other system elements including Product Integrated Controllers (PIC's)

B. BACnet. Advanced Application Controllers (AACs). 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. AAC shall reside on a BACnet network using the MS/TP or ARCNET Data Link/Physical layer protocol.

C. Custom Programming
The controller shall contain a graphical controller based programming language for creating complex control strategies for specific unique applications. Custom programs shall be retained in controller memory and shall not require a host CPU to operate. All custom programming point data shall be transferable from one controller to another (if networked) directly without an on-line CPU or host computer.

D. 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. Data Sharing. Each AAC shall share data as required with each networked.

E. 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 -29°C to 60°C (-20°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).

F. Memory.

1. The Controller shall have a Non-Volatile Memory providing indefinite storage of application and configuration data.
2. Controller memory shall support operating system, database, and programming requirements.

G. Controller Time.
Controller shall feature and maintain a 365-day Real-Time Clock/Calendar with holiday functions.

H. Stand alone capability. The controller shall be capable of providing all control functions of the HVAC system without the use of a computer.
1. It shall establish occupancy scheduling based on its own local occupancy schedule, the closure of a contact connected to an external time clock or EMS system, or by a timed override request (1 to 24 hours) through its space temperature sensor override button.

I. Networked capability. The controller shall include the inherent capability to access the system control selections as well as to monitor system performance by means of a communicating network with a PC and EMS software program.
1. When networked, occupancy may be established by user interface or occupancy signal from other controller located in network.

J. Scheduling. AAC 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.

K. Serviceability.
1. Controller 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.

L. Immunity to Power and Noise. AAC 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).

M. Input and output devices shall be wired to "quick-connect plug type" terminals to facilitate removal of the module without disconnecting wiring from the plug type terminal.

N. Alarm Processing. The controller shall contain a routine to process alarms. Alarm processing logic shall also monitor return to normal conditions as part of the alarm scan. The operator will have the ability to modify the alarm/alert priority level.

O. 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.

P. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of preconfigured minimum on-time and off-time settings, customized for the specific requirements of the application.

Q. 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.

R. Inputs. Shall support the following input types as a minimum
1. Dry or pulsed dry contacts
2. 0-5 VDC
3. 0-10 VDC
4. 4-20 mA
5. 10K thermistors
6. 1000-ohm Nickel RTD

S. Outputs. Shall support the following input types as a minimum
1. Discrete types
2. 0-10 VDC analog type
3. 4-20 mA analog type

T. Real-Time Clock. Shall feature and maintain a 365-day hardware clock/calendar with holiday functions.

U. Library of direct digital control routines. The following types of factory tested direct digital control routines shall be provided as a minimum:
1. Indoor/Outdoor Lighting Control
2. Time Schedule with/without override
3. Enthalpy/Analog Comparison
4. Analog Comparison
5. Interlock / Permissive Interlock
6. Fan Control
7. Time Schedule with/without override
8. Unit Heater
9. Constant Volume Air Source control with Demand Controlled Ventilation
10. VAV Air Source control with Demand Controlled Ventilation
11. WSHP Loop Monitor and Pump Control
12. WSHP Loop Cooling - Closed Circuit Tower
13. WSHP Loop Cooling - Open Circuit Tower
14. WSHP Loop Heating
15. Electric Meter with Demand Limit

2.1.3 COMMUNICATION

2.1.3.1 COMMUNICATION NETWORK

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

B. Install new wiring and network devices as required to provide a complete and workable control network. Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 16. All insulated wire to be stranded copper conductors and UL labeled for 90C minimum service.

C. Physically, bus extender devices (Repeaters) may be utilized to extend the MS/TP or ARCNET bus in length and number of networked controllers. Each Repeater shall be able to regenerate and transmit bi-directional signals and support communications for the added bus segment. The repeater shall be equipped with LED lights to indicate communications through its RS-485 port

D. Use existing Ethernet backbone for network segments marked "existing" on project drawings.

E. 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.

F. 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, and status 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. 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.

G. 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.

2.1.4 LOCAL OPERATORS INTERFACE

2.1.4.1 PORTABLE OPERATORS INTERFACE

A. Portable Keypad
   1. At least one Keypad with display shall be provided and shall be capable of connecting to any field controller.
   2. 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 provide a keypad and display, provide all necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

2.1.5 FIELD SENSORS

2.1.5.1 FIELD SENSORS: TEMPERATURE, HUMIDITY, CO2, PRESSURE, STATUS, ETC.

A. Temperature Sensors
   1. Space Temperature Sensors: Space Temperature Sensors shall be 10,000-ohm thermistors or resistance temperature detector types with wall plate adapter and blank cover assembly. If so indicated on the plans, the sensor shall include an integral occupancy override button, an RJ11 communications port, and optional space temperature adjustment slide.
   2. Duct Temperature Sensors: Duct Temperature Sensors shall be 1000-ohm single point or averaging type as need. Averaging sensors shall be RTDs, or 10,000-ohm averaging thermistors. Single point sensors shall be 5,000 ohm or 10,000-ohm thermistors.
   3. Outside Air Sensors: Outside Air Sensor shall 10,000-ohm thermistor, with integral PVC housing and ½" NPT conduit connector.
   4. Water Temperature Sensors: Water Temperature Sensors shall be well mounted or pipe-clamp types as specified on the plans. Sensors shall be 10,000-ohm thermistors, or 1,000-ohm RTDs. Locate as shown on the plans, and provide extended neck wells where applicable on insulated pipes.

a. Changeover thermostats shall be 10,000-ohm strap on thermistors with flexible copper plate and screw clamp for externally mounting on the pipe.

B. Humidity Sensors
1. Space and Duct Relative Humidity Sensors: Space Relative Humidity Sensors shall and have a range of 0-100% RH. The measuring accuracy shall be between 2% and 5% as indicated on the plans over the range of the device.
2. Outdoor Air Relative Humidity Sensors: Outdoor Relative Humidity Transmitters shall be enclosed in a weather-tight junction box and measure outdoor air humidity from 0% to 100% with accuracy between 2% and 5% as needed to fit the application. Transmitters shall not require calibration and shall provide a 2-wire 4-20 mA, 3 wire 0-5 Vdc, or 3 wire 0-10Vdc output signal.

C. CO2 Sensor Sensors
1. Space CO2 Sensor with Temperature Sensors: The wall mounted combination sensors shall contain a space temperature sensor and Carbon Dioxide (CO2) sensor in a single. TheCO2 sensor shall use single-beam absorption infrared diffusion technology and be self-calibrating. The CO2 range shall be 0-2000 PPM with analog outputs of 4-20 ma or 0-10 v. with a power source of 18-30 Vac, 50/60 Hz. The accuracy shall be +/- 100 PPM at 60F to 90F. The sensor shall include an integral occupancy override button, a set point adjustment slidebar, and an RJ14 communication port.
2. Space and Duct CO2 Sensors: The wall mounted, hand held, or duct mounted sensors shall utilize single-beam absorption infrared diffusion technology, and be self-calibrating. The CO2 range shall be 0-2000 PPM with analog outputs of 4-20 ma or 0-10 v. with a power source of 18-30 Vac, 50/60 Hz. The accuracy shall be +/- 100 PPM at 60F to 90F.

D. Pressure Transmitters
1. Pressure Transmitters: Transmitters shall provide accessible zero and span adjustments, and shall measure gauge or differential pressure of liquids or gases over several operating scales extending from 30 inches vacuum to 2000-psig. The Transmitter shall vary the output current in proportion to the input pressure, and shall operate with a nominal supply voltage of 12 to 32 V dc as needed and provide a 4-20 mA output signal.

E. Current to Pressure Transducers: Current to Pressure Transducers shall convert the 4 to 20ma or 0 to 10 Vdc analog output signal from the controller into a 3-15 PSI pneumatic output. It shall contain a 0-30 PSI manifold gauge indicating actual output air pressure.

F. Flow Transmitters:
1. Transmitters shall be powered by 24 Vdc, and provide a digital display of gpm and totalized flow. Transmitters shall convert a digital flow signal into a 4-20 mA output signal for flow rate indication, and divide the digital input signal into a selectable digital dry or electronic contact pulse output signal for flow totalization indication. Transmitters shall provide excitation voltage for flow sensors and an LED indication of pulse activity.

G. Flow Sensors: Flow Sensors shall utilize differential pressure or a vane to measure water flow and have an operating range with an adjustable setpoint as needed. Water flow types shall be complete with safety shut-off valves and all necessary connections. Flow sensors shall generate a 4-20ma or 0-10Vdc proportional signal as needed.

H. Status Indication: A current sensing or differential pressure device shall provide status indication for fans and pumps.
1. Current Sensing: The current sensing device shall be installed at the motor starter or motor to provide load indication. The device shall consist of a current transformer, a

solid state current sensing circuit with adjustable trip point, and a solid state or contact switch. A red light emitting diode (LED) shall indicate the ON OFF status of the unit. The switch shall provide a N.O. contact for wiring back to the General Purpose Controller.

2. Differential Pressure: A differential pressure sensing device shall be installed across the fan or pump and utilize two sensing elements to provide pressure indication. The device shall operate a SPDT switch with adjustable trip point contact for wiring back to the General Purpose Controller.
3. Filter / Status Switches: Filter Switch shall be a differential pressure type, adjustable across the range of the device, with a single pole double throw switch. The range, in inches water column, shall be as indicated on the plans.
4. Float Switches: Float Switches shall be equipped with a stainless steel float, magnetically actuated, and capable of sensing fluids with a specific gravity of 0.7 and higher.
5. High Temperature Detection Thermostats: High Temperature Detection Thermostats shall be of the manual reset type with sensing element arranged to insert into duct or casing and shall be set for 165F. The device shall have double pole, NO, NC contacts for supply fan shutdown and remote alarming.
6. Low Temperature Detection Thermostats: Low Temperature Detection Thermostats shall be of the manual reset, type unless otherwise specified, with sensing element not less than 20 feet long. The device shall have double pole, NO, NC contacts for supply fan shutdown and remote alarming. If alarming is not required, the device shall have a single pole, NC contact.
7. Duct High Pressure Cutout Switches: Duct High Cutout Pressure Switches shall include a manual reset single pole double throw pressure switch with a setpoint range of 1.4 to 5.5 inch water column, tubing and tubing adapters.
8. Start/Stop and Status Relays: Start/Stop and Status Relays shall be designed to plug into a screw terminal-mounting socket. Relays shall be single pole, or double pole as required with double throw contacts rated for required duty. Magnetic Latching Type Control Relay coils shall be activated by a pulsed input and shall maintain condition even during a power failure. A built-in indicator shall show set/reset condition.

I. Power Supplies and Transformers: Power Supplies and Voltage Transformers shall convert 120 Vac primary supply voltage into 24 Vac or 24 Vdc control voltage as needed.

2.1.5.2 FIELD SENSORS: COMMUNICATING

A. Communicating Sensors, General:
1. Communicating Sensors shall be powered by 12 VDC, and control the HVAC (heating, cooling, and ventilation) equipment through RS-485 bus communications.
2. The communicating sensors shall connect directly to the dedicated sensor network.
3. This communicating sensor network shall supports no less than 15 communicating sensors through a single port, to eliminating the need to consume multiple inputs on the controller.

B. Space Sensors:
The sensing element shall be enclosed in a plastic housing and shall have a hidden communication port to allow a handheld service tool access to the controller network.

Where indicated on the plans, provide Plus style sensors which shall be equipped with a sliding setpoint adjustment, an occupancy indicating LED and an override pushbutton.

Where indicated on the plans, provide Pro style sensors which shall be equipped with a liquid crystal display (LCD) with 4 push-button user interface for configuring setpoints and time schedules. Sensors shall store configuration parameters in non-volatile memory and provide coordinated control of the HVAC equipment after a power outage.

In areas when multiple space conditions are to be measured / controlled, all combinations of sensors shall be provided in one sensor housing and shall be installed on a standard 4” x 2” junction box. Any deviation from this requires written approval from the engineer and architect.

In addition to sensing temperature, communicating sensors shall have the following combinations of sensing capabilities:

1. Combination Space Temperature / RH Wall Sensors
   Temp Range of 50° F to 104° F (10° C to 40° C) Accuracy: ±0.5° F (0.3° C)
   Relative Humidity Range: 10% to 90% Accuracy: ±1.8% typical
2. Combination Space Temperature / CO2 Wall Sensors
   Temp Range of 50° F to 104° F (10° C to 40° C) Accuracy: ±0.5° F (0.3° C)
   CO2 Range/Accuracy: 400 to 1250 PPM = ±30PPM or 3% of reading, whichever is greater. 1250 to 2000 PPM = ±5% of reading plus 30 PPM
3. Combination Space Temperature / VOC Wall Sensors
   Temp Range of 50° F to 104° F (10° C to 40° C) Accuracy: ±0.5° F (0.3° C)
   VOC Range: 0 to 2,000 PPM Accuracy: ±100 PPM
4. Combination Space Temperature / RH / CO2 Wall Sensors
   Temp Range of 50° F to 104° F (10° C to 40° C) Accuracy: ±0.5° F (0.3° C) Relative Humidity Range: 10% to 90% Accuracy: ±1.8% typical
   CO2 Range/Accuracy: 400 to 1250 PPM = ±30PPM or 3% of reading, whichever is greater. 1250 to 2000 PPM = ±5% of reading plus 30 PPM
5. Combination Space Temperature / RH / VOC Wall Sensors
   Temp Range of 50° F to 104° F (10° C to 40° C) Accuracy: ±0.5° F (0.3° C)
   Relative Humidity Range: 10% to 90% Accuracy: ±1.8% typical
   VOC Range: 0 to 2,000 PPM Accuracy: ±100 PPM

C. Duct Sensors:
The communicating duct sensors shall measure the air temperature and/or humidity in ductwork. All duct sensors shall feature Polycarbonate enclosure with closed cell foam to seal the insertion hole and to absorb vibration. The enclosure shall be UV rated and comply with: UL94V-0, NEMA 4, IP66.

Enclosure mounting tabs shall allow for easy installation onto the wall of the duct. The sensors shall withstand high humidity and condensation environments

The communicating duct sensors shall be available in different models, including temperature only, temperature plus humidity, and temperature averaging

1. Temperature Duct Sensors:
   Temp Range of 20° F to 120° F (-5° C to 50° C) Accuracy: ±0.9° F (0.5° C)
   Temperature sensor probe: 304 SS / 0.25 in. (0.64 cm) diameter / Length (4 or 8 in.)
2. Combination Temperature / RH Duct Sensors
   Temp Range of 20° F to 120° F (-5° C to 50° C) Accuracy: ±0.36° F (0.2° C)
   Relative Humidity Range: 10% to 90% Accuracy: ±2% typical, Less than 0.5% drift per year.
   Temperature/humidity sensor probe: ABS with SS filter / 1.0 in. (2.5 cm) diameter / 6 in. (13.5 cm) length
3. Temperature Averaging sensor probe: Bendable aluminum / 3/16 in. diameter / Length of 8, 12, or 24 ft.

D. Clamp-on Sensors:
The communicating clamp-on sensors shall measure water temperature in filled pipe applications. All clamp-on sensors shall have bendable copper sensing plate that forms to

the curvature of the pipe.

All communicating clamp-on sensors shall feature Polycarbonate enclosure with adjustable hose clamp that holds the unit in place around the pipe. The enclosure shall be UV rated and comply with: UL94V-0, NEMA 4, IP66.

1. Temperature Clamp-on Sensors:
   a. Temp Range of -40° F to 212° F (-40° C to 100° C) Accuracy: ±1.3° F (0.72° C)
   b. Temperature sensor pad: 1.25” (3.18cm) Diameter copper

E. Outdoor Air Sensors:
The communicating Outdoor Air (OA) sensors shall measure the air temperature and/or humidity outdoor. All OA sensors shall be designed for outdoor mounting, with UV-resistant plastic shield to keep the sensor out of the sunlight and allows for excellent air circulation. OA sensors shall have etched Teflon® lead wires and shall be able to withstand high humidity and condensation environments.

The enclosure shall be UV rated and comply with: UL94V-0, NEMA 4, IP66.

The communicating OA sensors shall be available in different models, including temperature only, temperature plus humidity.

1. Temperature OA Sensors:
   Temp Range of -40° F to 212° F (-40° C to 100° C) Accuracy: ±1.3° F (0.72° C)
   Temperature sensor probe: Vented polycarbonate shield, .5 in. (1.27 cm) OD 1.2 in. (3.05 cm)
2. Combination Temperature / RH OA Sensors
   Temp Range of -40° F to 212° F (-40° C to 100° C) Accuracy: ±1.3° F (0.72° C)
   Relative Humidity Range: 10% to 90% Accuracy: ±2% typical, Less than 0.5% drift per year.
   Temperature/humidity sensor probe: ABS with SS filter 1.0 in. (2.5 cm) diameter 2.51 in. (6.39 cm) length

F. Immersion Sensors:
The communicating immersion sensors shall measure water temperature in pipe applications. All immersion sensors shall be potted inside a 1/4” stainless steel probe with a thermally conductive compound. All immersion units shall be mounted in a thermowell and have etched Teflon® lead-wires and double encapsulated sensors to create a watertight package that can withstand a wide range of humidity and condensation.

All communicating immersion sensors shall feature Polycarbonate. The enclosure shall be UV rated and comply with: UL94V-0, NEMA 4, IP66.

1. Temperature Immersion Sensors:
   a. Temp Range of -40° F to 212° F (-40° C to 100° C) Accuracy: ±1.3° F (0.72° C)
   b. Temperature sensor pad: 1.25” (3.18cm) Diameter copper

2.1.6 AUXILIARY CONTROL DEVICES

2.1.6.1 DAMPERS / VALVES / ACTUATORS

A. Motorized Control Dampers: Unless specified elsewhere, shall be as follows:
1. Multiple blade dampers shall be parallel or opposed blade type as listed below or as scheduled on the drawings.
2. Single blade round dampers shall have an elliptical blade.
3. Modulating outdoor air and exhaust dampers shall be opposed blade type with blade and side seals.
4. Modulating return air dampers shall be parallel blade type with blade and side seals.

5. Two position shut off dampers may be parallel or opposed blade type with blade and side seals.
6. Damper frames shall be 16 gauge galvanized steel channel or 1/8" extruded aluminum with reinforced corner bracing.
7. Damper blades shall not exceed 8" in width or 48" in length. Blades are to be suitable for medium velocity performance (<2000 fpm). Blades shall not be less than 16guage.
8. Damper shaft bearings shall be as recommended by manufacturer for the application, Oilite or better.
9. All blade edges and top and bottom of the frames shall be provided with replaceable butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel. The blade seals shall provide for a maximum leakage rate of 10 cfm/sq. ft at 4" w.c. differential pressure.
10. Individual damper sections shall not be larger than 48" wide x 60" high. Provide a minimum of one damper actuator per section.
11. Dampers shall have exposed linkages.

B. Electronic Valve and Damper Actuators: Unless specified elsewhere, shall be as follows:
1. Electronic actuators, less than 600 in-lb. of rated torque, shall have ISO Electronic 9001 quality certification and be UL listed under standard 873, CSA C22.2 No. 24 and have CE certification.
2. Electronic actuators used on valves or dampers shall be designed to directly couple and mount to a stem, shaft or ISO style-mounting pad. Actuator mounting clamps shall be a V-bolt with a toothed V-clamp creating a cold weld, positive grip effect. Single point, bolt, or single screw actuator type fastening techniques or direct-coupled actuators requiring field assembly of the universal clamp is not acceptable.
3. Actuators shall be fully modulating/proportional, pulse width, floating/tri-state, or two-position as required and be factory or field selectable. Actuators shall have visual position indicators and shall operate in sequence with other devices if required.
4. Optional auxiliary switches shall be available.
5. Actuators shall have an operating range of -22° to 122°F.
6. Proportional actuators shall accept a 0-10 VDC or 0-20 mA input signal and provide a 2-10 VDC or 4-20 mA (with a load resistor) operating range.
7. Actuators shall be capable of operating on 24, 120 or 230VAC, or 24VDC and Class 2 wiring as dictated by the application. Power consumption shall not exceed 50 VA for AC, including 120VAC actuators.
8. Actuators shall have electronic overload protection or digital rotation sensing circuitry to prevent actuator damage throughout the entire rotation.
9. For power-failure/safety applications, an internal mechanical spring return mechanism shall be built into the actuator housing. Spring return actuators shall be capable of CW or CCW mounting orientation. Spring return models > 60 in-lbs. will be capable of mounting on shafts up to 1.05" in diameter. Spring return actuators with more than 60 in-lb. of torque shall have a metal, manual override crank.
10. Upon loss of control signal, a proportional actuator shall fail open or closed based on the minimum control signal. Upon loss of power, a non-spring return actuator shall maintain the last position.
11. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required. Valves and dampers requiring greater torque or higher close off may be assembled with multiple low torque actuators.
12. Dual mounted actuators using additional anti-rotation strap mechanical linkages, or special factory wiring to function are not acceptable. Actuators in a tandem pair must be "off the shelf," standard actuators ready for field wiring.
13. Damper and valve actuators will not produce more than 62 dB when furnished with a mechanical fail-safe spring. Non-spring return actuators shall conform to a maximum noise rating of 45 dB(A) with power on or in the running or driving mode.

C. Direct Coupled Globe Valve Actuator and Adapter Bracket
   1. Actuator shall be designed with an integrated adapter bracket that will direct mount to the valve.
   2. Actuator shall provide a linear force capable of fulfilling the required close-off of the valve.
   3. Actuator shall include an automatic valve-coupling device that shall lock securely to the valve stem.
   4. Proportional and spring return actuators shall adapt upon powering the actuator. This adaptation will determine stroke length and enable the actuator to set the minimum and maximum limits of the supplied control signal, thereby utilizing the entire control signal range. Feedback, running time and other parameters are automatically adjusted to the effective stroke.
   5. Actuator shall have a manual override equipped with an inter-locking device to protect the actuator from over-torque of the manual override.

D. Industrial Type Actuators For Butterfly Valves
   1. The valve actuator shall consist of a capacitor-type reversible electric motor, gear train, limit switches and terminal block, all contained in a die cast aluminum enclosure.
   2. Enclosure shall be designed to meet NEMA 4 (weatherproof) requirements, or CSA approved for non-hazardous or hazardous locations.
   3. Output shaft shall be electroless nickel plated to prevent corrosion.
   4. The enclosure will have an industrial quality coating.
   5. Actuator shall have a motor rated for continuous duty.
   6. Actuator shall be suitable for operation in ambient temperature ranging from -22°F to +150°F [-30°C to +65°C].
   7. The motor shall be fractional horsepower; permanent split capacitor type designed to operate on a 120 VAC, 1 pH, 60 Hz supply. A self-resetting thermal switch shall be imbedded in the motor for overload protection.
   8. A 6 ft wiring harness shall be provided for ease in field wiring (Above 1500 in-lbs).
   9. Actuator will have a suitable sized NPT entry for external connections.
   10. Reduction gearing shall be designed to withstand the actual motor stall torque.
   11. Gears shall be hardened alloy steel, permanently lubricated. A self-locking gear assembly or a brake shall be supplied.
   12. Two adjustable cam actuated end travel limit switches shall be provided to control direction of travel.
   13. 2 SPDT auxiliary switches, rated at 250 VAC shall be included.
   14. Actuator shall be equipped with a hand wheel or shaft for manual override to permit operation of the valve in the event of electrical power failure or system malfunction. Hand wheel, where applicable, must be permanently attached to the actuator.
   15. When in manual operation electrical power to the actuator will be permanently interrupted.
   16. The hand wheel will not rotate while the actuator is electrically driven.
   17. Actuator shall have heater and thermostat to minimize condensation within the actuator housing.
   18. Modulating units shall include programmable card capable of 0-10 VDC, 2-10 VDC, 4-20mA, and 1-5 VDC default settings.

E. Electronic Control Valves: Unless specified elsewhere, shall be as follows.
   1. General
      a. The manufacturer shall be capable of providing individual valve identification tagging on each printed valve label. Valve tag identification shall be documented on the approved, submitted valve schedule.
      b. Valve actuator(s) shall provide the minimum torque, based on the manufacturers' calculations, required for the rated valve close off.
   2. Zone Valves
      a. Zone valves shall be as specified.

b. Zone valves with brass bodies shall be used in terminal unit water applications where sizing or physical limitations prohibit the use of characterized control valves, or in terminal equipment, where water sizing dictates a 2 or 3-way electronic control valve 3/4" or smaller.
c. The valve manufacturer shall provide the contractor a choice of threaded union male NPT, compression ends or copper sweat ends for each valve.
d. Zone valve actuators shall have a minimum of 30 psi close-off rating.

3. Control Valves
   a. Control valves shall be of the Characterized Control™ Valve type.
   b. Characterized Control™ Valves shall be used for all water applications where sizing permits.
   c. A Tefzel, flow-characterizing disc shall be installed in the inlet of 2-way characterized control valves and in the control port of 3-way valves. The valve trim shall utilize a stainless steel ball and stem for all water or glycol solutions up to 50%. For water applications, an optional chrome plated brass ball and brass stem can be used.
   d. Valve bodies shall be nickel-plated, forged brass with female NPT threads. Bodies to 1-1/4" shall be rated at 600 psi and sizes 1-1/2" to 2" at 400 psi. The maximum allowable pressure differential shall be 150 psi for on/off and 50 psi for modulating service.
   e. Characterized Control™ Valves shall have a self-aligning, blowout proof, brass stem with a dual EPDM O-ring packing design. Fiberglass reinforced Teflon seats shall be used.
   f. The valves shall have a four bolt mounting flange to provide a 4 position, field changeable, electronic actuator mounting arrangement.
   g. A non-metallic coupling, constructed of high temperature, continual use material shall provide a direct, mechanical connection between the valve body and actuator. The coupling shall be designed to provide thermal isolation and eliminate lateral and rotational stem forces. Vent hole shall be provided to reduce condensation build-up.
4. Globe valves
   a. 2-way and 3-way globe valves may be used only if characterized control valves do not fit the sizing criteria or application.
   b. Globe valves may be used for chilled or hot water, steam, or glycol solutions to 50%. Screwed and flanged water valves shall have equal percentage or linear flow characteristics for 2 or 3-way valves, respectively. All stems shall be stainless steel.
   c. Screwed globe valves 1/2" through 2" shall have bronze bodies rated at ANSI Class 250. For water or steam up to 35 psi, trim shall include a brass plug, a spring-loaded TFE packing, and a bronze seat. The maximum differential shall be 35 psi for water and 20 psi for steam.
   d. 2-way and 3-way flanged globe valves 2-1/2" to 6" shall have cast iron bodies rated for ANSI Class 125. The maximum differential shall be 25 psi for water and 10 psi for steam. Trim shall include stainless steel stems, bronze plugs, bronze seats, and a TFE V-ring packing.
   e. For steam inlet pressures higher than those stated above, furnish globe valves with stainless steel trim specifically rated for the application.
5. Butterfly Valves
   a. Butterfly valves 2 to 12" shall have a fully lugged, drilled and tapped, cast iron body. Flanges shall meet ANSI 125/150 standards. The one-piece body shall feature an extended neck allowing sufficient clearance for flanges and 2" of piping insulation. The disc shall be aluminum bronze and provide bi-directional bubble-tight close off in either direction for water or 50% glycol applications. The disc shall be polished and contoured to minimize torque and wear. The flow characteristic shall be modified equal percentage for 2-way valves and linear for 3-way valves. The 2" - 6" valves shall be rated for a maximum of 200

psi close-off and 8" - 12" shall be rated a maximum of 75 psi close-off.

b. The disc shall have full 360-degree concentric seating. A 316 stainless steel taper pin shall provide a positive connection of the disc to a one piece, 416 stainless steel shaft. A phenolic backed, non-collapsing, EPDM seat shall be field replaceable and shall create a positive seal between flange face and valve body. No gaskets shall be required between the valve and flange faces. The shaft shall be supported at three locations by PTFE bushings.
c. Butterfly valves may be used in all two-position applications, in modulating applications larger than 2-1/2", or where the close off rating of other valve styles does not meet the design requirements.
d. A CV Factor of (60) degrees shall be used for sizing all modulating butterfly valves.
e. High torque industrial valve actuators, >600 in-lb. of rated torque, may be used where low torque actuators are not suitable.
f. High torque electronic industrial actuator enclosures shall be designed to meet NEMA 4 (weatherproof) requirements, or have CSA approval for non-hazardous or hazardous locations. An NPT entry for external connections shall be provided.

2.1.6.2 VARIABLE SPEED DRIVE

A. Variable Frequency Drive (VFD)
1. The VFD shall be the AC adjustable frequency type for HVAC applications. Drive shall be factory programmed for variable torque applications, and for the specified motor and application voltage. Drive shall be ISO 9001 certified, and UL listed and CSA approved (up to 125 hp).

B. Drive Environmental Conditions:
1. The VFD shall be housed indoors in a NEMA 1 metal enclosure and subjected to an non-condensing (95% RH maximum) ambient environment between -14 to 104F.

C. Control System: The variable speed drive shall include the following features:
1. Full digital control.
2. Insulated Gate Bi-Polar Transistors (IGBT) used to produce the output pulse width modulated (PWM) waveform, allowing for quiet motor operation.
3. Inverters capable of operation at a frequency of 8 kHz so no acoustic noise shall be produced by the motor.
4. Digital display keypad module, mounted on the VFD enclosure.
5. Local/Remote and Manual/Auto function keys on the keypad.
6. UL-listed electronic overload protection.
7. Critical frequency avoidance.
8. Self diagnostics.
9. On-board storage of unit manufacturer's customer user settings, retrievable from the keypad.
10. RS232C communications capability standard.
11. RS485 communications capability (accessory card source required).
12. Internal electronic filtration to reduce EMI generation.

D. VFD Remote Display Service Module: Accessory package shall contain VFD adapter plate, remote display housing (to accept the keypad module removed from the VFD housing) and cable assembly with quick-connect plug to connect to mating plug on VFD adapter plate, to facilitate VFD diagnostics and servicing.

2.1.7 APPLICATION SPECIFIC CONTROLLERS

2.1.7.1 VVT SYSTEM APPLICATIONS

2.1.7.1.1 VVT CONTROLLERS FACTORY: ZONE AND BYPASS

A. Controller Software VVT
   1. Building and energy management application software shall reside and operate in system controllers. Applications shall be configurable through the operator workstation, web browser interface, or engineering workstation.
   2. Memory and System Time. All controllers shall have a Non-Volatile Memory providing indefinite storage of application and configuration data. The system must have an ability to maintain time, and automatically correct for daylight savings time and leap year adjustments. In the event of power failure or user generated power cycle, all system components must automatically updated with current time and date from a network Time Sync device. The controller shall also have the capability of changing occupancy mode by reading a set of discrete, dry contacts controlled by an external time clock.
   3. Stand alone capability. All controllers shall be capable of providing all control functions of the HVAC system without the use of a computer. The controllers shall include the inherent capability to access the system control selections as well as to monitor system performance by means of a communicating network with a PC and EMS software program.
   4. System Security.
      a. Other hand held or wall mounted local interface device that allow configuration access shall be password protected with minimum of two levels of security. Level one shall provide limited access to controller operational parameters and level two shall provide full access to controller operational and configuration parameters.
   5. Scheduling.
      a. System shall provide the following schedule options as a minimum:
      b. 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).
      c. 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.
      d. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.
   6. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms.
   7. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Sequence of Operations for HVAC Controls.
   8. 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.
   9. 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.
   10. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of preconfigured minimum on-time and off-time settings, customized for the specific requirements of the application.
   11. 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.

12. Zoning system compatible with constant volume air source (Variable Volume/Variable Temperature) (VVT). The zoning system shall be compatible with constant volume air source and consist of programmable, multiple communicating Zone Controllers and a Bypass Controller. The system shall also include a complete array of input and output devices. The system shall provide full control of HVAC heating and cooling equipment in a multiple zone application. The zoning system shall be capable of operating as a stand-alone system or networked with multiple systems to communicating air source controllers.
    a. Zone control. Each zone shall be capable of monitoring space conditions and providing the correct amount of conditioned air to satisfy the space load. Each zone shall be capable of the following:
        1) Space temperatures control. To maintain individual heating and cooling set points.
        2) Relative Humidity/Air Quality (DCV). Each zone shall be capable of maintaining space relative humidity set point or air quality set point (zone level demand control ventilation) as defined in ASHRAE 62-1989 (including Addendum 62a-1990).
        3) Demand coordination. Each zone shall be capable of zone demand data coordination with other zones in the system.
    b. Static pressure control. The zoning system shall be capable of maintaining a user adjustable supply air duct static pressure set point.
        1) The Bypass controller shall additionally provide the capability to increase system airflow during conditions when the temperature of the supply air from the equipment is approaching the limits of operation. In these cases, the Bypass controller shall raise the static pressure setpoint to a user configurable maximum limit in order to increase the system airflow during these conditions.
        2) The Bypass control shall contain the ability to monitor the bypass damper movement (or VFD speed) and automatically adjust the setpoint control band and/or hysteresis in order to provide stability and prevent premature actuator failure.
    c. Air source control. Shall control all associated HVAC rooftop equipment functions, and be capable of stand-alone or networked operation. The resident algorithms shall use error reduction logic as designated in ASHRAE standard 90.1 to provide temperature control and lower energy usage. The Air source shall be capable of zone demand data coordination with the associated zones.
    d. System Terminal Modes. Each air terminal mode shall be based on the current air source mode, terminal type, space temperature, and the current temperature set points.
        1) Off:
            a) All terminal dampers will maintain a 65% open position. Fans shall be disabled.
            b) If the zone requirement is heating, all single duct terminals shall maintain their damper position at 65%. Any zone controller servicing a parallel box shall fully close their dampers while the fan is operating. If local heat is available, the parallel fans shall start and local heat shall be enabled to maintain its unoccupied heating set point. The damper shall be modulated open to 65% after heating is no longer required.
        2) Cooling and Night Time Free Cooling (NTFC):
            a) If the zone requirement is none, then the zone controllers shall modulate their dampers to maintain their minimum cooling damper position or damper ventilation position if the supply air temp is between 65 and 75 F. During the NTFC mode the zone controller

shall control between its occupied heating and cooling set points. During the cooling mode, the zone controller shall modulate its damper to its appropriate (occupied or unoccupied) cooling set point.

b) If the zone requirement is cooling, then the zone controllers shall modulate their air dampers between their minimum and maximum cooling damper position to maintain their cooling set point. Parallel fans shall be disabled unless the damper has closed below the user adjustable fan-on minimum position (optional). In that case, the fan shall be energized to mix return air with the cold primary air in order to prevent “cold air dumping” from the diffusers.

c) If the zone requirement is heating, then the zone controllers shall modulate their dampers to maintain their minimum cooling damper position. Any zone controllers servicing single duct units with reheat capability shall maintain the greater of either the minimum cooling damper position or the specified reheat damper position. Zone controllers servicing parallel units shall enable their fans while the damper shall maintain its minimum cooling damper position.

3) Vent:

a) If the air source equipment is operating in a fan only mode to provide ventilation without mechanical heating or cooling, then the zone controllers shall maintain the user configured ventilation damper position.

4) Heat:

a) If the zone requirement is none, then the zone controller shall maintain its minimum heating damper position. Parallel fans shall be disabled and their air damper shall be modulated to maintain their minimum heating damper position.

b) If the zone requirement is cooling, then the zone controller shall modulate its damper to maintain its minimum heating damper position. Parallel fans shall be disabled.

c) If the zone requirement is heating, then the zone controllers shall modulate their air dampers between their minimum and maximum heating damper position to maintain their heating set point.

5) Pressurization:

a) If the zone requirement is none or cooling, then the zone controller shall maintain its maximum cooling damper position. Parallel fans shall be disabled.

b) If the zone requirement is heating, and the zone controller has been enabled to provide local heating, then the zone controller shall modulate its damper to its maximum cooling damper position and enable its auxiliary heat. If local heat is not available, the damper shall still be modulated to maintain its maximum cooling damper position.

6) Evacuation:

a) During the Evacuation mode all terminal fans shall be disabled and all dampers shall close.

13. Air source interface. The zoning system shall be capable of zone demand data coordination with a communicating rooftop. Setpoint and zone temperature information from the zones shall be shared with the rooftop controller so that the rooftop controller’s error reduction calculations can determine the proper number of heating or cooling stages to operate in order to satisfy the system load.

a. The zoning system shall have the capability of linking up to 32 zones to a single air source and determining system heating and cooling requirements.

b. The zoning system shall be capable of providing a communication check of all

associated controls and display device type as well as error conditions.

c. The zoning system shall coordinate and exchange the flowing data as minimum:
   1) Average zone temperature
   2) Average occupied zone temperature
   3) Average occupied and unoccupied heat/cool set points
   4) Occupancy status
d. Space temperature and space temperature set points for use by the air source controller shall include a weighted factor, proportional to the size of the zone.
e. Only those zones with valid temperature readings shall be included.
f. The zoning system shall provide periodic updates to the air source.
g. The zoning system shall obtain and support the following air source modes as a minimum:
   1) Off
   2) Cooling
   3) Heating
   4) Night Time Free Cooling
   5) Ventilation
   6) Pressurization
   7) Evacuation
h. The air source controller shall, through the Air Distribution System, bias its occupancy time schedules to provide optimization routines and occupant override.
i. For those zoning systems that do not include inherent air source interface capacity, each zone shall independently determine the operational mode of the equipment through its associated duct temperature sensor mounted in the supply ductwork. If there is air source controller, then the system will assumed to be always On.

14. HVAC Equipment Protection. The air sources controller shall be capable of monitoring the leaving air temperature to control stages in both the heating and cooling modes. It shall have the capability to shut down stages based on a rise or fall in leaving air temperature above or below adjustable or calculated values. Calculated supply air temperature requirements shall be based on error reduction calculations from reference zone data to determine the optimum supply air temperature to satisfy space requirements. The system shall provide protection from short cycling of heating and cooling by utilizing time guards and minimum run time configurations.
15. Energy Conservation.
    a. Load balancing from error reduction calculations that optimize staging.
    b. The locking out of mechanical heating or cooling modes based on configurable outside air temperature limits.
    c. Staggered start. The system shall intelligently start all equipment in a stagger start manner after a transition from unoccupied to occupied modes as well as power failure to reduce high peak power consumption on start-up.
    d. Peak Demand Limiting. Controllers in the system shall have the capability of being overridden by separate heating and cooling Peak Demand Limiting signals. Option/General purpose controller existing on the communications bus shall be able to send a demand limiting broadcast to reduce overall energy consumption and control on and off peak time kW usage
    e. Temperature compensated start. The zone controller shall be capable of supporting temperature compensated start with the air source. Prior to occupancy the zone controllers and Air Source shall work together to provide zone-by-zone temperature compensated conditioning. The air source will track the time required for recovery report the optimal start bias time to the zones prior to each occupied period so that the zone can start conditioning the space prior to occupancy.
16. Abnormal Conditions. The proposed system shall include the ability to detect

abnormal conditions, and to react to them automatically. A return to normal conditions shall also generate a return to normal notification and the system shall revert back to its original control scheme before the abnormal condition existed. The following abnormal terminal conditions shall automatically generate an alarm and the system shall take the following actions:

a. If a space temperature sensor is determined by the zone controller to be invalid, the zone controller shall generate an alarm. During this condition, the zone damper will be positioned to either the minimum heating, minimum cooling or the configured ventilation damper position, based on the air source equipment operating mode.
b. If a relative humidity sensor is determined by the zone controller to be invalid, the zone controller shall generate an alarm.
c. If an indoor air quality sensor is determined by the zone controller to be invalid, the zone controller shall generate an alarm, and disable its IAQ algorithm.
d. System level demand coordination. If an air source controller is participating in demand coordination with other zones and loses communication with the associated zones, it shall generate an alarm. Likewise, any zone detecting a communication failure, will generate an alarm.
e. Zone level demand coordination. If the system looses communication with one of the zones associated with that system the zoning system shall remove that zone temperature from its weighted averages. The zone controller shall continue to operate in a stand-alone mode.
f. If the zoning system if configured to interface with the air source for zone demand data coordination and that communication is broken, each zone controller shall determine the equipment operating mode based on the temperature of the primary air. The air source will be assumed to be always on.

B. Controllers VVT
1. General. The control system shall be available as a complete package with the required input sensors and devices readily available. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), and Sensors (SEN) as required to achieve performance specified in Controller Software Section.
2. 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.
3. BACnet.
   a. 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.
   b. 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.
   c. 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.
   d. 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 MS/TP or ARCNET Data Link/Physical layer protocol.

4) Each ASC shall reside on a BACnet network using the MS/TP or ARCNET Data Link/Physical layer protocol.

4. Communication.
   a. 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.
   b. 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.
   c. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
   d. 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.
5. 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).
6. Keypad. Where specified provide a local keypad and display for each BC and ASC. 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 ASC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.
7. Serviceability.
   a. Controllers shall have diagnostic LEDs for power, communication, and processor.
   b. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
   c. All controllers in the system 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.
   a. Controller memory shall support operating system, database, and programming requirements.
   b. Each controller in the system shall use nonvolatile memory providing indefinite storage of BIOS, application programming, and all configuration data in the event of 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. Factory Mounted Zone Controller (ZC). Defined as Application Specific Controllers (ASC) shall be capable of independent zone control or function as part of the zoning system to achieve performance as specified for zone control in Controller Software Section.
    a. Input and output devices shall be wired to “quick-connect plug type” terminals to facilitate removal of the module without disconnecting wiring from the plug

type terminal.

b. ZC shall have an integrated brushless actuator providing a minimum of 45 in/lbs of torque and be capable of operating zone dampers as well as parallel fan powered terminal boxes. The brushless actuator shall separable from the body of the controller for easy mounting and possible replacement. The direction of rotation shall be reversible in the field to accommodate field supplied bypass damper assemblies.
c. ZC shall be capable of controlling supplemental heat or auxiliary heat sources, including fan control, when required at the zone level.
d. The zone controller shall have the capability to support adjustable minimum and maximum damper positions.
e. ZC shall be capable of reading an analog signal from a CO2 sensor or other sensor measuring volatile contaminants, or relative humidity and provide DCV at the zone by calculating a DCV damper position and participate in system DCV operation with the air source.

11. Factory Mounted Bypass Controller. Defined as Application Specific Controllers (ASC) shall be capable of reading supply static pressure and controlling the bypass damper (or a VFD speed control output) to maintain the supply static set point. This operation shall be provided when operating within a zoning system application, as specified for bypass control in Controller Software Section or in a stand-alone mode.
    a. Input and output devices shall be wired to “quick-connect plug type” terminals to facilitate removal of the module without disconnecting wiring from the plug type terminal.
    b. The controller shall contain an onboard pressure sensor to measure duct static pressure. The sensor measuring range shall be from 0.0 to 2.0 inches H2O.
    c. Bypass Controller shall have an integrated brushless actuator providing a minimum of 45 in/lbs of torque and be capable of operating a bypass damper. The brushless actuator shall separable from the body of the controller for easy mounting and possible replacement. The direction of rotation shall be reversible in the field to accommodate field supplied bypass damper assemblies.
    d. Bypass Controller shall provide an analog output signal for an external actuator or to control the speed of a variable frequency drive (VFD).

12. Communicating Room Space Temperature (SPT)
    a. Shall have integrated, easy-to-read LCD on display. Able to display space temperature, outside air temperature, heating setpoint, cooling setpoint, and local override (after hours occupancy), time
    b. Shall have Precise 10K ohm thermistor with + 0.36ºF (0.2ºC) standard accuracy and less than 0.18ºF (0.01ºC) drift over a ten year span – requires no maintenance or re-calibration
    c. Shall allow zone setpoints adjustment by pressing the Warmer or Cooler buttons
    d. Shall have a hidden communication port allows a laptop computer or a handheld keypad to commission and maintain the connected equipment easily
    e. Shall allow multiple SPT sensors to be daisy-chained to one controller for temperature averaging or high/low select control
    f. Shall have ability to mount on a standard 2” x 4” electrical box for easy installation

2.1.7.2 VAV SYSTEM APPLICATIONS

2.1.7.2.1 VAV CONTROLLERS - FACTORY

A. VAV zoning system . The zoning system shall be compatible with variable air volume air source and consist of configurable, multiple communicating VAV Air Terminal Controllers. The system shall also include a complete array of input and output devices. The system

shall provide full control of HVAC heating and cooling equipment in a multiple zone application. The zoning system shall be capable of operating as a stand-alone system or networked with multiple systems to communicating air source controllers.

1. Zone control. Each zone shall be capable of monitoring space conditions and providing the correct amount of conditioned air to satisfy the space load. Each zone shall be capable of the following:
   a. Space temperatures control. To maintain individual heating and cooling set points.
   b. Relative Humidity/Air Quality (DCV). Each zone shall be capable of maintaining space relative humidity set point or air quality set point (zone level demand control ventilation) as defined in ASHRAE 62-1989 (including Addendum 62a-1990).
   c. Demand coordination. Each zone shall be capable of zone demand data coordination with other zones in the system.
2. Static pressure rest control.
   The static pressure reset function of the zone system shall automatically reset the central air source's supply-fan static pressure set point (downward) as a function of the zone damper position. This allows the system to automatically make adjustments to the static pressure and optimize performance of the central air source fan. The maximum pressure is determined by the set point configured at the equipment control. The minimum value is determined by the maximum value configured.
3. Air source control. Shall control all associated air source equipment functions, and be capable of stand-alone or networked operation. The resident algorithms shall use error reduction logic as designated in ASHRAE standard 90.1 to provide temperature control and lower energy usage. The Air source shall be capable of zone demand data coordination with the associated zones.
4. System Terminal Modes. Each air terminal mode shall be based on the current air source mode, terminal type, space temperature, and the current temperature set points.
   a. Off:
      No active control of temperature or CFM in the zone
   b. Cooling:
      When the fan is determined to be on, the linkage master zone controller reads the primary air temperature value. If the temperature is less than the average occupied zone temperature, as calculated by the linkage master zone controller, minus 2 degrees F, the mode is determined to be cooling.
   c. Night Time Free Cooling (NTFC):
      The following conditions must be present for free cooling mode:
      1) The fan is determined to be on by the linkage master zone controller
      2) The average zone temperature value is greater than the average unoccupied zone cooling temperature set point, as determined by the master zone controller
      3) The current time is between 3:00 AM and 7:00 AM
      4) The equipment is providing cooling to the system
      5) If the above conditions are true, then the mode is determined to be NTFC. This mode is then communicated to all the zone controllers in the system associated.
   d. Vent:
      Temperature requirement of the zone is satisfied. Minimum cooling CFM or damper position is maintained
   e. Heat:
      The zone controller will modulate the primary air damper to maintain the minimum heating CFM, unless the system is configured for VAV Central Heating. If a zone controller is configured for VAV heating, the zone controller will modulate the primary air damper between the minimum and maximum Heating CFM positions

f. Pressurization:
The system will bring in as much outside air as possible in order to pressurize the area. This mode is used for smoke control and prevents smoke from entering into an area that is adjacent to an area of smoke. Each zone controller will modulate its damper to provide maximum cooling airflow into the space. If the terminal contains a series fan, the fan will be turned on. If the terminal contains a parallel fan it will be turned off. If the terminal contains auxiliary heat, the heating will be controlled so as to maintain the current heating set point.

g. Evacuation:
1) During the Evacuation mode all terminal fans shall be disabled and all dampers shall close.

5. Air source interface. The zoning system shall be capable of zone demand data coordination with a communicating air source. Setpoints and zone temperature information from the zones shall be shared with the air source controller so that the air source controller's error reduction calculations can determine the proper amount of heating or cooling in order to satisfy the system load.
a. The zoning system shall have the capability of linking up to 128 zones to a single air source and determining system heating and cooling requirements.
b. The zoning system shall be capable of providing a communication check of all associated controls and display device type as well as error conditions.
c. The zoning system shall coordinate and exchange the flowing data as minimum:
1) Average zone temperature
2) Average occupied zone temperature
3) Average occupied and unoccupied heat/cool set points
4) Occupancy status
5) Damper position
6) RH and CO2 values (if applicable)
d. Space temperature and space temperature set points for use by the air source controller shall include a weighted factor, proportional to the size of the zone.
e. Only those zones with valid temperature readings shall be included.
f. The zoning system shall provide periodic updates to the air source.
g. The zoning system shall obtain and support the following air source modes as a minimum:
1) Off
2) Warm-up
3) Cooling
4) Heating
5) Night Time Free Cooling
6) Ventilation
7) Pressurization
8) Evacuation
h. The air source controller shall, through the Air Distribution System, bias its occupancy time schedules to provide optimization routines and occupant override.
i. For those zoning systems that do not include inherent air source interface capacity, each zone shall independently determine the operational mode of the equipment through its associated duct temperature sensor mounted in the supply ductwork. If there is air source controller, then the system will assumed to be always On.

6. Energy Conservation.
a. Load balancing from error reduction calculations that optimize staging.
b. The locking out of mechanical heating or cooling modes based on configurable outside air temperature limits.
c. Staggered start. The system shall intelligently start all equipment in a stagger start manner after a transition from unoccupied to occupied modes as well as

power failure to reduce high peak power consumption on start-up.

d. Peak Demand Limiting. Controllers in the system shall have the capability of being overridden by separate heating and cooling Peak Demand Limiting signals. Option/General purpose controller existing on the communications bus shall be able to send a demand limiting broadcast to reduce overall energy consumption and control on and off peak time kW usage

e. Temperature compensated start. The VAV Air Terminal Controller shall be capable of supporting temperature compensated start with the air source. Prior to occupancy the VAV Air Terminal Controllers and Air Source shall work together to provide zone-by-zone temperature compensated conditioning. The air source will track the time required for recovery report the optimal start bias time to the zones prior to each occupied period so that the zone can start conditioning the space prior to occupancy.

7. Abnormal Conditions. The proposed system shall include the ability to detect abnormal conditions, and to react to them automatically. A return to normal conditions shall also generate a return to normal notification and the system shall revert back to its original control scheme before the abnormal condition existed. The following abnormal terminal conditions shall automatically generate an alarm and the system shall take the following actions:

a. If a space temperature sensor is determined by the VAV Air Terminal Controller to be invalid the controller generates an alarm and disables all local heating or cooling. The controller modulates the damper to the minimum heat, minimum cool, or ventilation position based on the air source mode. Normal operation resumes when the controller detects a valid sensor value.

b. If a relative humidity sensor is determined by the VAV Air Terminal Controller to be invalid, the VAV Air Terminal Controller shall generate an alarm.

c. If an indoor air quality sensor is determined by the VAV Air Terminal Controller to be invalid, the VAV Air Terminal Controller shall generate an alarm, and disable its IAQ algorithm.

d. System level demand coordination. If an air source controller is participating in demand coordination with other zones and loses communication with the associated zones, it shall generate an alarm. Likewise, any zone detecting a communication failure, will generate an alarm.

e. Zone level demand coordination. If the system looses communication with one of the zones associated with that system the zoning system shall remove that zone temperature from its weighted averages. The VAV Air Terminal Controller shall continue to operate in a stand-alone mode.

f. If the zoning system if configured to interface with the air source for zone demand data coordination and that communication is broken, each VAV Air Terminal Controller shall determine the equipment operating mode based on the temperature of the primary air. The air source will be assumed to be always on.

B. VAV Air Terminal Controller (ATC). Product integrated factory mounted controller. Defined as Application Specific Controllers (ASC) shall be capable of independent zone control or function as part of the VAV zoning system to achieve performance as specified for zone control.

1. ATC shall be factory-mounted and wired and provide terminal or baseboard heat for pressure independent VAV air terminals. Terminals may be Single Duct, Parallel Fan Powered, or Series Fan Powered type.
2. Input and output devices shall be wired to “quick-connect plug type” terminals to facilitate removal of the module without disconnecting wiring from the plug type terminal.
3. ATRC shall have an integrated airflow pick-up and transducer, and brushless actuator minimum of 45 in/lbs of torque and be capable of operating zone dampers as well as series and parallel fan powered terminal boxes. The brushless actuator shall

separable from the body of the controller for easy mounting and possible replacement.
4. For Dual Duct applications a secondary ATRC shall be available with an integrated airflow pick-up and transducer, and brushless actuator minimum of 45 in/lbs of torque and be capable of operating zone dampers as well as series and parallel fan powered terminal boxes.
5. ATC shall have the capability to support adjustable minimum and maximum primary CFM control.
6. ATC shall have the capability to support VAV cooling and relative humidity control
7. ATC shall have the capability to support IAQ control (Demand Controlled Ventilation CO2 management as per ASHRAE 62) with optional comfort override
8. ATC shall be capable of controlling supplemental heat or auxiliary heat sources, including fan control, when required at the zone level.

C. Communicating Room Space Temperature (SPT)
1. Shall have integrated, easy-to-read LCD on display. Able to display space temperature, outside air temperature, heating setpoint, cooling setpoint, and local override (after hours occupancy), time
2. Shall have Precise 10K ohm thermistor with + 0.36ºF (0.2ºC) standard accuracy and less than 0.18ºF (0.01ºC) drift over a ten year span – requires no maintenance or re-calibration
3. Shall allow zone setpoints adjustment by pressing the Warmer or Cooler buttons
4. Shall have a hidden communication port allows a laptop computer or a handheld keypad to commission and maintain the connected equipment easily
5. Shall allow multiple SPT sensors to be daisy-chained to one controller for temperature averaging or high/low select control
6. Shall have ability to mount on a standard 2” x 4” electrical box for easy installation

2.2 SOFTWARE

2.2.1 OPERATOR INTERFACE: OPEN PROTOCOL-COMM BACNET, LON, MODBUS OPTION

A. Open Protocol Communications
DDC system shall allow communication to ancillary systems or controllers, such as lighting system or VFD controllers that utilize BACnet, Modbus, or LonWorks communication protocols. The quantity of data points available per protocol shall be based upon system memory and capacity and will not require the purchase of additional licenses or fees.
1. BACnet communication
   a. DDC System shall support BACnet/IP addressing as specified in ASHRAE/ANSI 135, BACnet Annex J using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol.
   b. DDC System shall support BACnet MS/TP or ARCNET communications using EIA-485 twisted pair topology running at 9600, 19200, 38400, and 76800 baud.

3.0 PART 3 - EXECUTION

3.1 EXECUTION

A. Examination
1. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.
2. Notify the Owners Representative in writing of conditions detrimental to the proper and timely completion of the work.

B. Installation (General)

1. Install hardware and software in accordance with manufacturer's instructions.
2. Provide all miscellaneous devices, hardware, software, interconnections installation and configuration required to insure a complete operating system in accordance with the sequences of operation and point schedules.
3. All wiring shall be installed as continuous lengths, where possible. Any required splices shall be made only within an approved junction box or other approved protective device.
4. Install equipment, piping, and wiring/raceways parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.

C. Location and Installation of Components
1. Locate and install components for easy accessibility; in general, mount 60 inches above floor with minimum 3'-0" clear access space in front of units. Obtain approval on locations from Owner's representative prior to installation.
2. All instruments, switches, transmitters, etc., shall be suitably wired and mounted to protect them from vibration, moisture and high or low temperatures.
3. Identify all equipment and panels. Provide permanently mounted tags for all panels.
4. Provide stainless steel or brass thermowells suitable for respective application and for installation under other sections; sized to suit pipe diameter without restricting flow.

D. Interlocking and Control Wiring
1. Provide all interlock and control wiring. All wiring shall be installed in a neat and professional manner in accordance with Specification Division 16 and all national, state and local electrical codes.
2. Provide wire and wiring techniques recommended by equipment manufacturers.
3. Control wiring shall not be installed in power circuit raceways. Magnetic starters and disconnect switches shall not be used as junction boxes. Provide auxiliary junction boxes as required. Coordinate location and arrangement of all control equipment with the Owner's representative prior to rough-in.
4. Provide auxiliary pilot duty relays on motor starters as required for control function.
5. Provide power for all control components from nearest electrical control panel or as indicated on the electrical drawings; coordinate with electrical contractor.
6. All control wiring in the mechanical, electrical, telephone and boiler rooms to be installed in raceways. All other wiring to be installed in a neat and inconspicuous manner per local code requirements.
7. When a cable enters or exits a building, a surge suppressor must be installed. The surge suppressor shall be installed according to the manufacturer's instructions.
8. All sensor wiring shall be labeled to indicate the origination and destination of data.

E. Field Services
1. Prepare and start the control system under provisions of this section.
2. Start-up and commission systems. Allow sufficient time for start-up and commissioning prior to placing control systems in permanent operation.
3. Provide the capability for off-site monitoring. As a minimum, off-site facility shall be capable of system diagnostics and software download. Owner shall provide internet connection for this service for 1 year or as specified.
4. Provide Owner's Representative with spare parts list. Identify equipment critical to maintaining the integrity of the operating system.
5. Provide the Owners Representative an in warranty maintenance proposal.

F. Training
1. Provide training to the owner in the operation of systems and equipment.
2. Provide basic operator training for a minimum of 3 people on all functions of the Operator Interface unit.
3. Provide training, as required, for up to 40 hours as part of this contract.

G. Demonstration

1. Provide systems demonstration of each sub-system.
2. Demonstrate a complete operating system to Owner's Representative.
3. Provide certificate stating that control system has been tested and adjusted for proper operation.

3.2 GLOSSARY OF TERMS

Terms used within the Specification Text:

A. Advanced Application Controller (AAC):
   1. A configurable control module with pre-tested and factory configured software specifically designed for regulating building equipment using closed-loop Direct Digital Control and facility management routines. 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.

B. Application Specific Controller (ASC):
   1. 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/VVT 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.

C. BACnet/IP:
   1. An approved BACnet network type which uses an Ethernet carrier and IP addressing.

D. BACnet MS/TP:
   1. 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.

E. Building Controller (BC):
   1. A control module which is capable of 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.

F. Direct Digital Control (DDC):
   1. 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 electronic controller.

G. PICS - Protocol Implementation Conformance Statement:
   1. A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.

H. Web services:
   1. 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:

A. adj.

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

B. AI, AO, AV, BI, etc. (Column Headings on Points List)
   1. AI = Analog Input. A physical input to the control module.
   2. AO = Analog Output. A physical output from the control module.
   3. 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.
   4. BI = Binary Input. A physical input to the control module.
   5. BO = Binary Output. A physical output from the control module.
   6. 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.

C. Sched = Schedule. The control algorithm for this equipment shall include a user editable schedule.

D. 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.)

E. 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.

F. Note: If the specifications require use of the BACnet protocol, all of the above shall be provided as BACnet objects.

G. KW Demand Limiting:
   1. An energy management strategy that reduces energy consumption when a system's electric power meter exceeds an operator-defined threshold.
   2. 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.

H. Occupant Override Switch, or Timed Local Override:
   1. A control option that allows building occupants to override the programmed HVAC schedule for a limited period of time.
   2. When the override time expires, the zone returns to its unoccupied state.

I. Occupant Setpoint Adjustment:
   1. 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.

J. Optimal Start-Up:
   1. 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.
   2. 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.

Contracting Terms:

A. Furnished or Provided:
   1. 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.

B. Install or Installed:
   1. 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.

C. Interface:
   1. 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.

D. Integrate:
   1. 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.

Abbreviations

A. 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
- VVT - Variable Volume Terminal Unit
- W/ - with
- W/O - without
- WSHP - Water Source Heat Pump

4.0 SEQUENCES OF OPERATION

4.1 SEQUENCE OF OPERATION FOR AHU1

4.1.1 CV ECON, ELEC, CHIL WTR
M4.2.3.2-SZCVEHCC (typical of 1)

Run Conditions:
The unit will supply conditioned air to its designated zone or linked air terminals (see below) and operate as a constant air volume unit. The unit will run according to the following user selectable modes:

- Off
- Continuously
- via BAS Command
- as Locally Scheduled
- via Linked Schedule

-- Off Mode:
The unit will not run and all dampers, valves and fans will remain in their off position.

-- Continuously:
The unit will run continuously in the occupied mode.

-- via BAS Command:
The unit will be enabled and disabled via a Bacnet Binary command, either from a remote source, or locally through the software interface. Once enabled, the unit will run continuously in the occupied mode.

-- as Locally Scheduled:
The air handling unit will operate as a constant volume unit having setpoints that represent those of a single zone unit. The unit will then run according to a user definable time schedule in the following modes

- Occupied Mode: The unit will maintain
  - A 74°F (adj.) space cooling setpoint
  - A 70°F (adj.) space heating setpoint.
- Unoccupied Mode (night setback): The unit will maintain

- A 85°F (adj.) space cooling setpoint.
- A 55°F (adj.) space heating setpoint.

Alarms will be provided as follows:

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

-- via Linked Scheduled:
The air handling unit will exchange information with the terminal units as follows:

Calculated information sent from the Air Handling Unit to the Terminal Units:
Current mode of operation.
Current supply air temperature
Current outside air temperature
Calculated information representative of all terminal units sent from the Terminal Units to the Air Handling Unit:
Space temperature
Setpoints, both occupied and unoccupied.
Maximum damper position
Indoor air quality (if present)
Space relative humidity (if present)

Based on the above information exchange, the air handling unit will determine which operation best meets the needs of the terminal units. The air handling unit will then operate as a constant volume unit, but one having setpoints representative of its designated group of terminal units. The unit will then run according to a user definable time schedule in the following modes

- Occupied Mode: The unit will maintain
  - A 74°F (adj.) space cooling setpoint
  - A 70°F (adj.) space heating setpoint.
- Unoccupied Mode (night setback): The unit will maintain
  - A 85°F (adj.) space cooling setpoint.
  - A 55°F (adj.) space heating setpoint.

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

Power-up Start-up Delay:
There will be a 60 second (adj.) delay in enabling the equipment on initial start-up or after a power loss.

Demand Limiting - Setpoint Optimization:
To lower power consumption, the cooling and heating setpoints will automatically relax (offset up when cooling and down when heating) when the facility power consumption exceeds definable thresholds. The amount of relaxation will be user configurable. The setpoints will automatically return to their previous settings when the facility power consumption drops below the thresholds.

Freeze Protection:
The unit will shut down and generate an alarm upon receiving a freezestat status.

Outside Air Conditions:
The controller will monitor the outside air temperature on a continual basis. These values will be made available to the system at all times.

Supply Fan:
The supply fan will run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan will have a user definable (adj.) minimum runtime.

Alarms will be provided as follows:

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

Electric Heating Stages - AO to Stage Sequencer:
The controller will measure the supply air temperature and stage the heating through an external stage sequencer to maintain its setpoint. The supply air temperature setpoint will be reset upwards (adj.) as the space temperature drops below its heating setpoint.

The heating will be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the space temperature is below heating setpoint.
- AND the supply fan status is on.
- AND the cooling (if present) is not active.

Cooling Coil Valve:
The controller will measure the supply air temperature and modulate the cooling coil valve to maintain its setpoint. The supply air temperature setpoint will be reset downwards (adj.) as the space temperature rises above its cooling setpoint.

The cooling will be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the space temperature is above cooling setpoint.
- AND the supply fan status is on.

The cooling coil valve will open to 50% (adj.) whenever the freezestat (if present) is on.

Economizer:
The controller will measure the mixed air temperature and modulate the economizer dampers in sequence to maintain mixed air temperature setpoint. The mixed air temperature setpoint will be reset downwards (adj.) as the outside air temperature rises. The outside air dampers will maintain a minimum adjustable position of 20% (adj.) open whenever occupied. The economizer will be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the outside air temperature is less than the current space temperature.
- AND the outside air enthalpy is less than enthalpy switch setpoint (adj.).
- AND the supply fan status is on.

The economizer will close whenever:

- Mixed air temperature drops from 45°F to 40°F (adj.).
- OR on loss of supply fan status.
- OR freezestat (if present) is on.

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

Nightime Free Cooling Mode:
The nightime free cooling mode will operate only during unoccupied hours. When enabled, the controller will measure the space temperature and modulate the economizer to maintain the space occupied cooling setpoint. This mode can be enabled/disabled in software via a user selectable configuration toggle.

Night Purge Mode:
The night purge mode will begin at a preset time prior to scheduled occupancy time and operate during optimal start. When enabled, the controller will measure the space temperature and modulate the economizer to maintain the optimal start space cooling setpoint, regardless of outside air temperature. This mode can be enabled/disabled in software via a user selectable configuration toggle.

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Air Temperature	×							×		×
Mixed Air Temp	×							×		×
Heating Output		×						×		×
Cooling Valve		×						×		×
Mixed Air Dampers		×						×		×
Freezestat			×					×	×	×
Supply Fan Status			×					×		×
Outside Air Enthalpy Switch			×					×		×
Supply Fan Start/Stop				×				×		×
Space Temp					×			×		×
Space Setpoint Adjust					×					×
Outside Air Temp					×			×		×
Space Unoccupied Override						×				×
Schedule							×			×
Heating Setpoint								×		×
Cooling Setpoint								×		×
High Space Temp									×	
Low Space Temp									×	
High Supply Air Temp									×	
Low Supply Air Temp									×	

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Fan Failure									×	
Supply Fan in Hand									×	
Supply Fan Runtime Exceeded									×	
High Mixed Air Temp									×	
Low Mixed Air Temp									×	
Totals	**2**	**3**	**3**	**1**	**3**	**1**	**1**	**13**	**10**	**16**

Total Hardware (9) **Total Software (28)**

4.2 SEQUENCE OF OPERATION FOR FCU

4.2.1 RFC MOD CW-ELEC HT-3 SPD FAN

M4.1.5.7-EH_MODCW (typical of 1)
SEQUENCE OF OPERATION

The Fan Coil OPEN controller will control mechanical cooling and heating based on its own space temperature input and setpoints. Optional CO2 (Indoor Air Quality) sensor mounted in the space can maximize the occupant comfort when used with the DCV ventilation damper option. Occupancy types are described in the scheduling section below. The following sections describe the functionality of the Fan Coil OPEN controller. All point objects that are referred to in this sequence of operation will be referenced to the objects as viewed in the BACview6 handheld user interface.

SCHEDULING:
Scheduling is used to transition the unit from occupied to unoccupied operation based upon a user configured time periods. The time periods are used to control the space temperature to specified occupied heating and cooling setpoints. The controller is defaulted to control to the occupied setpoints all the time, until either a Time Schedule is configured or a Third Party control system Enables/Disables the BAS On/Off point. The local time and date must be set for these functions to operate properly. The occupancy source can be changed to one of the following:

Occupancy Schedules - The controller will be occupied 24/7 until a Time schedule has been configured using either Field Assistant, i-Vu Open, BACview6 or a Third Party Enables/Disables the BAS On/Off point. This can be disabled by going to Config> Unit> Occupancy Schedules and change the point from Enable to Disable. Then click OK.

NOTE: This point must be Enabled in order for i-Vu Open, Field Assistant, or Bacview6 to assign a Time schedule to the controller.

Schedule_Schedule - The unit will operate according to the schedule configured and stored in the unit. The schedule is accessible via the BACview6 Handheld tool, i-Vu Open, or Field Assistant. The daily schedule consists of a start/stop time (standard or 24 hour mode) and seven days of the week, starting with Monday and ending on Sunday. To enter a daily schedule navigate to Config> then Sched, then enter Bavciew6 Admin Password (1111)> then schedule_schedule. From here you can enter either a Weekly or Exception schedule for the unit.

Occupancy Input Contact (Option) - If configured for remote occupancy control (default), the controller has the capability to use an external dry contact closure to determine the occupancy status of the unit. You will need to disable the Occupancy Schedules in order to utilize the occupancy contact input.

NOTE: Scheduling can only be controlled from one source.
BAS (Building Automation System) On/Off - For use with a Building Automation System that supports network scheduling, you will need to disable the Occupancy Schedules so the BAS system can control the unit through a network communication and the BAS scheduling function. NOTE: Scheduling can either be controlled via the unit or the BAS, but not both.

INDOOR FAN:
The indoor fan will operate in any one of three modes depending upon the user configuration selected. Fan mode can be defined/selected as Auto, Continuous, or Always on. In Auto mode the fan is in intermittent operation during both occupied and unoccupied periods, Continuous fan provides intermittent operation during unoccupied periods and continuous fan operation during occupied periods, while Always On operates the fan continuously during both occupied and unoccupied periods. In the default mode, Continuous, the fan will be turned on whenever any one of the following is true:

- It is in occupied mode. Determined by its occupancy status
- Whenever there is a demand for cooling or heating in the unoccupied mode
- When there is a call for dehumidification (optional)

When power is reapplied after a power outage or when transitioning from unoccupied to occupied operation, there will be a configured time delay of 5-600 seconds before starting the fan. There are also configured fan delays for Fan On and Fan Off. The fan on delay defines the delay time (0-30 seconds; default 30) before the fan begins to operate after heating or cooling is started while the fan off delay defines the delay time (0-180 seconds; default 120) the fan will continue to operate after heating or cooling is stopped. The fan on delay is automatically overridden if electric heating is active or the cooling type is DX cooling. The fan will run as long as cooling, heating, DCV or dehumidification is active. If the condensate overflow alarm or the test mode is active; the fan will be shutdown immediately regardless of occupancy state or demand.

Automatic Fan Speed Control - The Fan Coil OPEN controller is capable of controlling up to three fan speeds using a Fan Interface board or field installed relays. The controller will operate the fan motor at the lowest speed possible to provide quiet and efficient fan operation with the best latent capability during cooling. The motor will increase speed if additional cooling or heating is required to obtain the desired space temperature setpoint. The control increases the motor's speed as the space temperature rises above the cooling or below the heating setpoint. The amount of space temperature increase above or below the setpoint required to increase the fan speed is a user configurable setpoint. Also, the control will increase the fan speed as the Supply Air Temperature approaches the configured minimum or maximum SAT limits if DX cooling or electric heat is active.

Manual Fan Speed Override - When the Fan Coil OPEN controller is used with the appropriate SPT sensor, the automatic fan speed operation may be overridden from the wall mounted sensor and the user can select any available motor speed or automatic operation.

Fan Speed Control - Electric Heat override - Whenever electric heat is required and active, the control continuously monitors the supply air temperature to verify it does not rise above the configured Maximum Heating SAT Limit (110 deg Default). As the SAT increases above the Limit - 10 deg F, the control will increase the fan speed as required to insure the SAT will remain below the limit. This feature provides the most quiet and efficient operation by operating the fan at the lowest speed possible.

FAN STATUS (Option):
The optional input can be configured as either an occupancy input or a fan status input. If configured as fan status, the controller will compare the status of the fan to the desired commanded state. Whenever the fan is commanded to run (ON), the fan status will be checked and verified to match the commanded state. If the fan status is not on, then a fan status alarm will be generated after 1 minute and the equipment's OAD will be disabled. If the equipment has hydronic heat configured, the heating algorithm will maintain the desired fan off setpoint.

COOLING:
The Fan Coil OPEN controller will operate one stages of DX cooling or chilled water valve (2- position or modulating) to maintain the desired cooling setpoint. The cooling is controlled by the PI (Proportional-integral) cooling algorithm. The desired Supply Air temperature setpoint [Cooling Control Setpoint] will be calculated by the Fan Coil OPEN controller. This setpoint is compared to the actual supply air temperature and used to determine valve operation for modulating or 2-position control valves or staging for DX control. The following conditions must be true in order for the cooling algorithm to run:

- Cooling is set to Enable
- Space temperature reading is valid
- For 2-pipe systems - The water temperature is suitable for cooling
- Heat mode is not active and for DX, the 5 minute compressor time guard timer has expired

- OAT is greater than the Cooling lockout temperature if OAT is available
- Condensate Overflow input is Normal
- If occupied, the SPT is greater than the occupied cooling setpoint
- If unoccupied, the SPT is greater than the unoccupied cooling setpoint

If all the above conditions are met, cooling will be energized as required, otherwise it will be disabled. If cooling is active and should the SAT approach the minimum SAT limit, the cooling valve will modulate closed.

The configuration screens contain the Min SAT parameter as well as cooling lockout based on outdoor air temperature (OAT), both can be adjusted to meet various specifications.

Modulating Chilled Water - The control can operate a modulating (0-10 vdc) type, NO or NC, chilled water valve connected to the cooling coil of the unit in order to maintain the desired cooling setpoint. The valve will modulate to maintain the SAT at the calculated Cooling Control Setpoint. The control will also prevent the SAT from exceeding the Minimum Cooling SAT limit.

HEATING:
The Fan Coil OPEN will operate one stage of electric heat or a hot water valve (2-position or modulating) to maintain the desired heating setpoint. The heating is controlled by the PI (Proportional-integral) heating algorithm. The desired Supply Air temperature setpoint [Heating Control Setpoint] will be calculated by the Fan Coil OPEN controller. This setpoint is compared to the actual supply air temperature and used to determine valve operation for modulating or 2-position control valves or staging for electric heat. The following conditions must be true in order for the heating algorithm to run:

- Heating is set to Enable
- Space temperature reading is valid
- For 2-pipe systems - The water temperature is suitable for heating
- Cool mode is not active and for electric heat, the 2 minute minimum off timer has expired
- OAT is less than the Heating lockout temperature if OAT is available.
- Condensate Overflow input is Normal
- If occupied, the SPT is less than the occupied heating setpoint
- If unoccupied, the SPT is less than the unoccupied heating setpoint

If all the above conditions are met, the heating outputs will be energized as required, otherwise they will be de-energized. If the heating is active and should the SAT approach the maximum SAT limit, the heating valve will modulate closed. For electric heating, if the SAT rises above the configured Maximum SAT limit - 10 deg F., the fan will be indexed to a higher speed. Should this be insufficient and should the SAT rise above the maximum limit, the EH heating stage will be disabled. After the electric heater stage is turned off, it may be restarted again after the supply air temperature has fallen below the Maximum Heating SAT limit - 15 deg F. There is a minimum off time of 2 minutes for the electric heater stage to protect against excessive cycling. The configuration screens contain the Max SAT parameter as well as Heating Lockout based on outdoor air temperature (OAT), both can be adjusted to meet various specifications.

Single Stage Electric Heat - The control can operate a single stage of electric heat in order to maintain the desired heating setpoint. The heat stage will be controlled to prevent the SAT from exceeding the Maximum Heating SAT limit. The electric heat output will not be energized unless the SAT is < Maximum Heating SAT limit - 15 deg F. and once disabled, can not be restarted for at least 2 minutes to prevent excessive cycling.

INDOOR AIR QUALITY (IAQ):
The Fan Coil OPEN control can provide either two position or Demand Controlled Ventilation (DCV) in order to provide the necessary ventilation to the occupied space. [To meet ventilation requirements, the

fan should always be configured for Continuous or Always On operation. If the fan is configured for Automatic operation, the fan will be started during occupied periods if required, but ASHRAE base ventilation requirements will NOT be met using Automatic fan operation.]
Demand Control Ventilation (DCV) - If the optional indoor air quality sensor is installed, the Fan Coil OPEN can maintain indoor air quality, via a modulating OA damper providing demand controlled ventilation. The control operates the modulating OA damper during occupied periods. The control monitors the CO2 level and compares it to the configured setpoints and adjusts the ventilation rate as required. The control provides proportional ventilation to meet the requirements of ASHRAE specifications by providing a base ventilation rate and then increasing the rate as the CO2 level increases. The control will begin to proportionally increase ventilation when the CO2 level rises above the start ventilation setpoint and will reach the full ventilation rate when the CO2 level is at or above the maximum setpoint. A user configurable minimum damper position insures that proper base ventilation is delivered when occupants are not present. If the additional outdoor air being introduced for ventilation causes an unacceptable drop in the supply air temperature or could cause a potential coil freeze-up condition, then the control can be set to temper the supply air during DCV control. Reheat Enable must be set to "Enable" and 2-Pipe Changeover must be set to "NO". The control will utilize heating to prevent the supply air from falling below the user configured Temper / Reheat SAT setpoint. The IAQ configurations can be accessed through the configuration screen. The following conditions must be true in order for this algorithm to run:

- Damper Control is configured for DCV
- The unit is in an occupied mode
- The fan is on
- If enabled, the fan status must be on
- IAQ sensor reading is greater than the DCV Start Control Setpoint

The control has four user adjustable setpoints; DCV start control setpoint, DCV Maximum Control setpoint, Minimum damper position and the DCV Maximum damper position.

Two Position OA Ventilation Damper - The control can be configured to operate an OA ventilation damper in a two position mode to provide ventilation during occupied periods. The damper will open 100% during any occupied or override period to insure proper ventilation is delivered to the occupied space. If the fan is off or the space is unoccupied, the damper will close. The following conditions must be true in order for this algorithm to run:

- Damper Control is configured for 2 -Position
- The unit is in an occupied mode
- Fan is on
- If enabled, the fan status must be on

DEHUMIDIFCATION:
The Fan Coil OPEN can provide occupied and unoccupied dehumidification. This function requires an accessory space relative humidity sensor. When using a relative humidity sensor to control dehumidification during occupied or unoccupied times, the appropriate dehumidification setpoints are used accordingly. When the indoor relative humidity becomes greater than the dehumidification setpoint a request for dehumidification is generated. The dehumidification request will cause the unit to start if not already operating. If cooling or heating is currently operating, then dehumidification will be delayed until the cooling or heating load is satisfied. Once satisfied, dehumidification will enable cooling and the fan will operate at its lowest speed. During cooling the unit both cools and dehumidifies, however once the requirement for cooling has been satisfied and if there is still a call for dehumidification, the unit will continue to operate providing dehumidification and reheat as applicable. If a heating coil is installed downstream of the cooling coil and REHEAT is enabled, while dehumidification is active, the hydronic heating coil will maintain the supply air temperature at the configured Temper/Reheat SAT setpoint to prevent overcooling of the space as long as the space temperature remains at least 1 deg F below the

occupied cooling setpoint. Dehumidification will be disabled if the SPT falls below the Occupied Heating Setpoint. The following conditions must be true in order for this algorithm to run:

- Cooling is set to Enable
- Space temperature reading is valid
- OAT is greater than the Cooling lockout temperature if OAT is available
- Condensate Overflow input is Normal
- Space temperature is above the occupied heating setpoint
- Space temperature is below the current cooling setpoint
- If unoccupied, the space RH is greater than the Unocc Relative Humidity Setpoint
- If occupied, the space RH is greater than the Occ Relative Humidity Setpoint

The following must also be true in order for the reheat to operate during dehumidification:

- A hydronic heating coil is installed in the reheat position
- Space temperature is at least 1 deg F below the occupied cooling setpoint
- Changeover is set to no

DEMAND LIMIT:
The Fan Coil OPEN has the ability to accept three levels of demand limit from the network. In response to a demand limit, the unit will decrease its heating setpoint and increase its cooling setpoint to widen the range in order to immediately lower the electrical demand. The amount of temperature adjustment in response is user adjustable for both heating and cooling and for each demand level. The response to a particular demand level may also be set to zero.

THERMOSTAT LINKAGE:
The Fan Coil OPEN has the ability to utilize one wall mounted SPT type sensor to control multiple units using Thermostat Linkage. A single unit is selected as a master and configured for the total number of linked units (including the master). The slave units must be sequential addressed down from the master's address. The master will send the setpoints, occupancy status, space temperature, and optional RH or CO2 values from the master to the slave units. [NOTE- If a local sensor for either RH or CO2 is provided, then that value will be used at the slave fan coil rather than the value received through Thermostat Linkage.] In return, each slave will send its operating mode and supply air temperature. When using Thermostat Linkage, the units do not need to be of the same type or have the same coils. Each unit may be independently configured for coil types, fan operation, etc. Thermostat Linkage is designed to support a maximum of 8 units operating together using a single SPT sensor.

AIRSIDE LINKAGE:
The Fan Coil OPEN has the ability to receive information through Airside Linkage and then operate as an air source for a sub-zoned system using VVT terminals. The fan coil becomes the equipment master and receives its setpoints, occupancy and space temperature from the zoning system. Additionally, if an optional CO2 or RH sensor is connected to any zone, the fan coil will also receive that data through Linkage. [NOTE- DO NOT connect a RH or CO2 sensor to the fan coil unit if Airside Linkage is used. The local value will be overridden by Linkage.] The fan coil will then operate using this information to provide the necessary air required to satisfy the load in the zones. The operating mode and supply air temperature of the fan coil will be sent to all the zones in the system. When using Airside Linkage, it has the highest priority and overrides both local control and Thermostat Linkage.

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
SPT Space Temp	×							×	×	×

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
AI #1 Space RH / CO2 / IAQ	×							×	×	×
AI #2 Supply Air Temperature	×							×	×	×
AI #3 Return Air Temperature	×							×	×	×
AI #4 Changeover Sensor	×									×
AO #1 OA Damper		×								×
AO #2 Modulating Htg Valve / Modulating Valve (w/ changeover)		×								×
AO #3 Modulating Cooling Valve		×								×
BI #5 Remote Occ/Fan Status			×							×
BI #6 Condensate Overflow Contact			×						×	×
BO #1 Fan High Speed				×				×		×
BO #2 Fan Medium Speed				×				×		×
BO #3 Fan Low Speed				×				×		×
BO #4 2-Pos Htg Valve / EH Stg 1 2-Pos Valve(w/ Changeover)				×						×
BO #5 2-Pos Clg Valve / DX Stg 1/EH Stg 1 (w/ heat type 5)				×						×
Totals	**5**	**3**	**2**	**5**	**0**	**0**	**0**	**7**	**5**	**15**

Total Hardware (15) **Total Software (12)**