SECTION 230993 - SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 GENERAL REQUIREMENTS

A. This Section is coordinated with and complementary to the General Conditions and Supplementary General Conditions of the Work, wherever applicable to HVAC Work.

1.2 DESCRIPTION OF WORK

A. Provide labor, materials, equipment and services as required for the complete installation of a Direct Digital Control (DDC) System.

B. This contractor to provide dedicated controls system to all DDC panels and connect to existing Honeywell Excel 5000 system.

C. Provide wiring and conduit required to connect devices furnished as a part of, or accessory to, this automatic control system. Install wiring in accordance with requirements of "Electric Wiring" in Division 26, and the National Electrical Code and in accordance with local electrical code requirements. Electrical contractor to provide power circuit adjacent to all control panels and VFD's. Control contractor to provide wiring and connection to DDC control panels and VFD control panels. Power wiring to all motors shall be by the electrical contractor.

D. Provide all required devices for proper system operation, including special electrical switches, transformers, relays, pushbutton stations, etc.

E. The DDC system shall be a complete installation including labor, materials, equipment, service and training.

1.3 QUALITY ASSURANCE

A. The complete automatic temperature control system shall be comprised of a microprocessor based DDC System.

B. All work shall be installed only by skilled mechanics employed by the temperature control contractor or subcontractor.

C. Design, installation, supervision and checkout of the system shall be by factory-trained engineers and technicians directly employed by the DDC contractor. All components shall be fully tested and documented to operate as a complete system.

D. The DDC contractor shall provide an on-line support services allowing a service technician to provide remote-dial up emergency service.

E. The DDC control manufacturer shall be capable of providing local training

1.4 SUBMITTALS

A. The DDC manufacturer shall furnish submittals for approval in accordance with General Conditions of the contract. Submittals shall include but are not limited to:

1. Valve and Damper schedules.

2. Manufacturer's product data sheets for all components to be furnished.

3. System control drawings, including the following:

    a. System communication diagrams.
    b. System schematics.
    c. Device schedules.
    d. Point schedules.
    e. Wiring details.
    f. Panel layouts.
    g. Wiring details.

B. All control drawings shall be generated using computer aided drafting and shall be supplied to the owner in a .PDF file format upon project completion.

PART 2 - PRODUCTS

2.1 WEB SERVER FRONT END

A. Description: Existing Operator Interface Via Web Browser

1. The control system consists of a high-speed, peer-to-peer network of DDC controllers and a stand-alone Web Server. The stand-alone Web server is a compact device capable of routing peer to peer communications of devices on the RS-485 network to an Ethernet LAN. The Web Server is capable of storing all system device definitions within the Web server and will not require an external system manager, computer, or controller to define or access system control devices. The Web Server will allow users to interface with the network via dynamic color graphics served over the Intranet or Internet via a standard Web Browser. The Web server is capable of tabular and graphic displays of mechanical systems, building floor plans, or control devices depicted by point-and-click graphics.

B. Existing Operator Interface

1. Operators are able to access all necessary operational information in the system via personal computer utilizing standard Web browser software. The Web server will reside on the same Peer-to-Peer network as the Building Controllers.
2. The Web Server is connected via Ethernet to a LAN and is able to serve up controller information to simultaneous operators connected via the Ethernet or telephone with standard Web Browsers. Each standard browser connected to server is able to access all system information.
3. In addition to the primary operator interface, the system includes a secondary interface compatible with a locally available commercial wireless network and viewable on a commercially available wireless device such as a Wireless Access Protocol (WAP) enabled cellular telephone or personal digital assistant (PDA). This secondary interface is text-based and will provide a summary of the most important data.

C. Existing Web Browser Interaction

1. The Web server is capable of providing the operator, at a Web Browser, with both tabular or graphical pages of controller data. An operator with the proper password level is able to change setpoint and occupancy schedules or override points and remove overrides. Dynamic objects includes analog and binary values, dynamic text, static text, and animation files. Graphics have the ability to show animation by shifting image files based on the status of the object.
2. Alarms. An operator is able to access a tabular listing of the systems most recent alarm messages from a standard Web browser. This listing will allow the operator to manage the alarms and acknowledge, print, delete and hyperlink to trouble areas.

D. New Web Browser Interaction
1. Honeywell is to provide floor plan graphics showing all new equipment and have them loaded onto the front end computer.

E. Existing System Software
1. Operating System. Web server is an embedded web server device with factory loaded operating system and web server application.
2. System Graphics. Operator interface is graphically based and includes at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.
    a. Functionality. Graphics allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.
    b. Animation. Graphics are able to be animated by displaying different image files for changed object status.
    c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
    d. Format. Graphics are saved in an industry-standard format such as JPEG, or GIF. Web-based system graphics are viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format require no plug-in (such as HTML and JavaScript) or only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

2.2 CONTROL DEVICES

A. Safety/Status Devices:

1. Low Limit Detector: Electric type, with 20’ long serpentine element, with manual reset and auxiliary contacts to the DDC, set for 37°F for “freeze” protection and 55°F for fan discharge application. Provide a 20’ long element for every 25 sq. ft. of coil face area.

2. Pump status shall be provided through adjustable range current sensing element on pump motor.

3. Fan status shall be provided through adjustable range current on the fan motor.

B. Miscellaneous Devices:

1. Provide necessary relays, transformers, interface cards, required for a complete and operable system.

2.3 CONTROL CABINETS

A. Central and local DDC control panels shall be fully enclosed cabinet, baked enamel, steel, aluminum or composite material construction and shall meet the requirements of NEMA 1 enclosures. Panels shall have hinged door with a locking latch. Cover exposed electrical connections. Each component on front panel shall have an appropriate engraved label describing its function. Components inside the panel shall be appropriately labeled for ease of identification. Stick-on labels are not acceptable. Panels shall be either free-standing or wall-mounted. Provide support steel framing.

2.4 DIRECT DIGITAL CONTROL SYSTEM

A. The basic elements of the Direct Digital Control System structure shall consist of standard components kept in inventory by the equipment supplier. The components shall not require customizing other than setting jumpers and switches, adding modules or software programming to perform required functions. Future expansion shall not require hardware modifications to the controller. The entire system shall be a Direct Digital processing type with electric output devices.

B. The DDC system shall consist of the following:

1. Central and local DDC panels.

2. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

3. Central and local DDC panels shall be able to access any data from, or send control commands and alarm reports directly to any other DDC panel, operator workstation, or printer on the network.

2.5 NETWORKING/COMMUNICATIONS

A. Inherent in the system's design shall be the ability to expand or modify the network via the local area network.

B. Local Area Network:

1. Workstation/DDC Panel Support: Operator workstations and DDC panels shall directly reside on a local area network such that communications may be executed directly between controllers, workstations, and between controllers and workstations on a peer-to-peer basis.

2. Dynamic Data Access: The system shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network.

3. General Network Design: Network design shall include the following provisions:

a. The minimum baud rate shall be 9600 bps.

b. Message and alarm buffering and default device definition to prevent information from being lost.

c. Synchronization of the realtime clocks in all DDC panels shall be provided.

4. A PC workstation may serve as an operator device on a local area network, as well as a dial-up workstation for multiple auto-dial DDC panels or networks. Alarm and data file transfers

handled via dial-up transactions shall not interfere with local area network activity, nor shall local area network activity keep the workstation from handling incoming calls.

2.6 FIELD INSTALLED CONTROLLERS

A. General: The Field Installed Controller shall be a solid state sixteen bit micro controller with pretested and factory configured software specifically designed for regulating building equipment using closed loop Direct Digital Control and facility management routines.

B. General Purpose Electronic Controller (GPEC):

1. The GPEC shall be located where shown on the plans and shall include inherent input/output capability. Each controller shall include a minimum of eight inputs and eight outputs. If the GPEC's input/output capability is exceeded, additional controllers with inherent input/output capability shall be provided. The GPEC's input/output capability shall include a combination of standard HVAC sensor input and output types. The GPEC shall support discrete and either 0-10vdc and 4-20ma type analog outputs. The GPEC shall support the following sensor input types as a minimum:

2. Dry contact and pulsing dry contacts

    a. 0-10vdc and 4-20ma
    b. 5K and 10K thermistors
    c. 1000 ohm Nickel RTD

3. Communication status for the primary communication bus and Local Interface Device (LID) shall be indicated by LEDs. The separate LEDs shall flash whenever communications are occurring. The GPEC shall communicate to all connected points at least once a second.

C. General Purpose Electronic Expandable Controller (GPEX):

1. The GPEX shall be located where shown on the plans and shall include inherent input/output capability. Each GPEX shall include a minimum of eight inputs and eight outputs. If the GPEX's input/output capability is exceeded, the GPEX shall be capable of supporting additional GPEX I/O modules. Each GPEX I/O module shall be capable of supporting a minimum of eight additional inputs and outputs. The GPEX's and associated GPEX I/O modules shall include the ability to support a combination of universal HVAC sensor input and output types. The GPEX and GPEX I/O modules shall include the inherent ability to support any combination of discrete, 0-10vdc and 4-20ma outputs and the following sensor inputs types as a minimum:

    a. Dry contact and pulsing dry contacts
    b. 0-10vdc and 4-20ma
    c. 10K thermistors
    d. 1000 ohm Nickel RTD

2. All output channels shall include diagnostic LED's. Whenever a discrete output has been enabled by the GPEX, a LED associated with that channel shall light.

3. Each input and output channel shall include a configuration switch such that the user shall be able to select the input or output type from any of the types listed above. The GPEX and GPEX I/O shall not require wiring to a terminal strip. Both types of controllers shall utilize "plug type" terminals such that the user may be able to disconnect and replace a module simply by removing the plug type connectors and plugging them into a new module.

4. The GPEX shall be provided with the capability of HAND-OFF-AUTO (H-O-A) override switches for all output channels. The H-O-A switches shall be accessible to the user and shall allow the user the ability to force the controllers discrete outputs on, off, or in an automatic mode allowing the GPEX to command the discrete output channel on and off. When used with analog output channels, the hand position will command the analog output to its maximum value. When the switch is indexed to the automatic mode the GPEX's algorithm will command the output, and when the switch is placed in the off position the analog output will be commanded to its minimum output value.

D. Controller Attributes

1. The controller shall be powered from standard, off the shelf, Class II, 24 volt transformers. The controller shall be listed under UL916 PAZX (Energy Management), UL 864 UDTZ (General Utility Signaling), VDE, and CSA. Products shall be manufactured in a facility having a Quality System that is registered to either ISO 9002 or ISO 9001 Quality Assurance Standard. The controller shall be designed to be easily mounted in a standard NEMA 1 type enclosure without special rails or mounting hardware and as local and national code dictates.

2. The controller shall include a 365 day real time clock and watchdog timer diagnostic indicator provided by a LED. The watchdog timer shall reset upon power on and be resettable by software thereafter. Should the watchdog timer not be resettable during the timing period, it shall time out and set all outputs to their non powered state. The LED shall illuminate solidly to indicate this failure.

3. The controller shall not require a battery. All configuration data, custom programs, etc. will be stored in non-volatile memory. The controller shall provide a minimum of two days data retention for the time clock and consumable data (runtimes, GPM, KWH, etc.). Systems that require a battery to store data is not acceptable.

4. The controller shall include the capability to provide a local interface for all operating values, alarms, etc., via a hand held, panel mounted, or remotely mounted Local Interface Device. The controller shall also be capable of interfacing to a portable PC for configuring or altering the configuration, setting the address, performing uploads/downloads, entering of custom programs, etc. through a separate, additional RJ14 plug.

5. The controller shall be capable of operating in either a standalone mode or as part of a network with an EMS operator's station and other system elements including Product Integrated Controllers (PICs).

E. Controller Software

1. The controller shall provide stand-alone operation and shall accept analog and discrete signals from sensors, switches, relays, etc. and shall multiplex the various signals into digital format. All closed loop Direct Digital Control routines shall utilize controller based software algorithms that shall be resident in its memory. All standard and custom control controller based algorithms shall operate independently, and systems that require an on line host computer or intermediary processor to control mechanical or electrical equipment is not acceptable.

2. Time Schedules- Each time schedule shall include provisions for eight individual day types (Monday through Sunday and holidays), and each individual day type shall contain at least seven individual on off time periods. The controller shall support one minute granularity. Systems that use a granularity of greater than one minute shall not be accepted.

3. Setpoint Schedules - Each setpoint schedule shall be individually definable in terms of:

a. Engineering Units
b. Occupied High Setpoint
c. Occupied Low Setpoint
d. Unoccupied High Setpoint
e. Unoccupied Low Setpoint

4. Controller software shall include the capability to link specific time schedules with corresponding setpoint schedules for any particular DDC loop.

5. Remote Timed Override- The controller shall support remote timed override through the use of a space sensor with an integral override button or a momentary contact switch. Whenever the override is initiated during the unoccupied period and the controller is configured to provide remote override the time schedule associated with the override shall become occupied for 0-4 hours (operator selectable). Whenever the time schedule becomes occupied the controller shall control its associated control points to their occupied setpoints.

6. The controller shall provide a power fail restart routine that shall provide an adjustable staggered time delay for each DO point selected, to avoid sudden power peaks.

F. Input/Output Signal Processing

1. Input Processing

a. Each connected or calculated input point shall be independently processed to provide accurate data values. All point processing shall be performed by the controller. All connected and calculated points, both analog and discrete, shall be individually configured and be capable of displaying their values at the LID, portable PC or at a connected EMS operator's station. Input points may be added, deleted or modified via the Local Interface Device, portable PC, and if tied into a network, by the EMS operator's station. Discrete input points shall be monitored for status, alarm or consumable data.

b. Analog inputs shall be monitored to provide feedback to a control loop, to annunciate that an analog alarm limit has been exceeded, to offer centralized analog monitoring or to monitor consumable data. Discrete and analog inputs shall be able to interact with controller resident algorithms for local processing.

c. The operator shall be able to create sensor groups for use in the algorithms. The sensor groups will provide the lowest, highest, or average values, as applicable to the application and algorithm.

d. Controller software shall include a trim function to allow for the field calibration of analog input sensors.

2. Alarm Processing

a. The controller shall contain a routine to process alarms and alerts. Alarm processing shall be initiated once per second and shall consist of a scan of all input points. 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.

3. Output Processing

a. Discrete Outputs-Discrete outputs shall be used to command two state devices (on/off, open/close, etc.). Each discrete output point must be capable of being individually configured by the operator.

b. The following types of direct digital control routines shall be provided for discrete outputs as a minimum:

1) Enthalpy/Analog Comparison
2) Analog
3) Interlock
4) Time Clock/Cycling
5) Time Clock/Cycling with Temperature Override
6) Staged thermostat (Minimum of four stages plus fan)
7) Staging control (Minimum of 6 stages. For VAV, CV air handlers with electric heat and/or DX cooling and cooling towers)
8) Lead/lag pump control with automatic fault logic

c. Staging algorithms will include adjustable on/off delays as well as adjustable differential between stages.

4. Analog Outputs

a. Analog outputs shall be used to command modulating/variable position devices. Each analog output must be capable of individual configuration via the operator.

b. As a minimum, the following preprogrammed analog out algorithms shall be resident at the controller:

1) Cooling Coil Control with Dehumidification (CV and VAV)
2) Heating Coil Control (CV and VAV)
3) Mixed Air Damper Control (CV and VAV including Indoor Air Quality damper override)
4) Minimum outside air CFM for VAV air handlers
5) Air and water Reset
6) Humidification
7) Sequenced Cooling and Heating coil control For CV applications
8) Static Pressure and Fan Tracking Control
9) Adaptable Control

c. Systems which require a host computer to perform any of the above algorithms shall not be acceptable. The algorithms shall support both dual (master/submaster) and single control loops, and shall include PID control, as required.

5. Overrides and Interlocks

a. Provide the capability to manually override a controller's input or output value and input a different value in its place. Manual overrides shall be capable of being initiated via the Local Interface Device, portable PC or the EMS operator's station, if part of a network. All manually initiated overrides shall be manually removed. The controller shall also be capable of providing event initiated overrides of normal control algorithms. Specific preprogrammed interlock sequence programming shall be configured via either the Local Interface Device, portable PC or the EMS operator's station, if part of a network.

6. Standalone Data Collection

    a. The controller shall include the inherent ability to accept a data collection module to perform automatic point tracing based on a change in value of a discrete or analog point. The trace function shall be operator selectable to store up to 60 samples at an operator configured interval. When the point trace is full the operator shall be able to have the trace stop, wrap around, or to stop and trigger another trace of the point to begin. The trace values shall be displayed at the LID, portable PC or EMS operator's station, if part of a network.

    b. Runtimes/consumables- Any discrete input may be linked by the operator to a runtime table for the purposes of displaying equipment runtime totals.

    c. Any discrete or analog input shall be capable of being used to calculate and display consumable data such as; GPM, KWH, #/hour, etc. This information shall be displayed at the LID.

G. Facility Management Application Software

1. The controller shall contain the following preprogrammed application software:

    a. Night Time Free Cooling (NTFC)
    b. Adaptive Optimal Start/Stop
    c. Power fail restart

H. Custom Programming

1. Provide a controller based, user-friendly interactive, programming language for the purpose of creating custom programs for specific, unique applications. Complex control strategies shall be able to be developed by the end user.

2. All custom programming must be performed in English language shall be addressable by user specific English names without requiring alphanumeric addresses or point numbers. Programming languages such as BASIC or FORTRAN shall not be acceptable for these applications, and the custom programs shall be retained in controller memory and shall not require a host CPU to operate correctly. Custom programs shall be capable of supporting either SI metric or customary US units. All custom programming point data shall be capable of being transferred from one controller to another (if networked) directly without an on line CPU or host computer.

I. Local Interface device

1. At least one Local Interface Device (LID) shall be provided and shall connect to the controller through a RJ14 plug. Systems that require wiring of the LID via any other means of simply plugging in, will permanently mount a LID on the face of every control panel. The LID shall provide the local means of configuring and modifying the data base, viewing point statuses, alarms, maintenance data, equipment runtimes, or consumable data such as; GPM, KWH, and #/hour, without the need of a portable PC or any other type of external interface.

2. The LID shall be password protected and shall include a backlit, alphanumeric liquid crystal display, and shall be capable of displaying at least two lines of data; 24 characters per line. The keypad shall include function, operative, and numeric keys. The LID shall utilize a hierarchy of levels (menus) such that the operator may easily access functions by simply following the menu prompts.

3. The LID display shall include 24 character point descriptors (as a minimum), and shall display the point values in either SI Metric or Customary US units. The LID shall automatically log off after ten minutes of no operator activity. The default LID screen shall include the controllers name, current time and date, and present alarm status as a minimum.

J. Networking

1. The controller shall include the inherent ability to be networked with other system elements to allow a dynamic exchange and sharing of information without the addition of communication cards or additional software. Systems that require a host computer to be in the system architecture or on line is not acceptable. This information exchange shall include but not be limited to the following:

    a. Broadcast of time, date, holiday, outside air temperature and relative humidity
    b. Data Collection of consumable and runtime data in addition to stand alone controller based consumable and runtime data.
    c. Data transfer to receive and utilize input/output point data from and to other system elements.
    d. Timed force and Facility time schedule
    e. Tenant billing
    f. Peak Demand Limiting
    g. Maintenance management
    h. Water System Manager (To allow a dynamic exchange of information between the air handler load and the water source)
    i. Dynamic linkage software between an air handler and its associated air terminals
    j. DataPort (ASCII conversion) and alarm printer interface
    k. Custom programming

K. Communications Bus (When part of a network)

1. The Communications Bus shall be a three conductor cable with shield. EIA Standard RS-485 Communication's protocol shall be employed. The communication bus shall comply with FCC part 15, Subpart J, class A for bus radiated and conductive noise.

2. Communications Bus shall be capable of having multiple system elements connected. Each Communications Bus shall allow for the use of modules as an interface to secondary Buses.

3. Whenever the Communications Bus enters or leaves a building, the Bus shall be provided with adequate lightning suppression devices.

4. The Communications Bus shall be capable of communicating through a telephone modem to a remote building. This interface shall allow any EMS operator's station, as applicable, to communicate with any other remotely located, compatible, communications Bus.

2.7 AUXILIARY EQUIPMENT/DEVICES

A. Analog Sensors:

1. Duct sensors (greater than four square feet)- Monitoring range to suit application. Platinum or nickel wound RTD Type + 0.1% of range. Factory calibration point – 70 Deg. F at 1000 OHMS.

2. Space Temperature Sensors- Space Temperature Sensors shall be 5,000 or 10,000 ohm thermistor with wall plate adapter and blank cover assembly. The sensor shall include an integral occupancy override button and shall also include a RJ11 communications port. Space

Temperature Sensors shall include space temperature adjustment slides where shown on the plans. The Space Temperature Sensors shall be mounted approximately 60" above the floor.

3. Hydronic Well Temperature Sensors-Water Temperature Sensors shall be well mounted 5,000 or 10,000 ohm thermistors.

4. Status Indication- Status indication for fans and pumps shall be provided by a current sensing sensor. The sensor shall be installed at the motor starter or motor to provide load indication. The unit shall consist of a current transformer, a solid state current sensing circuit (with adjustable set point) and a solid state 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 Field Installed Controller.

5. Combination CO_2 and Space Temperature Sensors: CO_2 and space sensors are comprised of two sensors housed in one unit designed to measure both CO_2 in the air and the building air temperature. Combination sensor shall have the following features:

    a. Self Calibration CO_2 sensor with 5 year calibration interval.
    b. Push button overide.
    c. CO_2 sensitivity +/- 20 ppm.
    d. CO_2 accuracy +/- 100 ppm.
    e. Space sensor: 5 or 10K thermistor.

B. Damper actuators:

    a. Provide 24 VAC control operators which are 0-10 VDC input proportional or two position control with spring return as needed by control sequence and designed for damper operation. Operator on air handlers shall be synchronous motor driven with up to 150 in. lb. force and force sensor safety stop.

PART 3 - EXECUTION

3.1 BUILDING MANAGEMENT SYSTEM – GENERAL

A. Space mounted devices are to be identical in appearance. All devices shall be mounted under the same style cover.

B. Provide all relays, switches, sources of electricity and all other auxiliaries, accessories and connections necessary to make a complete operable system in accordance with the sequences specified.

C. Install controls so that adjustments and calibrations can be readily made. Controls are to be installed by the control equipment manufacturer.

D. Mount surface-mounted control devices, tubing and raceways on brackets to clear the final finished surface of insulation.

E. Conceal control conduit and wiring in all spaces except in the Mechanical Equipment Rooms and in unfinished spaces. Install in parallel banks with all changes in directions made at 90 degree angles.

F. Install control valves horizontally with the power unit up. Installation of control valves will be by the piping contractor.

G. Unless otherwise noted, install wall mounted sensors, thermostats and humidistats at 5'-0" above the finished floor measured to the center line of the instrument. Room devices are to be of the concealed type without indicator. Submit device locations, mounting heights and details for approval.

H. General System Requirements

1. Normal (no signal or electricity) positions for controlled components:

a.	Reheat Valves	-	Closed
b.	Outside Air Dampers	-	Closed
c.	Return Air Dampers	-	Open
d.	Exhaust Air Dampers	-	Open

2. The Building Management System (BMS) shall be programmed to start and stop the HVAC equipment based on occupancy schedules coordinated with the owner. The BMS shall also provide equipment interlocks as required.

3. All control valves that are sequenced shall be provided with dedicated analog outputs.

4. Emergency Override Stop

   a. The Fire Alarm System shall provide dry contact outputs to notify the BMS of fire alarms. Coordinate zoning required with Division 16.

   b. All fan systems (min. 1000 cfm) shall be stopped from the FAS. When the fan system stops, all associated dampers shall close.

   c. All return and exhaust fans shall be stopped from the FAS. When the fan stops, all associated dampers shall close.

   d. All relays, electrical wiring, panels, outputs, etc. to make a complete operational system, shall be provided and installed by this section.

   e. See sequences of operation for details.

5. All safeties shall be automatically and remotely reset from BMS.

6. All set points shall be adjustable from BMS console via single point commands.

7. All reset schedule parameters shall be adjustable from BMS console via single point commands

3.2 **CONTROL SEQUENCES OF OPERATION**

1. Rooftop Units

Run Conditions - Scheduled:
The unit shall run based upon an operator adjustable schedule.

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

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

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

Alarms shall 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.).

Supply Air Duct Static Pressure Control:
The controller shall measure duct static pressure and shall modulate the supply fan VFD speed to maintain a duct static pressure setpoint of 1.5in H2O (adj.). The supply fan VFD speed shall not drop below 30% (adj.).

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan VFD Fault.

Return Fan:
The return fan shall run whenever the supply fan runs.

Alarms shall be provided as follows:

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

Supply Air Temperature Setpoint - Optimized:
The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on zone cooling and heating requirements

The supply air temperature setpoint shall be reset for cooling based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 55°F (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 53°F (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 72°F (adj.) .

If more zones need heating than cooling, then the supply air temperature setpoint shall be reset for heating as follows:

- The initial supply air temperature setpoint shall be 82°F (adj.).
- As heating demand increases, the setpoint shall incrementally reset up to a maximum of 85°F (adj.).
- As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 72°F (adj.).

Cooling Stages:
The controller shall measure the supply air temperature and stage the cooling to maintain its cooling setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.
- AND the heating (if present) is not active.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 5°F (adj.) greater than setpoint.

Gas Heating Stages:
The controller shall measure the supply air temperature and stage the heating to maintain its heating setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

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

The heating stages shall run for freeze protection whenever:

- Supply air temperature drops from 40°F to 35°F (adj.).
- AND the supply fan status is on.

Alarms shall be provided as follows:

- Low Supply Air Temp: If the supply air temperature is 5°F (adj.) less than setpoint.

Economizer:
The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to

maintain a setpoint 2°F (adj.) less than the supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the outside air enthalpy is less than 22Btu/lb (adj.)
- AND the outside air temperature is less than the return air temperature.
- AND the outside air enthalpy is less than the return air enthalpy.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 40°F to 35°F (adj.)
- OR on loss of supply fan status.

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

Minimum Outside Air Ventilation - Fixed Percentage:
The outside air dampers shall maintain a minimum adjustable position during building occupied hours and be closed during unoccupied hours.

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 90°F (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 45°F (adj.).

Return Air Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the unit is running.

Return Air Humidity:
The controller shall monitor the return air humidity and use as required for economizer control (if present) or humidity control (if present).

Alarms shall be provided as follows:

- High Return Air Humidity: If the return air humidity is greater than 70% (adj.).
- Low Return Air Humidity: If the return air humidity is less than 35% (adj.).

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for setpoint control or economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 90°F (adj.).
- Low Return Air Temp: If the return air temperature is less than 45°F (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Air Static Pressure	x								x	x	x
Mixed Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Humidity	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Supply Fan VFD Speed		x							x		x
Mixed Air Dampers		x							x		x
Return Air Smoke Detector			x						x	x	x
Supply Air Smoke Detector			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Return Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x
Return Fan Start/Stop				x					x		x
Cooling Stage 1				x					x		x
Cooling Stage 2				x					x		x
Heating Stage 2				x					x		x
Heating Stage 1				x					x		x
Supply Air Static Pressure Setpoint					x				x		x
Supply Air Temp Setpoint					x				x		x
Economizer Mixed Air Temp Setpoint					x				x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Schedule								x			
High Supply Air Static Pressure										x	
Low Supply Air Static Pressure										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
Return Fan Failure										x	
Return Fan in Hand										x	
Return Fan Runtime Exceeded										x	
High Supply Air Temp										x	
Compressor Runtime Exceeded										x	
Low Supply Air Temp										x	
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
High Return Air Carbon Dioxide Concentration										x	
High Return Air Humidity										x	
Low Return Air Humidity										x	
High Return Air Temp										x	
Low Return Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	**6**	**2**	**5**	**6**	**3**	**0**	**0**	**1**	**21**	**24**	**22**

Total Hardware (19) **Total Software (49)**

2. Variable Air Volume - Terminal Unit

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

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

Alarms shall be provided as follows:

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

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

Reversing Variable Volume Terminal Unit - Flow Control:
The unit shall maintain zone setpoints by controlling the airflow through one of the following:

Occupied:

- When zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is between the cooling setpoint and the heating setpoint, the zone damper shall maintain the minimum required zone ventilation (adj.).
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its heating setpoint. Additionally, if warm air is available from the AHU, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum heating airflow (adj.) until the zone is satisfied.

Unoccupied:

- When the zone is unoccupied the zone damper shall control to its minimum unoccupied airflow (adj.).
- When the zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.

- When zone temperature is less than its unoccupied heating setpoint, the controller shall enable heating to maintain the zone temperature at the setpoint. Additionally, if warm air is available from the AHU, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the auxiliary heating airflow (adj.) until the zone is satisfied.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Airflow	x								x		x
Zone Damper		x									x
Airflow Setpoint					x				x		x
Heating Mode						x			x		
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Totals	**3**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**6**	**2**	**7**

Total Hardware (4) **Total Software (11)**

3.3 ELECTRICAL WIRING AND MATERIALS

A. Install, connect and wire the items included under this section. This work includes providing required conduit, wire, fittings, and related wiring accessories.

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

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

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

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

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

G. All wiring to be compliant to local building code, the NE and Division 16 specifications.

H. Provide electrical wall box and conduit sleeve for all wall mounted devices.

I. All wiring to be installed in EMT in exposed areas. Plenum cable shall be used elsewhere.

3.4 PERFORMANCE

A. Unless stated otherwise, control temperatures within plus or minus 2°F humidity plus or minus 3% of the set point and static pressure within 3% of set point.

3.5 COMMISSIONING, TESTING AND ACCEPTANCE

A. Perform a three-phase commissioning procedure consisting of field I/O calibration and commissioning, system commissioning and integrated system program commissioning. Document all commissioning information on commissioning data sheets which shall be submitted prior to acceptance testing. Commissioning work which requires shutdown of system or deviation from normal function shall be performed when the operation of the system is not required. The commissioning must be coordinated with the owner and construction manager to ensure systems are available when needed. Notify the operating personal in writing of the testing schedules so that authorized personnel from the owner and construction manager are present throughout the commissioning procedure

1. Prior to system program commissioning, verify that each control panel has been installed according to plans, specifications and approved shop drawings. Test, calibrate and bring on line each control sensor and device. Commissioning to include, but not be limited to:

a. Sensor accuracy at 10, 50 and 90% of range.

b. Sensor range.

c. Verify analog limit and binary alarm reporting.

d. Point value reporting.

e. Binary alarm and switch settings.

f. Actuator and positioner spring ranges.
g. Fail safe operation on loss of control signal, pneumatic air, electric power, network communications, etc.

B. After control devices have been commissioned (i.e., calibrated, tested and signed off), each DDC program shall be put on line and commissioned. The contractor shall, in the presence of the owner and construction manager, demonstrate each programmed sequence of operation and compare the results in writing. In addition, each control loop shall be tested to verify proper response and stable control, within specified accuracy's. System program test results shall be recorded on commissioning data sheets and submitted for record. Any discrepancies between the specification and the actual performance will be immediately rectified and retested.

C. After all DDC programs have been commissioned, the contractor shall verify the overall system performance as specified. Tests shall include, but not be limited to:

1. Data communication, both normal and failure modes.
2. Fully loaded system response time.
3. Impact of components failures on system performance and system operation.
4. Time/Data changes.
5. End of month/end of year operation.
6. Season changeover.
7. Global application programs and point sharing.
8. System backup and reloading.
9. System status displays.
10. Diagnostic functions.
11. Power failure routines.
12. Battery backup.
13. Smoke control, etc., vents, in concert with Fire Alarm System testing.
14. Testing of all electrical and HVAC systems with other division of work.

D. Submit for approval, a detailed acceptance test procedure designed to demonstrate compliance with contractual requirements. This acceptance test procedure will take place after the commissioning procedure but before final acceptance, to verify that sensors and control devices maintain specified accuracy's and the system performance does not degrade over time.

E. Using the commissioning test data sheets, the contractor shall demonstrate a minimum of 15 percent of each point type, as randomly selected by the owner. The contractor shall also demonstrate 15 percent of the system functions, as randomly selected by the owner. Based on the above samples, the owner may accept the entire system or require the contractor to demonstrate all points and system functions until all devices and functions meet specification.

F. The contractor shall supply all instruments for testing and turn over same to the owner after acceptance testing.

1. All test instruments shall be submitted for approval.

Test Instrument Accuracy:

Temperature:	1/4F or ½% full scale, whichever is less.
Pressure:	High Pressure (psi): 2 psi or ½% full scale, whichever is less.
Low Pressure:	½% of full scale (in w.c.)

Humidity: 2% RH

Electrical: ¼% full scale

G. After the above tests are complete and the system is demonstrated to be functioning as specified, a thirty day performance test period shall begin. If the system performs as specified throughout the test period, requiring only maintenance, the system shall be accepted. If the system fails during the test, and cannot be fully corrected within eight hours, the owner may request that performance test be repeated.

H. Move In Checkout

1. Each floor shall be re-tested 24 hours prior to move in. The test shall ensure all corrective work is complete and all systems are 100% operational.

2. Provide all overtime required for all BMS trades as required.

I. Additional testing, debugging and fine tuning

1. Provide and additional 16 overtime hours of appropriate highest labor cost category to be used at the owner's discretion to test, debug and fine tune the system after occupancy.

END OF SECTION 230993