SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 GENERAL

1.0 BUILDING AUTOMATION SYSTEM - GENERAL DESCRIPTION

A. Provide a new Building Automation System (BAS) to integrate and control all mechanical equipment associated with this project.

1. The Building Automation System shall be as indicated on the drawings and described in these specifications. System must be fully integrated and coordinated with mechanical equipment DDC controllers furnished and installed in the equipment manufacturer's factory as specified in those sections. The intent of the BAS is to integrate all mechanical equipment into one system for global monitoring, control, and alarming associated with the building. It is the BAS manufacturer's responsibility to provide all the design, engineering, and field coordination required to ensure all equipment sequence of operations are met as specified and the designated BAS operators have the capability of managing the building mechanical system to ensure occupant comfort while maintaining energy efficiency.

2. The BAS shall meet open standard protocol communication standards (As defined in System Communications Section) to ensure the system maintains "interoperability" to avoid proprietary arrangements that will make it difficult for the Owner to consider other BAS manufacturers in future projects.

3. Direct Digital Control (DDC) technology shall be used to provide the functions necessary for control of mechanical systems and terminal devices on this project.

4. Approved vendors, products and web services shall comply with SOC2 Type I as defined by the AICPA. SOC2 Type 1 compliance is a certification that confirms that a service provider has established and implemented effective controls to secure their clients' data in accordance with the Trust Services Criteria (TSC).

a. SOC2 Type 1 compliance provides assurance to customers that the service provider has established and implemented effective security controls and is committed to protecting their data.

b. To achieve SOC2 Type 1 compliance, the manufacturer shall have completed an independent audit to assess design and implementation of their controls, policies, and procedures.

5. The BAS shall accommodate simultaneous multiple user operation. Access to the control system data should be limited only by the security permissions of the operator role. Multiple users shall have access to all valid system data. An operator shall be able to log onto any workstation on the control system and have access to all appropriate data.

1.1 QUALITY ASSURANCE

A. BAS Manufacturer Qualifications

1. The BAS manufacturer shall have an established business office within 50.00 miles of the project site and must provide 24 hours/day, 7 days/week response in the event of a customer warranty or service call.

2. The BAS Manufacturer shall have factory trained and certified personnel providing all engineering, service, startup, and commissioning field labor for the project from their local office location. BAS manufacturer shall be able to provide training certifications for all local office personnel upon request.

3. The BAS shall be provided by a single manufacturer and this manufacturer's equipment must consist of operator workstation software, Web-based hardware/software, Open Standard Protocol hardware/software, Custom application Programming Language, Graphical Programming Language, Building Controllers, Custom Application Controllers, and Application Specific Controllers. All other products specified herein (i.e., sensors, valves, dampers, actuators, etc.) need not be manufactured by the BAS manufacturer listed in this specification.

4. Independent representatives of BAS manufacturers are not acceptable. BAS vendor must be corporate owned entity of BAS manufacturer.

1.2 CODES AND STANDARDS

A. Codes and Standards: Meet requirements of all applicable standards and codes, except when more detailed or stringent requirements are indicated by the Contract Documents, including requirements of this Section.

1. Underwriters Laboratories: Products shall be UL-916-PAZX listed.

2. National Electrical Code -- NFPA 70.

3. Federal Communications Commission -- Part J.

4. ASHRAE/ANSI 135-2012 (BACnet) - (System Level Devices) - Building Controllers shall conform to the listed version of the BACnet specification in order to improve interoperability with various building system manufacturers' control systems and devices.

5. ASHRAE/ANSI 135-2012 (BACnet) - (Unit Level Devices) - Unit Controllers shall conform to the listed version of the BACnet specification in order to improve interoperability with various building system manufacturers' control systems and devices.

1.3 SYSTEM PERFORMANCE

A. Performance Standards. The BAS system shall conform to the following:

1. Graphic Display. The system shall display a graphic with a minimum of 20 dynamic points. All current data shall be displayed within 10 seconds of the operator's request.

2. Graphic Refresh. The system shall update all dynamic points with current data within 10 seconds.

3. Object Command. The maximum time between the command of a binary object by the operator and the reaction by the device shall be 5 seconds. Analog objects shall start to adjust within 5 seconds.

4. Object Scan. All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or workstation will be current within the prior 10 seconds.

5. Alarm Response Time. The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed 10 seconds.

6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.

7. Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every 5 seconds. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

8. Multiple Alarm Annunciations. All workstations on the network shall receive alarms within 5 seconds of each other.

1.4 SUBMITTAL REQUIREMENTS

A. BAS manufacturer shall provide shop drawings and manufacturers' standard specification data sheets on all hardware and software being provided for this project. No work may begin on any segment of this project until the Engineer and Owner have reviewed submittals for conformity with the plan and specifications.

1. Provide submittal package for review and approval.

B. Quantities of items submitted shall be reviewed by the Engineer and Owner. Such review shall not relieve the BAS manufacturer of furnishing quantities required based upon contract documents.

C. Provide the Engineer and Owner, any additional information or data which is deemed necessary to determine compliance with the specifications or which is deemed valuable in documenting and understanding the system to be installed.

D. All shop drawings shall be provided to the Owner electronically as .dwg or .dxf file formats once they have been approved and as-built drawings have been completed.

E. Submit the following within 90 days of contract award:

1. A complete bill of materials of equipment to be used indicating quantities, manufacturers, and model numbers.

2. A schedule of all control dampers including damper size, pressure drop, manufacturer, and model number.

3. Provide all manufacturers' technical cut sheets for major system components. When technical cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Include:

a. Building Controllers

b. Custom Application Controllers

c. Application Specific Controllers

d. Operator Workstations

e. Portable Operator Terminals

f. Auxiliary Control Devices

4. Provide proposed Building Automation System architectural diagram depicting various controller types, workstations, device locations, addresses, and communication cable requirements.

5. Provide detailed termination drawings showing all required field and factory terminations, as well as terminal tie-ins to DDC controls provided by mechanical equipment manufacturers. Terminal numbers shall be clearly labeled.

6. Provide a sequence of operation for each controlled mechanical system and terminal end devices.

7. Provide a BACnet Protocol Implementation Conformance Statement (PICS) for each BACnet system level device (i.e. Building Controller & Operator Workstations) type. This defines the points list for proper coordination of interoperability with other building systems if applicable for this project.

F. Project Record Documents: Upon completion of installation, submit three (3) copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and include:

1. Project Record Drawings - These shall be as-built versions of the submittal shop drawings. One set of electronic media including CAD .dwg and .pdf drawing files shall be provided.

2. Testing and Commissioning Reports and Checklists signed off by trained factory (equipment manufacturers) and field (BAS) commissioning personnel.

3. Operating and Maintenance (O & M) Manuals - These shall be as-built versions of the submittal product data. In addition to the information required for the submittals, Operating & Maintenance manual shall include:

a. Procedures for operating the BAS including logging on/off, alarm management, generation of reports, trends, overrides of computer control, modification of setpoints, and other interactive system requirements.

b. Explanation of how to design and install new points, new DDC controllers, and other BAS hardware.

c. Documentation, installation, and maintenance information for all third party hardware/software products provided including personal computers, printers, hubs, sensors, etc.

d. Original issue media for all software provided, including operating systems, programming language, operator workstation software, and graphics software.

e. Licenses, Guarantee, and Warranty documents for all equipment and systems.

G. Training Manuals: The BAS manufacturer shall provide a course outline and copies of training manuals at least two weeks prior to the start of any corporate training class to be attended by the Owner.

1.5 WARRANTY REQUIREMENTS

A. Warrant all work as follows:

1. BAS system labor and materials shall be warranted free from defects for a period of twelve (12) months after final completion acceptance by the Owner. BAS failures during the warranty period shall be adjusted, repaired, or replaced at no charge to the Owner. The BAS manufacturer shall respond to the Owner's request for warranty service within 24 hours of the initiated call and will occur during normal business hours (8AM-5PM).

2. At the end of the final start-up/testing, if equipment and systems are operating satisfactorily to the Owner and Engineer, the Owner shall sign certificates certifying that the BAS is operational and has been tested and accepted in accordance with the terms of this specification. The date of Owner's acceptance shall be the start of the warranty period.

3. To ensure that the owner will have the most current operating system provided by the manufacturer, the BAS manufacturer shall include licensing and labor costs to facilitate software/firmware updates throughout the warranty period at no charge to the owner. These updates shall include upgrades for functional enhancements associated with the following: operator workstation software, project specific software, graphics, database, firmware updates, and all security related service packs. Written authorization by the Owner must be granted prior to the installation of these updates.

4. The BAS manufacturer shall provide a web-accessible Users Network for the proposed System and give the Owner free access to question/answer forum, user tips, upgrades, and training schedules for a one-year period of time correlating with the warranty period.

1.6 SYSTEM MAINTENANCE AND REMOTE ANALYSIS

A. The BAS Manufacture shall provide Building Automation System remote support and system analysis for a period of 1 year (beginning the date of substantial completion).

B. The BAS manufacturer shall set up a secure remote connection for data collection, analytics and remote technical support for the HVAC systems included in this contract.

1. Provide technician support during the warranty period to diagnose issues remotely through the secure remote connection.

C. Connectivity / Remote Access / Network Security

1. Provide and maintain secure remote access to the facilities Building Automation System (BAS) or other building systems. Users accessing service through this connection shall not have access to the building owners network. Secure remote access to the BAS shall not require ANY inbound ports on a firewall to be "exposed" or "forwarded".

2. Secure remote access to the BAS shall be available anywhere, anytime, using a compatible client device (PC/tablet/phone)

3. The Owner will provide up to Three (3) IP drops and IP addresses on the owners network to gain access to the internet. The BAS manufacture shall coordinate with the Owners IT team, verify the proposed system shall meet all network security requirements and any other network configuration information necessary to each control contractor for the purpose of configuring each Area Controller on the network. It shall be the responsibility of the BAS manufacture to coordinate with the owner for network connectivity.

D. The BAS Manufacture shall provide a professional analysis for the facility HVAC systems.

1. The analysis shall consist of an evaluation of HVAC systems including charts and graphs which indicate both current building performance and opportunities for building and HVAC system performance improvement.

E. The following shall be provided after substantial completion of the project:

1. Orientation meeting with the building owner's representative to identify the HVAC systems that will be evaluated.

2. System setup for data collection and analytics. BAS Manufacture to setup a secure remote data collection and analytics for identified systems.

3. Assessment analysis shall be performed by trained personnel with relevant professional credentials in HVAC systems, energy management and building optimization methodologies.

4. Consultation meeting with owner to review performance reports and improvement opportunities.

F. Do not assign or transfer maintenance service to agent or subcontractor without prior written consent of owner.

1.7 OWNERSHIP OF PROPRIETARY MATERIAL

A. Project specific software and documentation shall become the owner's property upon project completion. This includes the following:

1. Operator Graphic files

2. As-built hardware design drawings

3. Operating & Maintenance Manuals

4. BAS System software database

1.8 DEFINITIONS

A. DDC: Direct digital control

B. I/O: Input/output.

C. MS/TP: Manager Subordinate / Token Passing.

D. POT: Portable Operator's Terminal.

E. PID: Proportional plus integral plus derivative.

F. RTD: Resistance temperature detector.

G. BAS/ATC: Building Automation System/Automatic Temperature Controls.

PART 2 PRODUCTS

2.0 MATERIALS:

A. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Do not use this installation as a product test site unless explicitly approved in writing by the owner or the owner's representative. Spare parts shall be available for at least five years after completion of this contract.

B. All hardware and software shall be compatible with Niagara Information and Conformance Statement (NICS).

2.1 SYSTEM COMMUNICATION

A. System Communications

1. The Niagara Information and Conformance Statement (NICS) for all Niagara Software shall allow open access and be set as follows: accept.station.in="*" accept.station.out="*" accept.wb.out="*" accept.wb.in="*". In any case, the end user shall maintain the right to instruct the contractor to modify any software license, regardless of supplier, as desired by the end user. The contractor shall not install any "brand-specific" software, applications or utilities on Niagara Framework-based devices unless accessible by any brand of Niagara tools.

2. All hardware and field-level devices installed shall not be limited in their ability to communicate with a specific brand of Niagara Framework JACE. They shall also be constructed in a modular fashion to permit the next generation and support components to be installed, in replacement of or in parallel with existing components. All controllers must be able to be programmed within the Niagara Workbench.

3. At the completion of the project, the owner shall be given all existing platform and station login credentials to include super user (admin) usernames; passwords and passphrases.

4. Each workstation, building controller, and equipment controller communication interface shall utilize the BACnet™ protocol with an Ethernet (IEEE 802.3), Wi-Fi (IEEE 802.11), RS485 (EIA-485), or Zigbee® (802.15.4) physical interface and an appropriate data link technology as defined in ANSI®/ASHRAE® Standard 135-2012. (e.g. BACnet over IP, BACnet over IPv6, BACnet SC, BACnet over MS/TP, BACnet Zigbee).

5. All system controllers shall be BTL listed as a BACnet Building Controller (B-BC) as defined in ANSI®/ASHRAE® Standard 135-2012.

6. All documented status and control points, schedule, alarm, and data-log services or objects shall be available as standard object types as defined in ANSI®/ASHRAE® Standard 135-2012.

7. Each System Controller shall communicate with a network of Custom Application and Application Specific Controllers utilizing one or more of the interfaces documented within Field Bus Communications below.

8. All Operator Workstations (B-OWS, B-AWS) and Building Controllers (B-BC) shall support BACnet Secure Connect (BACnet SC), a secure and encrypted datalink layer specifically designed for those networks.

B. Field Bus Communications

1. BACnet™

a. All equipment and plant controllers shall be BTL listed as a BACnet Application Specific Controller (B-ASC) or a BACnet Advanced Application Controller (B-AAC) as defined in ANSI®/ASHRAE® Standard 135-2012.

b. All communication shall conform to ANSI®/ASHRAE® Standard 135-2012.

c. System Controller shall function as a BACnet router to each unit controller providing a globally unique BACnet Device ID for all BACnet controllers within the system.

d. BACnet MS/TP

1) Communication between System Controller and equipment/plant controllers shall utilize BACnet MS/TP as defined in ANSI®/ASHRAE® Standard 135-2012.

2.2 OPERATOR INTERFACE

A. Provide Building Operator Web Interface

1. Manufacturer shall provide a user interface with time-of-day schedules, data collection, dashboards, reports and building summary, system applications, and self-expiring timed overrides. Manufacturer shall provide a published user and applications

guide(s) that detail the system application operation, configuration, setup and troubleshooting.

2. The building operator web interface shall be accessible via a web browser without requiring any "plug-ins" (i.e. JAVA Runtime Environment (JRE), Adobe Flash).

3. User Roles

a. The system shall include pre-defined "roles" that allow a system administrator to quickly assign permissions to a user.

b. User logon/logoff attempts shall be recorded.

c. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user definable.

4. On-Line Help and Training

a. Provide a context sensitive, online help system to assist the operator in operation and configuration of the system.

b. Online help shall be available for all system functions and shall provide the relevant data for each particular screen.

5. Equipment and Application Pages

a. The building operator web interface shall include standard pages for all equipment and applications. These pages shall allow an operator to obtain information relevant to the operation of the equipment and/or application, including:

1) Animated Equipment Graphics for each major piece of equipment and floor plan in the System. This includes:

a) Each rooftop unit, VAV Terminal, and kitchen makeup and exhaust system.. These graphics shall show all points dynamically as specified in the points list.

b) Animation capabilities shall include the ability to show a sequence of images reflecting the position of analog outputs, such as valve or damper positions. Graphics shall be capable of launching other web pages.

2) Alarms relevant to the equipment or application without requiring a user to navigate to an alarm page and perform a filter.

3) Historical Data (As defined in Trend Logs section of CONTROLLER SOFTWARE) for the equipment or application without requiring a user to navigate to a Data Log page and perform a filter.

b. Single-zone and Multi-zone VAV Air System. An operator shall be able to view and control (where applicable) the following parameters via the building operator web interface:

1) System Mode

2) System Occupancy

3) Ventilation (Outdoor air flow) setpoint

4) Ventilation (Outdoor air flow) status

5) Rooftop Unit Static pressure setpoint

6) Rooftop Unit Static pressure status

7) Rooftop Unit occupancy status

8) Rooftop Unit Supply air cooling and heating set points

9) Rooftop Unit minimum, maximum and nominal static pressure setpoints

10) VAV box minimum and maximum flow (Multi-zone only)

11) VAV box drive open and close overrides (Multi-zone only)

12) VAV box occupancy status (Multi-zone only)

13) VAV box Airflow to space (Multi-zone only)

14) Average space temperature

15) Minimum space temperature

16) Maximum space temperature

6. System Graphics. Building operator web interface shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each Rooftop Unit, and graphics that summarize conditions on each area included in this contract. Indicate thermal comfort on floor plan summary graphics using colors to represent zone temperature relative to zone set point.

a. Graphic imagery – graphics shall use 3D images for all standard and custom graphics. The only allowable exceptions will be photo images, maps, schematic drawings, and selected floor plans.

b. Animation. Graphics shall be able to animate by displaying different Image lies for changed object status.

c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.

7. Graphics Library. Furnish a library of standard HVAC equipment such as air handlers, terminals, fan coils, rooftop units, and VAV boxes, in 3-dimensional graphic depictions. The library shall be furnished in a file format compatible with the graphics generation package program.

8. Manual Control and Override

a. Point Control. Provide a method for a user to view, override, and edit if applicable, the status of any object and property in the system. The point status shall be available by menu, on graphics or through custom programs.

b. Temporary Overrides. The user shall be able to perform a temporary override wherever an override is allowed, automatically removing the override after a specified period of time.

c. Override Owners. The system shall convey to the user the owner of each override for all priorities that an override exists.

d. Provide a specific icon to show timed override or operator override, when a point, unit controller or application has been overridden manually.

9. Scheduling. - The scheduling application shall provide graphical representation of the day, week, month and exception events.

10. Alarm/Event Notification

a. Alarm/Event Log. The operator shall be able to view all logged system alarms/events from any building operator web interface.

1) The operator shall be able to sort and filter alarms from events. Alarms shall be sorted in a minimum of 4 categories based on severity.

2) The operator shall be able to acknowledge and add comments to alarms

3) Alarm/event messages shall use full language, easily recognized descriptors.

b. Alarm Suppression. Alarms shall be able to be suppressed based on load/source relationships to present the likely root cause to the building operator as described in ASHRAE Guideline 36. Load/Source relationships shall be configurable by the user through a web interface.

11. Reports and Logs.

a. The building operator web interface shall provide a reporting package that allows the operator to select reports.

b. The building operator web interface shall provide the ability to schedule reports to run at specified intervals of time.

c. The following standard reports shall be available without requiring a user to manually configure the report:

1) All Points in Alarm Report: Provide an on demand report showing all current alarms.

2) All Points in Override Report: Provide an on demand report showing all overrides in effect.

3) Commissioning Report: Provide a one-time report that lists all equipment with the unit configuration and present operation.

4) Points report: Provide a report that lists the current value of all points

d. The controls vendor shall provide a hardening report that summarizes the port configuration details to ensure sites have not been exposed to the Internet in alignment with Cyber Security best practices.

B. Provide Mobile App Interface

1. Provide mobile (smart phone or tablet) interfaces to the building automation system, compatible with iOS and Android™ operating systems.

2. Controls manufacturer shall provide a phone/tablet interface with the ability to view/override status and setpoints, view/change schedules, view/acknowledge/comment on alarms, and view graphics for all spaces and equipment.

3. This phone/tablet interface shall resize itself appropriately for the size of the interface (i.e. no "pinching and zooming" required).

4. This phone/tablet interface shall function remotely from the facility while following IT security best practices (e.g. no ports exposed to the internet).

5. The operator interface shall support system access on a mobile device via a mobile app to:

a. Alarm log

b. System Status

c. Equipment status

d. Space Status

e. Standard Equipment graphics

f. Override set points

g. Override occupancy

h. Acknowledge Alarms

i. Add Comment(s) to Alarms

2.3 BUILDING CONTROLLER SOFTWARE

A. Manufacturer shall provide standard applications to deliver HVAC system control. Standard applications include Time of Day Scheduling with Optimal Start/Stop, VAV Air Systems Control, Historical Trend Logs and Trim and Respond. Manufacturer shall provide system optimization strategies for functions such as fan pressure optimization and ventilation optimization.

B. Furnish the following applications software for building and energy management. All software applications shall reside and run in the system controllers. Editing of applications shall occur at the building operator interface.

1. VAV Air Systems Applications

a. The BAS shall provide air system applications that coordinate air handlers (AHU)/rooftop units (RTU) and Variable Air Volume Terminal equipment.

b. The air system applications shall perform the following functions:

1) Startup and shutdown the air handler safely. Ensure the VAV boxes are open sufficiently when the air handler is running, to prevent damage to the ductwork and VAV boxes due to high air pressure.

2) Fan Pressure Optimization (ASHRAE 90.1, Guideline 36) - Minimize energy usage by controlling system static pressure to the lowest level while maintaining zone airflow requirements. Trim and respond reset logic shall reset setpoint within the range of min and max values based on zone requests.

3) During commissioning, and with the engineer/owner, the controls contractor shall confirm the performance of Fan Pressure Optimization by conducting a field functional test that demonstrates critical zone reset.

4) Ventilation Optimization (ASHRAE 62) – properly ventilate all spaces while minimizing operating energy costs, using measured outdoor air flow. Dynamically calculate the system outdoor air requirement based on “real time” conditions in the spaces (i.e., number of occupants, CO2 levels, etc.) minimizing the amount of unconditioned outdoor air that must be brought into the building.

5) Demand Controlled Ventilation – the active ventilation setpoint shall modulate between the occupied ventilation and occupied standby ventilation setpoint; Resetting the setpoint based on CO2 levels in the space.

6) Discharge Air Temperature Reset (ASHRAE 90.1, Guideline 36) - Minimize energy usage by controlling discharge air temperature in response to building loads and outdoor air temperature. Trim and respond reset logic shall reset setpoint within the range of min and max values based on zone requests.

c. The Air Systems application shall provide a user interface that includes status of current system operation with real time data of key operating parameters. Key operating parameters for Guideline 36 include:

1) Duct Static Pressure

2) Duct Static Optimization Setpoint

3) Outdoor Airflow

4) Ventilation Optimization Setpoint

5) Duct Static Optimization Maximum VAV Damper/Source VAV Box

6) Ventilation Optimization Maximum VAV Vent Ratio/Source VAV box

7) Discharge Air Temperature

8) Discharge Air Temperature Optimization Setpoint

9) Duct Static Optimization System Requests

10) Discharge Air Temperature Optimization System Requests

d. The air system application status screens shall explain what optimization calculations are occurring, critical parameters, and source equipment members. The optimization status, inputs, and results shall be displayed for VAV Ventilation Optimization (calculating proper outside air intake), VAV Discharge Air Temperature Optimization (calculating proper discharge air temperature) and VAV Duct Static Pressure Optimization (calculating proper fan static pressure).

e. The air systems applications shall provide a user interface that enables configuration changes made by swipe and type fields, selection list, and check box entry for feature definition:

1) VAV Auxiliary Night Heat

2) VAV Source Temperature Distribution

3) Changeover System control

4) Start/Stop Delay operation

5) Enable/Disable Optimization Strategies (Duct Static Optimization, Discharge Air Temperature Optimization and Ventilation Optimization)

f. The operation of VAV Terminal equipment members of the VAV Air System shall be selected by check box to optionally participate in the following functions when for Guideline 36 applications:

1) System calculations (min, max, average)

2) Duct Pressure Optimization

3) Ventilation Optimization

4) Drive to Maximum Override

5) Common Source Temperature

6) Common Space

7) Discharge Air Temperature Optimization

g. The air system application vendor shall provide a published applications guide that details the air system application operation, configuration, setup, and troubleshooting. The applications guide documentation shall be maintained under version control and updated by the manufacture to reflect most recent feature updates as made available. Contents of the guide shall include:

1) Description of System Operation

2) Required Components

3) Sequences of Operation

4) Installation

5) Controller Setup

6) Required Programming

7) Commissioning

8) Optimization Strategies

9) Special Applications

10) Troubleshooting

h. The air system application shall present in plain user language the current operation with source zone information and reset events.

2. Trend Logs

a. The system shall harvest trend logs for defined key measurements for each controlled HVAC device and HVAC application. Trend logs shall be captured for a minimum of 5 key operating points for each piece of HVAC equipment and HVAC application and stored for no less than 1 year at 15-minute intervals. Data Logs shall be capable of being configured on an interval or change of value basis.

1) Air Handling Unit/Rooftop (VAV)

a) Discharge Air Temperature

b) Discharge Air Temperature Setpoint Active

c) Space Temperature Active

d) Cooling Capacity Status

e) Discharge Air Flow

2) VAV Box

a) Discharge Air Temperature

b) Space Temperature Active

c) Space Temperature Setpoint Active

d) Air Flow Setpoint Active

e) Discharge Air Flow

3. Trim and Respond

a. The BAS shall provide a setpoint reset application program based on ‘trim and respond’ functionality as outlined in ASHRAE Guideline 36.

2.4 BUILDING / SYSTEM CONTROLLERS

A. There shall be one or more independent, standalone microprocessor-based System Controllers to manage the global strategies described in CONTROLLER SOFTWARE section.

1. The controller shall provide a USB communications port for connection to a PC.

2. The operating system of the Controller shall manage the input and output communications signals to allow distributed controllers to share real and virtual point information and allow central monitoring and alarms.

3. All System Controllers shall have a real time clock and shall be able to accept a BACnet time synchronization command for automatic time synchronization.

4. Data shall be shared between networked System Controllers.

5. Serviceability – The System Controller shall have a display on the main board that indicates the current operating mode of the controller.

B. Controls manufacturer shall provide secure remote access to the Building Automation System (BAS). Secure remote access shall not require IP ports to be "exposed" (i.e. port-forwarded or external public IP addresses) to the Internet. Controls manufacturer shall update secure remote access software as necessary to follow cyber security best practices and respond to cyber security events.

2.5 ADVANCED APPLICATION CONTROLLERS

A. The Application Controller shall be a microprocessor-based DDC controller which, through hardware or firmware design, controls specified equipment. The controller is not user programmable, but is customized for operation within the confines of the equipment it is designed to serve.

B. The Application Controller shall be capable of operating as a stand-alone controller or as a member of a Building Automation System (BAS).

C. When the Application Controller is operating as a member of a Building Automation System (BAS), the application controller shall operate as follows:

1. Application Controller will receive operation mode commands from the BAS network controller. The BAS commands shall include but not be limited to the follow: Occupied Heat/Cool, Unoccupied Heat/Cool, Morning Warm-up, / Pre-cool, Occupied Bypass).

2. Application Controller will provide equipment status parameters to the BAS through BACnet communication.

3. Application Controller will operate as a stand-alone controller in the event of communication failure with the BAS.

4. In case of communications failure stand-alone operation shall use default values or last known values for remote sensors read over the network such as outdoor air temperature.

D. Software

1. To meet the sequence of operation for each zone control, the controller shall use programs developed and tested by the controller manufacturer that are either factory loaded or customized with use of service tool native to the controller.

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

1. Storage: -55° to 203° F (-48° to 95° C) and 5 to 95% Rh, non-condensing.

2. Operating: -40° to 158° F (-40 to 70° C) and 5 to 95% Rh, non-condensing.

3. Controllers used indoors shall be mounted in a NEMA 1 enclosure at a minimum.

4. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40° to 158° F [-40° to 70° C].

F. Controller Input/Output: The controller shall have on board capable of performing all functionality needed for the application. Controls provided by the equipment manufacture must supply the required I/O for the equipment.

1. For flexibility in selection and replacement of valves, the controllers shall be capable of supporting all of the following output types; 0-10VDC, 0-5VDC, 4-20mA, Binary.

2. For flexibility in selection and replacement of sensors, the controllers shall be capable of reading sensor input ranges of 0 to10V, 0 to 20mA, Pulse counts, and 200 to 20K ohm.

G. Serviceability – The controller shall provide the following in order to improve serviceability of the controller.

1. Diagnostic LEDs shall indicate correct operation or failures/faults for all of the following: power, sensors, BACnet communications, and I/O communications bus.

2. All binary output shall have LED’s indicating the output state.

3. All wiring connectors shall removable without the use of a tool.

4. Software service tool connection through the following methods: direct cable connection to the controller, connection through another controller on BACnet link.

H. Software Retention: All Zone Controller operating parameters, setpoints, BIOS, and sequence of operation code must be stored in non-volatile memory in order to maintain such information for months without power.

I. Controller shall meet the following Agency Compliance:

1. UL916 PAZX, Open Energy Management Equipment

2. UL94-5V, Flammability

3. FCC Part 15, Subpart B, Class B Limit

4. BACnet Testing Laboratory (BTL) listed

2.6 APPLICATION SPECIFIC CONTROLLERS:

A. General Description

1. Application Specific Controllers (ASC) shall be microprocessor-based DDC controllers which, through hardware or firmware design, control specified equipment. They are not user programmable, but are customized for operation within the confines of the equipment they are designed to serve.

2. Zone Controllers are controllers that operate equipment that control the space temperature of single zone. Examples are controllers for VAV and Fan coil.

B. The Application Specific Controller shall be capable of operating as a stand-alone controller or as a member of a Building Automation System (BAS).

C. When the Application Specific Controller is operating as a member of a Building Automation System (BAS), the application controller shall operate as follows:

1. Application Controller will receive operation mode commands from the BAS network controller. The BAS commands shall include but not be limited to the follow: Occupied Heat/Cool, Unoccupied Heat/Cool, Morning Warm-up, / Pre-cool, Occupied Bypass).

2. Application Controller will provide equipment status parameters to the BAS through BACnet communication.

3. Application Controller will operate as a stand-alone controller in the event of communication failure with the BAS.

4. In case of communications failure stand-alone operation shall use default values or last known values for remote sensors read over the network such as outdoor air temperature.

D. Stand-Alone Operation: Each piece of equipment specified in section “A” shall be controlled by a single controller and provide stand-alone control in the event that a BAS is not present.

E. Software

1. To meet the sequence of operation for each zone control, the controller shall use programs developed and tested by the controller manufacturer that are either factory loaded or downloaded with service tool to the controller.

2. For controlling ancillary devices and for flexibility to change the sequence of operation in the future, the controller shall be capable running custom programs written in a graphical programming language.

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

1. Storage: -55° to 203° F (-48° to 95° C) and 5 to 95% Rh, non-condensing.

2. Operating: -40° to 158° F (-40 to 70° C) and 5 to 95% Rh, non-condensing.

3. Controllers used indoors shall be mounted in a NEMA 1 enclosure at a minimum.

4. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40° to 158° F [-40° to 70° C].

G. Input/Output:

1. For flexibility in selection and replacement of valves, the controllers shall be capable of supporting all of the following valve control types 0-10VDC, 0-5VDC, 4-20mA, 24VAC floating point, 24VAC - 2 position (Normally Open or Normally Closed).

2. For flexibility in selection and replacement of sensors, the controllers shall be capable of reading sensor input ranges of 0 to10V, 0 to 20mA, pulse counts, and 200 to 20Kohm.

3. For flexibility in selection and replacement of binary devices, the controller shall support dry and wetted (24VAC) binary inputs.

4. For flexibility in selection and replacement devices, the controller's shall have binary output which are able to drive at least 12VA each.

5. For flexibility in selection and replacement of motors, the controller shall be capable of outputting 24VAC (binary output), DC voltage (0 to 10VDC minimum range) and PWM (in the 80 to 100 Hz range).

6. For future needs, any I/O that is unused by functionality of equipment control shall be available to be used by custom program on the controller and by another controller on the network.

7. For future expansion and flexibility, the controller shall have either on board or through expansion, 20 hardware input/output points. Expansion points must communicate with the controller via an internal communications bus. Expansion points must be capable of being mounted up to 650ft. (200 m) from the controller. Expansion points that require the BACnet network for communication with the controller are not allowed.

H. Serviceability – The controller shall provide the following in order to improve serviceability of the controller.

1. Diagnostic LEDs shall indicate correct operation or failures/faults for all of the following: power, sensors, BACnet communications, and I/O communications bus.

2. All binary output shall have LED's indicating the output state.

3. All wiring connectors shall removable without the use of a tool.

4. Software service tool connection through all of the following methods: direct cable connection to the controller, connection through another controller on BACnet link

5. For safety purposes, the controller shall be capable of being powered by a portable computer for the purposes of configuration, programming, and testing programs so that this work can be accomplished with the power off to the equipment.

6. Capabilities to temporarily override of BACnet point values with built-in time expiration in the controller.

7. BACnet MAC Address shall be set using decimal (0-9) based rotary switches.

a. Configuration change shall not be made in a programming environment, but rather by a configuration page utilizing dropdown list, check boxes, and numeric boxes.

8. For ease of troubleshooting, the Controller shall support BACnet data trend logging.

a. With a minimum of 20,000 trending points total on controller

b. Trends shall be capable of being collected at a minimum sample rate of once every second.

c. Shall be capable of trending all BACnet points used by controller

d. Trends shall be capable of being scheduled or triggered

I. Software Retention: All Zone Controller operating parameters, setpoints, BIOS, and sequence of operation code must be stored in non-volatile memory in order to maintain such information for months without power.

J. Application controller shall meet the following Agency Compliance:

1. UL916 PAZX, Open Energy Management Equipment

2. UL94-5V, Flammability

3. FCC Part 15, Subpart B, Class B Limit

4. BACnet Testing Laboratory (BTL) listed as BACnet Application Specific Controller (B-ASC)

2.7 APPLICATION CONTROLLER FOR PACKAGED ROOFTOP UNITS

A. The Rooftop Unit (RTU) Application Controller shall be a microprocessor-based DDC controller which, through hardware or firmware design, controls specified equipment. The controller is not user programmable, but is customized for operation within the confines of the equipment it is designed to serve.

B. The Application Controller shall be capable of operating as a stand-alone controller or as a member of a Building Automation System (BAS).

C. When the Application Controller is operating as a member of a Building Automation System (BAS), the application controller shall operate as follows:

1. Application Controller will receive operation mode commands from the BAS network controller. The BAS commands shall include but not be limited to the follow: Occupied Heat/Cool, Unoccupied Heat/Cool, Morning Warm-up, / Pre-cool, Occupied Bypass).

2. Application Controller will provide equipment status parameters to the BAS through BACnet communication.

3. Application Controller will operate as a stand-alone controller in the event of communication failure with the BAS.

4. In case of communications failure stand-alone operation shall use default values or last known values for remote sensors read over the network such as outdoor air temperature.

D. Software

1. To meet the sequence of operation for each zone control, the controller shall use programs developed and tested by the controller manufacturer that are either factory loaded or customized with use of service tool native to the controller.

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

1. Storage: -55° to 203° F (-48° to 95° C) and 5 to 95% Rh, non-condensing.

2. Operating: -40° to 158° F (-40 to 70° C) and 5 to 95% Rh, non-condensing.

3. Controllers used indoors shall be mounted in a NEMA 1 enclosure at a minimum.

4. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40° to 158° F [-40° to 70° C].

F. Controller Input/Output: The controller shall have on board capable of performing all functionality needed for the application. Controls provided by the equipment manufacture must supply the required I/O for the equipment.

1. For flexibility in selection and replacement of valves, the controllers shall be capable of supporting all of the following output types; 0-10VDC, 0-5VDC, 4-20mA, Binary.

2. For flexibility in selection and replacement of sensors, the controllers shall be capable of reading sensor input ranges of 0 to10V, 0 to 20mA, Pulse counts, and 200 to 20Kohm.

G. Serviceability – The controller shall provide the following in order to improve serviceability of the controller.

1. Diagnostic LEDs shall indicate correct operation or failures/faults for all of the following: power, sensors, BACnet communications, and I/O communications bus.

2. All binary output shall have LED’s indicating the output state.

3. All wiring connectors shall removable without the use of a tool.

4. Software service tool connection through the following methods: direct cable connection to the controller, connection through another controller on BACnet link.

H. Software Retention: All Zone Controller operating parameters, setpoints, BIOS, and sequence of operation code must be stored in non-volatile memory in order to maintain such information for months without power.

I. Controller shall meet the following Agency Compliance:

1. UL916 PAZX, Open Energy Management Equipment

2. UL94-5V, Flammability

3. FCC Part 15, Subpart B, Class B Limit

4. BACnet Testing Laboratory (BTL) listed

2.8 VARIABLE AIR VOLUME TERMINAL UNIT CONTROLLERS

A. General Description

1. Variable Air Volume (VAV) controllers shall be microprocessor-based DDC controllers which, through hardware or firmware design, control specified equipment. They are typically not user programmable, but are configurable for operation of VAV terminal units.

2. Variable Air Volume (VAV) controllers are controllers that operate equipment that control the space temperature of single zone.

B. The VAV controller shall be capable of operating as a stand-alone controller or as a member of a Building Automation System (BAS).

C. When the VAV controller is operating as a member of a Building Automation System (BAS), the application controller shall operate as follows:

1. The VAV controller will receive operation mode commands from the BAS network controller. The BAS commands shall include but not be limited to the following: Occupied Heat/Cool, Unoccupied Heat/Cool, Morning Warm-up, / Pre-cool, Occupied Bypass).

2. The VAV controller will provide equipment status parameters to the BAS through BACnet communication.

3. The VAV controller will operate as a stand-alone controller in the event of communication failure with the BAS.

4. In case of communications failure stand-alone operation shall use default values or last known values for remote sensors read over the network such as outdoor air temperature.

D. Stand-Alone Operation: Each VAV Terminal Unit shall be controlled by a single controller and provide stand-alone control in the event that a BAS is not present.

E. The VAV controller shall communicate to the building automation system via BACnet™ MS/TP as defined in ANSI®/ASHRAE® Standard 135-2020.

1. BACnet™ MS/TP

a. To allow maximum communications speed and co-existence with other controllers, the controller shall support at a minimum the following BACnet MS/TP manager baud rates: 9600, 19200, 38400, 76800.

F. Each VAV terminal unit shall use a space zone sensor(s) to measure the space condition it is serving.

1. Each zone sensor communication interface shall be capable of many-to-one sensors per controller to support averaging, monitoring, and multiple zone applications.

2. Zone sensors shall have display, setpoint adjustment, override button, CO2 sensor and POT jack. Sensor shall have the capability to be programmed for sensing and local control, and sensing and local override range of +/- 2 degrees F.

G. Software

1. To meet the sequence of operation for each zone control, the controller shall use programs developed and tested by the controller manufacturer that are either factory loaded or downloaded with service tool to the controller.

2. For controlling ancillary devices and for flexibility to change the sequence of operation in the future, the controller shall be capable running custom programs written in a graphical programming language.

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

1. Storage: -55° to 203° F (-48° to 95° C) and 5 to 95% Rh, non-condensing.

2. Operating: -40° to 158° F (-40 to 70° C) and 5 to 95% Rh, non-condensing.

3. Controllers used indoors shall be mounted in a NEMA 1 enclosure at a minimum.

4. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40° to 158° F [-40° to 70° C].

I. Input/Output:

1. For flexibility in selection and replacement of valves, the controllers shall be capable of supporting all of the following valve control types 0-10VDC, 0-5VDC, 4-20mA, 24VAC floating point, 24VAC - 2 position (Normally Open or Normally Closed).

2. For flexibility in selection and replacement of sensors, the controllers shall be capable of reading sensor input ranges of 0 to10V, 0 to 20mA, and 200 to 20Kohm.

3. For flexibility in selection and replacement of binary devices, the controller shall support dry and wetted (24VAC) binary inputs.

4. For flexibility in selection and replacement devices, the controller shall have binary output which are able to drive at least 12VA each.

5. For flexibility in selection and replacement of motors, the controller shall be capable of outputting 24VAC (binary output), DC voltage (0 to 10VDC minimum range) and PWM (in the 80 to 100 Hz range).

J. Serviceability – The controller shall provide the following in order to improve serviceability of the controller.

1. Diagnostic LEDs shall indicate correct operation or failures/faults for all of the following: power, sensors, BACnet communications, and I/O communications bus.

2. All binary output shall have LED’s indicating the output state.

3. All wiring connectors shall removable without the use of a tool.

4. Software service tool connection through all of the following methods: direct cable connection to the controller, connection through another controller on BACnet link and through the controller's zone sensor.

5. For safety purposes, the controller shall be capable of being powered by a portable computer for the purposes of configuration, programming, and testing programs so that this work can be accomplished with the power off to the equipment.

6. Capabilities to temporarily override of BACnet point values with built-in time expiration in the controller.

7. BACnet MAC Address shall be set using decimal (0-9) based rotary switches.

a. Configuration change shall not be made in a programming environment, but rather by a configuration page utilizing dropdown list, check boxes, and numeric boxes.

8. For ease of troubleshooting, the Controller shall support BACnet data trend logging.

a. Trends shall be capable of being collected at a minimum sample rate of once every second.

b. Shall be capable of trending all BACnet points used by controller

c. Trends shall be capable of being scheduled or triggered

K. Software Retention: All Zone Controller operating parameters, setpoints, BIOS, and sequence of operation code must be stored in non-volatile memory in order to maintain such information for months without power.

L. Controller shall meet the following Agency Compliance:

1. UL916 PAZX, Open Energy Management Equipment

2. UL94-5V, Flammability

3. FCC Part 15, Subpart B, Class B Limit

4. AS/NZS CISPR 32:2016

5. VCCI-CSPR 32:2016

6. CAN ICES-003(B)/NMB-003(B)

7. To ensure integration to the building automation system the controller must be BTL (BACnet Testing Lab) listed. The following BACnet profiles are in order of most functionality (B-BC) to least functionality (B-ASC).

a. BACnet Building Controller (B-BC)

b. BACnet Advance Applications Controller (B-AAC)

c. BACnet Application Specific Controller (B-ASC)

2.9 INPUT/OUTPUT INTERFACE:

A. Hardwired inputs and outputs may tie into the system through building, custom application, or ASCs.

B. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24V of any duration, such that contact with this voltage will cause no damage to the controller.

C. Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense “dry contact” closure without external power (other than that provided by the controller) being applied.

D. Pulse accumulation input objects. This type of object shall conform to all the requirements of binary input objects and also accept up to 10 pulses per second for pulse accumulation.

E. Analog inputs shall allow the monitoring of low voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary outputs shall provide for on/off operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on building and custom application controllers shall have status lights. Outputs shall be selectable for either normally open or normally closed operation.

G. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10VDC or a 4 to 20 mA signal as required to provide proper control of the output device. Analog outputs shall not exhibit a drift of greater than 0.4% of range per year.

H. Tri-State Outputs. Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal unit control applications (VAV terminal units, duct-mounted heating coils, zone dampers, radiation, etc.). Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

I. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.

2.10 POWER SUPPLIES:

A. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish overcurrent protection in both primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in overvoltage and overcurrent protection and shall be able to withstand a 150% current overload for at least three seconds without trip-out or failure.

a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MIL-STD 810C for shock and vibration.

b. Line voltage units shall be UL recognized and CSA approved.

2.11 AUXILLARY CONTROL DEVICES:

A. Motorized dampers, unless otherwise specified elsewhere, shall be as follows:

1. Damper frames shall be 16 gauge galvanized sheet metal or 1/8" extruded aluminum with reinforced corner bracing.

2. Damper blades shall not exceed 8" in width or 48" in length. Blades are to be suitable for medium velocity performance (2,000 fpm). Blades shall be not less than 16 gauge.

3. Damper shaft bearings shall be as recommended by manufacturer for application.

4. All blade edges and top and bottom of the frame shall be provided with compressible seals. Side seals shall be compressible stainless steel. The blade seals shall provide for a maximum leakage rate of 10 CFM per square foot at 2.5" w.c. differential pressure.

5. All leakage testing and pressure ratings will be based on AMCA Publication 500.

6. Individual damper sections shall not be larger than 48" x 60". Provide a minimum of one damper actuator per section.

B. Control dampers shall be parallel or opposed blade types as scheduled on drawings.

C. Electric damper actuators

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

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

3. All rotary spring return actuators shall be capable of both clockwise or counter clockwise spring return operation. Linear actuators shall spring return to the retracted position.

4. Proportional actuators shall accept a 0-10 VDC or 0-20 ma control signal and provide a 2-10 VDC or 4-20 ma operating range.

5. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return

actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.

6. Actuators shall be provided with a conduit fitting and a minimum 1m electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.

7. Actuators shall be Underwriters Laboratories Standard 873 listed.

8. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque.

D. Binary Temperature Devices

1. Low-voltage space thermostat shall be 24 V, bimetal-operated, mercury-switch type, with either adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C to 30°C (55°F to 85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

2. Line-voltage space thermostat shall be bimetal-actuated, open contact type, or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listed for electrical rating, concealed setpoint adjustment, 13°C to 30°C (55°F to 85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

3. Low-limit thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type, with an element of 6 m (20 ft) minimum length. Element shall respond to the lowest temperature sensed by any 30 cm (1 ft) section. The low-limit thermostat shall be manual reset only.

E. Wired Temperature Sensors

1. Temperature sensors shall be RTD or thermistor.

2. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m2 (10 ft2) of duct cross section.

3. Immersion sensors shall be provided with a separable stainless steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed. The well must withstand the flow velocities in the pipe.

4. Space sensors shall be equipped with setpoint adjustment, override switch, display, and/or communication port as shown on plans.

5. Provide matched temperature sensors for differential temperature measurement.

F. Wired Humidity Sensors

1. Duct and room sensors shall have a sensing range of 20% to 80%.

2. Duct sensors shall be provided with a sampling chamber.

G. Static Pressure Sensors

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

2. Sensor sensing elements shall withstand continuous operating conditions plus or minus 50% greater than calibrated span without damage.

H. Low Limit Thermostats

1. Safety low limit thermostats shall be vapor pressure type with an element 6m [20 ft] minimum length. Element shall respond to the lowest temperature sensed by any one foot section.

2. Low limit shall be manual reset only.

2.12 WIRING AND RACEWAYS:

A. General: Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of this specification.

B. All insulated wire to be copper conductors, UL labeled for 90°C (194°F) minimum service.

C. Fiber Optic Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. The sheath shall be UL Listed OFNP in accordance with NEC Article 770. The optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125 μm.

PART 3 EXECUTION

3.0 EXAMINATION:

A. The Contract Documents shall be thoroughly examined for coordination of control devices, their installation, wiring, and commissioning. Coordinate and review mechanical equipment specifications, locations, and identify any discrepancies, conflicts, or omissions that shall be reported to the Architect/Engineer for resolution before rough-in work is started.

B. The BAS manufacturer shall inspect the jobsite in order to verify that control equipment can be installed as required, and any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.

3.1 PROTECTION:

A. The BAS installation contractor shall protect all work and material from damage by their work or personnel, and shall be liable for all damage thus caused.

B. The BAS manufacturer shall be responsible for their work and equipment until final inspection, testing, and acceptance. The BAS installing contractor shall protect their work against theft or damage, and shall carefully store material and equipment received on site that is not immediately installed. The Contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.2 COORDINATION:

A. Site

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

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

B. Submittals. Refer to the "Submittals," section of this specification for requirements.

C. Test and Balance

1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.

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

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

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

D. Life Safety

1. Duct smoke detectors required for rooftop unit shutdown shall be supplied by the electrical contractor. The contractor shall interlock smoke detectors to rooftop units for shutdown as described in the Sequences of Operation for this project.

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

1. All communication media and equipment shall be provided as specified in the "Communication" section of this specification.

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

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

3.3 GENERAL WORKMANSHIP:

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

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

C. Install all equipment in readily accessible locations as defined by National Electric Code (NEC). Control panels shall be attached to structural walls or properly supported in a free-standing configuration, unless mounted in equipment enclosure specifically designed for that purpose. Panels shall be mounted to allow for unobstructed access for service.

D. Verify integrity of all control wiring to ensure continuity and freedom from shorts and grounds prior to commencing the startup and commissioning procedures.

E. All control device installation and wiring shall comply with Contract Documents, acceptable industry specifications, and industry standards for performance, reliability, and compatibility. Installation and wiring shall be executed in strict adherence to local codes and standard practices referenced in Contract Documents.

3.4 FIELD QUALITY CONTROL:

A. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Contract Documents.

B. BAS manufacturer shall continually monitor the field installation for building code compliance and quality of workmanship. All visible piping and or wiring runs shall be installed parallel to building lines and properly supported.

C. BAS installing Contractor(s) shall arrange for field inspections by local and/or state authorities having jurisdiction over the work.

3.5 COMMUNICATION WIRING:

A. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer’s installation recommendations for all communication cabling.

B. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.

C. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer shall not be exceeded during installation.

D. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.

E. When a cable enters or exits a building, a lighting arrestor must be installed between the line and ground.

F. All runs of communication wiring shall be unspliced length when the length is commercially available.

G. All communication wiring shall be labeled to indicate origin and destination.

3.6 FIBER OPTIC CABLE:

A. All cabling shall be installed in a neat and workmanlike manner. Minimum cable and unjacketed fiber bend radii as specified by cable manufacturer shall be maintained.

B. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post installation residual cable tension shall be within cable manufacturer's specifications.

C. Fiber optic cabinets, hardware, and cable entering the cabinet shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii as specified by cable manufacturer shall be maintained.

3.7 INSTALLATION OF SENSORS:

A. Sensors required for mechanical equipment operation shall be factory installed and wired as specified in mechanical equipment specifications. BAS manufacturer shall be responsible for coordinating these control devices and ensuring the sequence of operations will be met. Installation and wiring shall be in accordance with the BAS manufacturer's recommendations.

B. Sensors that require field mounting shall meet the BAS manufacturer’s recommendations and be coordinated with the mechanical equipment they will be associated.

C. Mount sensors rigidly and adequately for the environment the sensor will operate.

D. Room temperature sensors shall be installed on concealed junction boxes properly supported by the block wall framing. For installation in dry wall ceilings, the low voltage sensor wiring can be installed exposed and must meet applicable National and Local Electrical Codes.

E. All wires attached to wall mounted sensors shall be sealed off to prevent air from transmitting in the associated conduit and affecting the room sensor readings.

F. Install duct static pressure tap with tube end facing directly down-stream of air flow.

G. Install space static pressure sensor with static sensing probe applicable for space installation where applicable.

H. Sensors used in mixing plenums, and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.

I. All pipe mounted temperature sensors shall be installed in matched thermowells. Install all liquid temperature sensors with heat conducting fluid in thermal wells for adequate thermal conductance.

J. Wiring for space sensors shall be concealed in building drywall. EMT conduit is acceptable within mechanical equipment and service rooms.

K. Install outdoor air temperature sensors on north wall complete with sun shield at manufacturer’s recommended location and coordinated with Engineer.

3.8 WARNING LABELS:

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the BAS system.

B. Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects.

3.9 IDENTIFICATION OF HARDWARE AND WIRING:

A. All field wiring and cabling, including that within factory mounted, and wired control panels and devices for mechanical equipment, shall be labeled at each end within 2" of termination with a cable identifier and other descriptive information for troubleshooting, maintenance, and service purposes. BAS manufacturer to coordinate this labeling requirement with mechanical equipment manufacturer as it relates to controls.

B. Permanently label or code each point of field terminal strips to show the instrument or item served and correlate them to the BAS design drawings.

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

D. Identifiers shall match record documents. All plug-in components shall be labeled such that removal of the component does not remove the label.

3.10 CONTROLLERS:

A. Provide a separate DDC Controller for individual HVAC mechanical equipment. BAS manufacturer shall furnish and coordinate DDC controllers and control devices and ensure that installation and wiring adhere to BAS manufacturer's design recommendations. For those mechanical equipment units that do not have factory installed controls specified, the BAS manufacturer shall field mount controls and coordinate all installation and termination information to ensure the specified sequence of operations are met.

B. Building Controllers and Custom Application Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type (analog or digital) found at each location. If input points are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used in each controller.

1. Future use of spare I/O point capacity shall require providing the field instrument and control device, field wiring, engineering, programming, and commissioning. No additional Controller boards or point modules shall be required to implement use of these spare points.

3.11 PROGRAMMING:

A. Provide sufficient internal memory for all controllers to ensure specified sequence of operations, alarming, trending, and reporting requirements are achieved. BAS manufacturer shall provide a minimum of 25% spare memory capacity for future use.

B. Point Naming: System point names shall be modular in design, allowing easy operator interface without the use of a written point index.

C. Software Programming

1. Provide programming for individual mechanical systems to achieve all aspects of the sequence of operation specified. It is the BAS manufacturer's responsibility to ensure all mechanical equipment functions and operates as specified in sequence of operations. Provide sufficient programming comments in controller application software to clearly describe each section of the program. The comment statements shall reflect the language used in the sequence of operations.

D. BAS Operator's Interface

1. When Operator Workstation is specified, provide color graphics for each piece of mechanical equipment depicting sufficient I/O to monitor and troubleshoot operation. Operator color graphics shall include Air Handling Units, Rooftop Units, VAV Terminal Boxes, Make-up Air Unit, Exhaust Fans, etc. These standard graphics shall depict all points dynamically as specified in the points list and/or indicated in sequence of operation.

2. The BAS manufacturer shall provide all the labor necessary to install, initialize, start up, and trouble-shoot all operator interface software and their functions as described in this section. This includes any operating system software, the operator interface data base, and any third party software installation and integration required for successful operation of the operator interface.

3. As part of this execution phase, the BAS manufacturer shall perform a complete test of the operator interface.

3.12 CONTROL SYSTEM CHECKOUT AND TESTING:

A. Start-up testing. All testing in this section shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration.

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service all of the instruments, controls, and accessory equipment furnished under this specification.

2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.

3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturer's recommendations.

4. Verify all binary output devices (relays, two-position actuators, magnetic starter, etc.) operate properly and normal positions are correct.

5. Verify all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to damper blade travel.

6. Verify the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops and optimal start/stop routines.

7. Alarms and Interlocks

a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.

b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.

c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

3.13 CLEANING:

A. The BAS manufacturer's installing contractor(s) shall clean up all debris resulting from their installation activities on a daily basis. The installation contractors shall remove all cartons, containers, crates, etc. under his control as soon as their contents have been removed. Waste shall be collected and placed in a location designated by the Owner, Construction Manager, General Contractor, and/or Mechanical Contractor.

B. At the completion of work in any area, the installation contractor shall clean all of their work, equipment, etc., making it free from dust, dirt and debris.

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

3.14 TRAINING:

A. Provide minimum of (4) hours of operator training throughout the contract period. The training will be provided for personnel designated by the Owner.

B. These objectives will be divided into logical groupings; participants may attend one or more of these, depending on level of knowledge required:

1. Day-to-day BAS Operators

2. BAS Troubleshooting & Maintenance

3.15 SEQUENCE OF OPERATION

A. ROOFTOP UNIT, RTU-1 (Single Zone VAV), RTU-4 (Multi Zone VAV)

1. Building Automation System Interface:
a. The Building Automation System (BAS) shall send the controller Occupied Bypass, Morning Warm-up/Pre-Cool, Occupied/Unoccupied and Heat/Cool modes. The BAS shall also send the discharge air temperature setpoint and the duct static pressure setpoint. If a BAS is not present, or communication is lost with the BAS the controller shall operate using default modes and setpoints.

2. Starting Sequence

a. Occupied operation begins when the unit is placed in Occupied via BAS or when OAUTS-7 & 8 is closed on the field wiring terminal strip (shipped with factory installed jumper).

3. Modulating Outdoor & Return Air Dampers

a. Outdoor Air Damper Position Command is adjusted to meet the *Outdoor Air Damper Minimum Position Setpoint*. The supply fan starting sequence begins immediately (no end switch installed).

4. Supply Fan Operation

a. After completing initial startup, the supply fan startup sequence will begin by enabling the Supply Fan Start Stop Command and setting the Supply Fan Speed Command to 50% for the initial 30-seconds of operation.

b. Space Temperature Control (Single Zone VAV)

1) Supply air flow is adjusted to maintain space temperature. Typically, it operates at minimum air flow until the discharge air setpoint reaches minimum or maximum, indicating that the heating/cooling demand is high, at which point the supply air flow is increased to meet the demand.

2) With Single Zone VAV operation, Supply Fan Speed Command is adjusted to maintain the Supply Fan Air Flow Active to the Supply Fan Air Flow Setpoint Active. During normal operation, the Supply Fan Air Flow Setpoint Active is set to the Supply Fan Air Flow Minimum Setpoint Active. If the Discharge Air Temperature Setpoint Active (which adjusts based on space conditions) reaches the Discharge Air Temperature Setpoint Minimum (Cooling) or Maximum (Heating), the Supply Fan Air Flow Setpoint Active will begin to adjust up by comparing the Space Temperature Active to the Space Temperature Setpoint Active. As the air flow setpoint rises above minimum, the discharge setpoint is set to the respective minimum/maximum setpoint.

3) Supply Fan Air Flow Minimum Setpoint Active is a program-determined point based on factory settings, mode of operation, outdoor air flow setpoints, or other factors.

c. Supply Duct Static Pressure Control (Multi Zone VAV)

1) During the occupied mode the unit controller shall modulate the output to the variable speed drive as required to maintain the supply duct static pressure setpoint of 1.5 inches of W.C. (adj.). If the supply duct static pressure falls below 1.3 inches of W.C. (adj.) the unit controller shall increase the output to the variable speed drive to maintain setpoint. If the supply duct static pressure rises above 1.7 inches of W.C. (adj.) the unit controller shall decrease the output to the variable speed drive to maintain setpoint.

2) If for any reason the supply air pressure exceeds the supply air pressure high limit, the supply fan shall shut down. The unit shall be allowed to restart three times after a 15 minute off period. If the over pressurization condition occurs on the fourth restart, the unit shall shut down and a manual reset diagnostic is displayed at the remote panel and/or the BAS system.

5. Economizer Operation

a. The following section describe the standard sequence of operation for economizer. Additional options are available for enabling economizer mode, such as dry bulb economizer. Contact the factory for additional information.

b. Economizer Mode w/ Supplemental Mechanical Cooling

1) Enthalpy (Comparative) Economizer

a) Units equipped with modulating outdoor/return air dampers have factory installed outdoor and return air temperature/humidity sensors for determining Economizer Mode. Before allowing Economizer Mode, unit must be in Cooling or Dehumidification Mode. Economizer Mode is enabled whenever the outdoor air enthalpy falls below the return air enthalpy (1.5 btu/lb. deadband).

b) During Economizer Mode with mechanical cooling, the outdoor air damper position opens to the maximum setpoint, and mechanical cooling is allowed to operate to achieve the discharge air temperature setpoint.

c. Economizer w/o Mechanical Cooling (Free Cooling)

1) Enthalpy (Comparative) Economizer

a) Units equipped with modulating outdoor/return air dampers have factory installed outdoor and return air temperature/humidity sensors for determining Economizer Mode. Before allowing Economizer Mode, unit must be in Cooling or Dehumidification Mode. Economizer Mode is enabled whenever the outdoor air enthalpy falls below the return air enthalpy (1.5 btu/lb. deadband).

b) Free Cooling Mode (without mechanical cooling) is enabled during Economizer Mode when the outdoor air temperature active is 5deg below the discharge setpoint active and is not in Dehumidification Mode. During Free Cooling, mechanical cooling is locked out, and the outdoor air damper position is modulated to maintain the discharge setpoint active.

6. Ventilation Mode

a. Ventilation Mode is used during neutral outdoor air conditions when there isn’t a need for heating, cooling, or dehumidification. A demand for dehumidification locks out Ventilation Mode

b. Single Zone VAV

1) Ventilation Mode is enabled when the outdoor air temperature is between the high and low ventilation setpoints active (adj.), and the space temperature is within 2deg of setpoint. During Ventilation Mode, all forms of heating, cooling, and energy recovery are disabled, and the supply fan runs at minimum air flow.

7. Dehumidification Mode

a. The following sections describe the standard sequence of operation based on ordered options. Additional options are available for enabling and controlling dehumidification. Contact the factory for additional information.

b. Dehumidification Mode Single Zone VAV

1) A space dewpoint setpoint is calculated using space temperature setpoint active and space dehumidification setpoint (relative humidity). Dehumidification Mode is enabled when the space dewpoint rises above the space dewpoint calculated enable setpoint or when the outdoor air dewpoint rises above 60deg (3deg deadband). Dehumidification Mode is terminated based on the setpoint deadbands for the space dewpoint or the outdoor air dewpoint.

2) During Dehumidification Mode, cooling is controlled to the dehumidification temperature setpoint active, and hot gas reheat (if installed) controls to the discharge air temperature setpoint active. Dehumidification temperature setpoint active is reset by comparing the space dewpoint to the space dewpoint calculated enable setpoint but is limited to not rise above the discharge air temperature setpoint active. The discharge air temperature setpoint active and supply fan speed are reset based on space temperature. Refer to [supply fan section] to see a detailed explanation.

3) If the hot gas reheat remains at 100% and there is insufficient reheat to meet the discharge temperature setpoint, the first circuit compressor capacity may be increased to provide additional reheat. If the reheat boost is still not able to meet the discharge air temperature setpoint and the space becomes overcooled for an extended period, dehumidification mode will be terminated to allow the heat to warm the space back to setpoint.

4) If the space humidity sensor is not installed or is in fault, the space dewpoint is ignored, and the unit reverts to using only outdoor air conditions to determine dehumidification, with a constant dehumidification temperature setpoint of 48deg.

8. Heating and Cooling Mode

a. Heating and Cooling Modes are determined using a series of time-delay latches that vary based on distance from setpoint and a variable deadband. Generally, the mode of operation will be changed from cooling to heating whenever the cooling capacity is at 0% and the temperature is below the setpoint minus the deadband, occupied offset. Vice-versa when switching from heating to cooling mode.

9. Heating Mode

a. During Heating Mode, the entire range of heating capacity is done in “stages” of each component, with each “stage” stacking on top of the previous one to achieve the total heating capacity. The stages of heat, in order from first to last, are: ERV, Heat Pump, Primary Heat, and finally Secondary Heat. The heat types installed on a unit can be all, none, or any combination of those. This section describes normal heating operation, but each component has a dedicated operation for specifics on how they’re controlled.

b. During Heating Mode, each of the various heat capacities are controlled to the discharge air temperature setpoint active. To see a detailed explanation of how each component is controlled, refer to the section that describes each component in detail.

c. Energy Recover Wheel Variable Effectiveness

1) First, the energy recovery wheel is used as variable effectiveness by modulating exhaust air flow across the ERV using the bypass damper. Once energy recovery is at full capacity (exhaust air bypass fully closed), the next stage of heat is engaged after a delay, and the exhaust air bypass remains fully closed while the next stage of heat is in operation.

d. Primary Heat

1) The primary heater is engaged, and heating capacity is modulated to the discharge air temperature setpoint active.

10. Cooling Mode

a. During Cooling Mode, Cooling Capacity controls to Discharge Air Temperature Setpoint Active.

11. Exhaust Fan Starting Sequence

a. Starting Sequence with Gravity or Barometric Dampers

1) Gravity dampers are either a weighted (barometric) or non-weighted (gravity) damper. The powered exhaust fan starts immediately on a call for exhaust and the dampers are opened using the air flow from the exhaust. On initial startup, the exhaust fan speed is set to 50% signal for the first 30-seconds of operation.

12. Exhaust Fan Operation

a. Return Static Pressure Control

1) Standard on units equipped with exhaust fan(s) and modulating outdoor/return air dampers with economizer. A differential duct pressure transducer is factory provided and field installed.

2) After completing the exhaust fan startup sequence, the exhaust fan controls to the *Return Static Pressure Setpoint* (0.25” WC default, adj.).

3) When there is no demand for the exhaust fan, the fan will operate at minimum speed for 5-minutes before disabling the fan. The isolation exhaust dampers (if installed) will be closed after the exhaust fan is disabled.

13. Energy Recovery Wheel (ERV)

a. The energy recovery wheel is used to pre-condition the outdoor air using energy recovered from the exhaust air. All units equipped with an ERV will be provided with modulating bypass dampers on both the outdoor and exhaust air paths. During Occupied operation,

b. The ERV is typically on/off, with variable speed via an optional VFD. The ERV operates during occupied operation except during Ventilation or Economizer Mode.

1) Outdoor Air Bypass Damper (with VFD on ERV)

a) The outdoor air bypass and VFD on the ERV is used as frost control for the ERV during low ambient conditions. First, the ERV speed is reduced whenever the exhaust leaving temperature (after ERV) falls below 15deg. Once the ERV reaches minimum speed and the exhaust temperature is still below 15deg, outdoor air bypass damper is modulated open and the ERV remains at minimum speed. The bypass damper is set to fully open whenever the ERV is disabled.

14. Unoccupied Mode Operation

a. Unoccupied operation is enabled from the factory whenever the unit is ordered as Space Control or Single Zone VAV Control. In unoccupied operation the unit will use 100% return air unless the unit is not equipped with a return air damper. In that cause the outdoor air damper will open to 100%.

b. Unoccupied Cooing Mode

1) Unoccupied cooling mode is enabled when the space temperature active is above the unoccupied cooling enable setpoint and remain until space temperature is 2 degrees below setpoint.

c. Unoccupied Dehumidification Mode

1) Unoccupied dehumidification mode is enabled when space humidity active is above the unoccupied humidity enable setpoint and remain until space humidity is 5% below setpoint.

d. Unoccupied Heating Mode

1) Single Zone VAV: Unoccupied heating mode is enabled when the space temperature active is below the unoccupied heating enable setpoint and remain until space temperature is 2 degrees above setpoint.

2) Multi Zone VAV: The RTU fan shall be de-energized. The space heating shall be provided by VAV terminal units.

15. Evaporator Coil Frost Protection

a. All units equipped with compressors will have a suction pressure transducer on at least the first circuit. Since the evaporator coils are generally interlaced for dual circuit units, circuit 1 suction pressure is generally a good indication of both circuits.

But, in some cases, the second circuit may also have a suction transducer for expanded frost protection, depending on configuration, such as dual digital scroll.

b. During compressor operation, the frost control first attempts to limit the modulating capacity (variable or digital scroll, either circuit) before disabling compressors. The expectation is that if there's a demand for cooling below the point at which the unit will freeze, then the unit will actively control to the point just above that point. Generally, this frost point is 95-100psi (29-32deg saturated) at the compressor but may vary slightly depending on operating conditions and unit configuration.

16. Compressor Low Ambient lockout

a. Compressor operation will be locked out when the outdoor air temperature is below the *Compressor Cooling Low Ambient Lockout Setpoint*. (Factory set at zero deg. Adj) Unit can remain in cooling mode while compressors are locked out.

17. Hot Gas Reheat

a. Hot gas reheat is fully modulating from 0-100%, utilizes waste energy absorbed from the evaporator coil on circuit 1, and is used to temper the discharge air temperature during dehumidification or some cases, during cooling mode. Because it uses waste heat that would have been rejected through the condenser, it requires the refrigerant circuit to be operational to provide heat. The hot gas reheat coil is located downstream of the evaporator before the supply fan.

b. When enabled, the Hot Gas Reheat Valve Command is adjusted to maintain the Discharge Air Temperature Setpoint Active and is always enabled during Dehumidification Mode.

18. Hot Gas Reheat Operation with Modulating Capacity Compressors

a. Units equipped with modulating compressors (digital scroll or variable speed) on the first circuit will enable the hot gas reheat only during Dehumidification Mode. During Dehumidification Mode, the compressors control to the dehumidification temperature setpoint active, and the hot gas reheat controls to the discharge air temperature setpoint active.

B. ROOFTOP UNITS, RTU-3, 7 (Single Zone VAV)

1. Building Automation System Interface:
a. The Building Automation System (BAS) shall send the controller Occupied Bypass, Morning Warm-up/Pre-Cool, Occupied/Unoccupied and Heat/Cool modes. The BAS shall also send the discharge air temperature setpoint and the duct static pressure setpoint. If a BAS is not present, or communication is lost with the BAS the controller shall operate using default modes and setpoints.
b. After completing initial startup, the supply fan startup sequence will begin by enabling the Supply Fan Start Stop Command and setting the Supply Fan Speed Command to 50% for the initial 30-seconds of operation.

2. Occupied:

a. Supply air flow is adjusted to maintain space temperature. Typically, it operates at minimum air flow until the discharge air setpoint reaches minimum or maximum, indicating that the heating/cooling demand is high, at which point the supply air flow is increased to meet the demand.

b. With Single Zone VAV operation, Supply Fan Speed Command is adjusted to maintain the Supply Fan Air Flow Active to the Supply Fan Air Flow Setpoint Active. During normal operation, the Supply Fan Air Flow Setpoint Active is set to the Supply Fan Air Flow Minimum Setpoint Active. If the Discharge Air Temperature Setpoint Active (which adjusts based on space conditions) reaches the Discharge Air Temperature Setpoint Minimum (Cooling) or Maximum (Heating), the Supply Fan Air Flow Setpoint Active will begin to adjust up by comparing the Space Temperature Active to the Space Temperature Setpoint Active. As the air flow setpoint rises above minimum, the discharge setpoint is set to the respective minimum/maximum setpoint.

c. Supply Fan Air Flow Minimum Setpoint Active is a program-determined point based on factory settings, mode of operation, outdoor air flow setpoints, or other factors.

3. Unoccupied:

a. Unoccupied Cooing Mode

1) Unoccupied cooling mode is enabled when the space temperature active is above the unoccupied cooling enable setpoint and remain until space temperature is 2 degrees below setpoint.

b. Unoccupied Dehumidification Mode

1) Unoccupied dehumidification mode is enabled when space humidity active is above the unoccupied humidity enable setpoint and remain until space humidity is 5% below setpoint.

c. Unoccupied Heating Mode

1) Unoccupied heating mode is enabled when the space temperature active is below the unoccupied heating enable setpoint and remain until space temperature is 2 degrees above setpoint.

4. Optimal Start:

a. The BAS shall monitor the scheduled occupied time, occupied space setpoints and space temperature to calculate when the optimal start occurs.

5. Optimal Stop:

a. The BAS shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

6. Morning Warm-Up Mode:

a. During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the unit shall enable the heating and fan(s). The outside air damper shall remain closed. When the space temperature reaches the occupied heating setpoint (adj.), the unit shall transition to the occupied mode.

7. Pre-Cool Mode:
   a. During optimal start, if the average space temperature is above the occupied cooling setpoint, pre-cool mode shall be activated. When pre-cool is initiated the unit shall enable the fan and cooling or economizer. The outside air damper shall remain closed, unless economizing. When the space temperature reaches occupied cooling setpoint (adj.), the unit shall transition to the occupied mode.

8. Occupied Bypass:
   a. The BAS shall monitor the status of the ON and CANCEL buttons of the space temperature sensors. When an occupied bypass request is received from a space sensor, the unit shall transition from its current occupancy mode to occupied bypass mode and the unit shall maintain the space temperature to the occupied setpoints (adj.).

9. Heat/Cool Mode:
   a. COOLING: The unit controller shall use the discharge air temperature sensor and discharge air temperature cooling setpoint to determine when to initiate requests for cooling. Discharge air setpoint shall be maintained by controlling the cooling as required.
   b. HEATING: The unit controller shall use the discharge air temperature sensor and discharge air temperature heating setpoint to determine when to initiate requests for heating. Discharge air setpoint shall be maintained by controlling the heating as required. During Unoccupied Heating or Morning Warm-Up Mode, the unit heat request shall be communicated to the system VAVs prior to commencing heating operation to allow VAV units to open. The variable speed drive shall be commanded to 100% and the heat shall be staged on and off to satisfy the zone temperature setpoint.

10. Discharge Air Temperature Reset Control:
    a. The discharge air temperature setpoint shall be reset to the optimal setpoint communicated by the BAS. The BAS shall reset the discharge air temperature setpoint based on the current outside air temperature, but shall override this reset function and return the discharge air temperature setpoint to 55.0 deg. F (adj.) if more than two (adj.) zones begin to overheat. Also, the BAS shall override this reset function whenever outdoor dew point is higher than 60.0 deg. F (adj.) or indoor humidity is higher than 60% RH (adj.). If the discharge air temperature drops below the minimum limit, a low temperature alarm shall annunciate and the unit shall shut down. If the discharge air temperature rises above the maximum limit, a high temperature alarm shall annunciate.

11. Economizer:
    a. ENABLE (Comparative Enthalpy): Outside air (OA) enthalpy shall be compared with Return air (RA) enthalpy point. The economizer shall enable when OA enthalpy

is less than RA enthalpy - 2.0 BTU/LB. The economizer shall disable when OA enthalpy is greater than RA enthalpy.
b. OPERATION: The supply air sensor shall measure the dry bulb temperature of the air leaving the evaporator coil while economizing. When economizing is enabled and the unit is operating in the cooling mode, the economizer damper shall be modulated between its minimum position and 100% to maintain the discharge air temperature setpoint. The economizer damper shall modulate toward minimum position in the event the discharge air temperature falls below the discharge low limit temperature setpoint. Compressors shall be delayed from operating until the economizer has opened to 100%.

12. Ventilation Control:
    a. When the space CO2 level is greater than or equal to the Design Minimum CO2 Setpoint, the outdoor air damper shall open to the Design Minimum Outdoor Air Damper Setpoint. When the space CO2 level is less than or equal to the DCV Minimum CO2 Setpoint, the outdoor air damper shall close to the DCV Minimum Outdoor Air Damper Setpoint. If there is a call for economizer cooling, the damper shall be opened further to satisfy the cooling request.

13. Supply Fan:
    a. The supply fan shall be enabled while in the occupied mode and cycled on during the unoccupied mode.

14. Supply Duct Static Pressure Control:
    a. During the occupied mode the unit controller shall modulate the output to the variable speed drive as required to maintain the supply duct static pressure setpoint of 1.5 inches of W.C. (adj.). If the supply duct static pressure falls below 1.3 inches of W.C. (adj.) the unit controller shall increase the output to the variable speed drive to maintain setpoint. If the supply duct static pressure rises above 1.7 inches of W.C. (adj.) the unit controller shall decrease the output to the variable speed drive to maintain setpoint. Upon a call for heating or cooling in the unoccupied mode the unit controller shall modulate the speed of the variable speed drive to 100%.

15. Static Pressure High Limit:
    a. If for any reason the supply air pressure exceeds the supply air pressure high limit, the supply fan shall shut down. The unit shall be allowed to restart three times after a 15 minute off period. If the over pressurization condition occurs on the fourth restart, the unit shall shut down and a manual reset diagnostic is displayed at the remote panel and/or the BAS system.

16. Relief Air and Building Pressure Control:
    a. A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the differential pressure setpoint, the unit controller shall open the relief air damper, turn on the relief fan and modulate the relief air damper to control building pressure to the differential pressure setpoint. If the building pressure decreases below the differential pressure setpoint, the associated controller shall deactivate the relief fan and close the relief air damper.
    b. A differential pressure switch shall monitor the differential pressure across the relief air fan. If the switch is detected to be open for 40 consecutive seconds after a

request for relief fan operation a fan failure alarm shall annunciate at the BAS and the relief fan shall stop. A manual reset shall be required.

17. Filter Status:
    a. A differential pressure switch shall monitor the differential pressure across the filter(s) when the fan is running. If the switch closes during normal operation a dirty filter alarm shall annunciate at the BAS.

18. Smoke Detector Shutdown:
    a. The unit shall shut down in response to a signal from the smoke detector indicating the presence of smoke. The smoke detector shall be interlocked to the unit through the dry contacts of the smoke detector. A manual reset of the smoke detector shall be required to restart the unit.

19. Condensate Overflow Shutdown:
    a. The unit shall shut down in response to a signal from the condensate overflow sensor. The sensor shall be interlocked to the unit cooling controller for immediate shutdown of cooling.

C. ROOFTOP UNIT VAV AIR SYSTEM, RTU-2, 4, 5, and 6: This sequence of operations describes the “system-level” control functions of a rooftop unit (RTU) with VAV terminal units that are part of the air system, which includes coordinating the operation of the RTU and the zone-level VAV units during the various operating modes. The “equipment-level” control functions of the RTU and the terminal units are contained in their respective sequence of operations documents.

1. System Operating Modes:
    a. The Building Automation System (BAS) controller shall include a user-adjustable time-of-day schedule to define when the various areas of the facility are expected to be occupied versus unoccupied. Then, based on current zone conditions, the BAS determines the current system operating mode. The BAS controller shall send the following operating modes to the unit level controllers that are a member of the air system: Occupied Heat/Cool, Unoccupied Heat/Cool and Morning Warmup/Pre-cool.

2. Occupied Heat/Cool:
    a. During the Occupied Mode, each VAV terminal unit shall be activated to maintain zone temperature at the occupied setpoint (cooling or heating). Meanwhile, the rooftop unit (RTU) modulates the supply fan to deliver the required airflow to the zones, positions the outdoor-air damper to bring in required amount of ventilation, and increases/decreases the source of cooling or heating to maintain discharge air at the desired setpoint.

3. Unoccupied Heat/Cool:
    a. During the Unoccupied Mode, each VAV terminal unit shall be activated to maintain zone temperature at the unoccupied setpoint (cooling or heating). Meanwhile, the RTU shuts off, unless a zone requires unoccupied cooling. If needed to operate, the RTU modulates the supply fan to deliver the required airflow to the zones, closes the outdoor-air damper and increases/decreases the source of cooling or heating to maintain discharge air at the desired setpoint.

4. Morning Warm-Up/Pre-Cool:
   a. During the Morning Warm-up/Pre-cool Mode, each VAV terminal shall be activated to raise or lower the zone temperature to the occupied setpoint (heating or cooling) and then closes. Meanwhile, the RTU modulates the supply fan to deliver the required airflow to the zones, closes the outdoor-air damper and increases/decreases the source of cooling or heating to maintain discharge air at the desired setpoint.

5. Optimized System-Level Control Sequences:
   a. The BAS controller shall perform the following optimized system-level control strategies:

6. Optimal Start:
   a. The BAS shall initiate Optimal Start mode such that the RTU is started and VAV boxes are enabled to allow the zone temperature to reach the occupied heating or cooling setpoint prior to scheduled occupancy. The system shall wait as long as possible before starting, so that the temperature in each zone reaches the occupied setpoint just in time or scheduled occupancy.

7. Optimal Stop:
   a. The BAS shall initiate Optimal Stop mode such that cooling or heating is disabled so that the zone temperature does not drift beyond the occupied standby setpoint by the end of the scheduled occupancy period. The RTU supply fan shall continue operating, and ventilation control shall continue, through the end of the scheduled occupancy period.

8. Unoccupied Economizing (Night Purge):
   a. Between 4:00 AM (adj.) and 6:00 AM (adj), the system controller shall initiate Unoccupied Economizing mode if the current zone temperature is at least 1°F warmer than the occupied cooling setpoint and the outdoor dry-bulb temperature is more than 15°F (adj) cooler than the current zone temperature. When initiated, the RTU is started (OA damper fully open, cooling source is off) and VAV boxes are enabled to allow the zone temperature to cool to the occupied cooling setpoint.

9. Optimized Control of Supply Duct Static Pressure (Fan-Pressure Optimization):
   a. At a frequency of once every 2 minutes (adj), the system controller shall monitor the damper position and airflow of all VAV terminal units. The system controller shall calculate a new supply fan duct static pressure setpoint based on the criteria shown below, and send this newly-calculated setpoint to the RTU controller.
   b. All values below are adjustable:
      1) If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
      2) Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
      3) Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
      4) Else if the damper position is less than 95%, send 0 requests.

c. System shall default to ignoring the first 2 requests (adj). When Requests > Ignores the system shall respond by adjusting setpoint upward by (Requests – Ignores) * .06 inH20 (adj), but no larger than .13 inH20 (adj). When Requests are equal to, or less than Ignores the setpoint shall be reset downward by -.05 inH20 (adj). Setpoint shall be bound by a minimum and maximum value which can be set per air handler.

10. Optimized Control of Discharge Air Temperature (DAT Reset):
    a. At a frequency of once every 2 minutes (adj), the system controller shall monitor the outdoor dry-bulb temperature, as well as the zone temperature and damper position of all VAV terminal units. The system controller shall calculate a new discharge air temperature (DAT) setpoint based on the criteria shown below, and send this newly-calculated DAT setpoint to the RTU controller. When the outdoor air (OA) temperature is warmer than 65°F (adj), the maximum DAT setpoint shall be 55°F (adj). When the OA temperature is colder than 55°F (adj), the maximum DAT setpoint shall be 65°F (adj). When the OA temperature is between 55°F (adj) and 65°F (adj), the maximum DAT setpoint shall be reset proportionally between 55°F (adj) and 65°F (adj).
    b. All values below are adjustable.
        1) If the zone temperature exceeds the zone's cooling set point by 5°F for 2 minutes, send 3 requests.
        2) Else if the zone temperature exceeds the zone's cooling set point by 3°F for 2 minutes, send 2 requests.
        3) Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
        4) Else if the cooling loop is less than 95%, send 0 requests.
    c. System shall default to ignoring the first 2 requests (adj). When Requests > Ignores the system shall respond by adjusting setpoint downward by (Requests – Ignores) * -0.3°F (adj), but no larger than 1.0 °F (adj). When Requests are equal to, or less than Ignores the setpoint shall be reset upward by 0.2°F (adj). Setpoint shall be bound by a minimum and maximum value which can be set per air handler.

11. Optimized Control of Ventilation (Ventilation Optimization) with OA Flow Measurement:
    a. The actual outdoor airflow shall be sensed at the outdoor air intake of the RTU, and controlled to an airflow setpoint determined according to ASHRAE Standard 62.1. When the BAS time-of-day schedule indicates that a zone is unoccupied, the required outdoor airflow for that zone shall be zero. When the schedule indicates that a zone is occupied, the required outdoor airflow for that zone shall equal the design outdoor airflow, unless the zone is equipped with occupancy sensor and/or a carbon dioxide (CO¬2) sensor, or uses a time-of-day ventilation schedule, to reduce the required outdoor airflow during periods of partial occupancy. The required outdoor-air fraction (current required outdoor airflow divided by the current primary airflow) shall be continuously calculated for each zone (VAV terminal unit). At a frequency of once every 10 minutes, the BAS shall gather this data from all VAV terminal units, calculate the minimum required outdoor airflow for the system according to ASHRAE 62.1, and send this newly-calculated outdoor airflow setpoint to the RTU controller.

12. Economizer:

a. ENABLE (Comparative Enthalpy): Outside air (OA) enthalpy shall be compared with Return air (RA) enthalpy point. The economizer shall enable when OA enthalpy is less than RA enthalpy - 2.0 BTU/LB. The economizer shall disable when OA enthalpy is greater than RA enthalpy.
b. OPERATION: The supply air sensor shall measure the dry bulb temperature of the air leaving the evaporator coil while economizing. When economizing is enabled and the unit is operating in the cooling mode, the economizer damper shall be modulated between its minimum position and 100% to maintain the discharge air temperature setpoint. The economizer damper shall modulate toward minimum position in the event the discharge air temperature falls below the discharge low limit temperature setpoint. Compressors shall be delayed from operating until the economizer has opened to 100%.

D. SHUT-OFF TERMINAL UNIT WITH HEATING COIL

1. The BAS contractor shall provide new electronic controllers and actuators for all VAV terminal units. Coordinate with mechanical contractor type of controller being furnished and all other control devices required for unit operation as well as method of installation of control equipment to provide a fully integrated and operational system. The BAS contractor shall provide all sensors, thermostats, relays, wiring and programming required to perform the specified sequence of control for all units. The BAS contractor shall provide all wiring, relays and programming required for all units. The contractor shall be responsible for programming all units into the base building BAS.

2. Sequence of Operation: The VAV shall operate on occupied and unoccupied and a morning warm-up modes. The modes of operation shall be set on a preprogrammed schedule by the BAS.
a. During occupied mode the supply damper shall modulate open, on a rise space temperature above the wall mounted electronic cooling thermostat setpoint (75F, adj.). On a drop in space temperature below the set point the VAV damper shall modulate closed towards its minimum open position. When the air valve is at minimum position and the room temperature is below heating setpoint (72F, adj.), the heating coil shall be activated to maintain room temperature setpoint.
b. During the unoccupied mode, the supply damper shall modulate open, on a rise space temperature above the wall mounted electronic cooling thermostat setpoint (80F, adj.) On a drop in space temperature below the set point, the VAV damper shall modulate closed towards its minimum open position. When the air valve is at minimum position and the room temperature is below heating setpoint (50F, adj.), the heating coil shall be activated to maintain room temperature setpoint.

E. SERIES FAN POWERED TERMINAL UNIT WITH HEATING COIL

1. The BAS contractor shall provide electronic controller, actuator for fan powered unit and heating coil for all units. Coordinate with mechanical contractor type of controller being furnished and all other control devices required for unit operation as well as method of installation of control equipment to provide a fully integrated and operational system. The BAS contractor shall provide sensors, thermostat, relays, wiring and programming required to perform the specified sequence of control. The contractor shall be responsible for programming all units into the base building BAS.

2. Sequence of Operation: The fan powered unit shall operate on occupied, unoccupied and morning warm-up mode of operation.

a. During the occupied mode, operation shall be as follows. The fan shall run continuously. On a rise in space temperature above the controlling thermostat cooling set point, the primary air damper shall modulate open. On a drop in temperature below the cooling set point, the reverse shall occur. On a drop in space temperature below the heating set point, the primary air damper shall be closed to the minimum open position and the electric heating coil shall be staged on. On a rise above the heating set point temperature, the reverse shall occur.

b. In the unoccupied mode, the primary air damper shall go to a fully closed position. The fan shall cycle on and the electric heating coil shall be staged on when the space temperature drops below the unoccupied heating set point. On a rise in space temperature above the unoccupied cooling set point, the primary air damper shall modulate open and the fan shall be activated.

c. In the warm-up mode, the primary air damper shall be open to minimum position. The fan shall run continuously. The heating coil shall be energized to maximum heat. When the occupied heating space temperature is reached, the unit shall revert into the occupied mode.

F. TOILET EXHAUST FANS, EF-1, 2, 3, 4, 5, 6

1. The fan shall be interlocked with light switch.

G. TOILET/JANITOR EXHAUST FANS, EF-7, 8

1. The fan shall run continuously during occupied hours via BAS.

2. Provide a wall-mounted switch to each space to override and activate the fan during unoccupied hours.

H. TRANSFORMER EXHAUST FANS, EF-9, 10, 11, 12

1. The fan shall run continuously via BAS.

I. ELECTRICAL ROOM EXHAUST, EF-13

1. The fan shall energize through a wall switch.

J. KITCHEN GREASE HOOD EXHAUST AND MAKE-UP AIR SYSTEMS

1. The hood exhaust fan, make-up air unit, and hood shall be interlocked. When the hood is on, the exhaust fan and make-up air unit shall be activated. When the hood is not in use, the exhaust fan and make-up air unit shall be de-activated.

2. The gas-fired furnace in make-up air unit shall be activated to maintain the make-up air temperature (65F, adj.)

3. Refer to kitchen system drawing on M506 for more information.

3.16 POINT LISTS

A. Rooftop Units (typical)

System Point Description	POINTS									ALARMS					
	GRAPHIC	ANALOG HARDWARE INPUT (AI)	BINARY HARDWARE INPUT (BI)	ANALOG HARDWARE OUTPUT (AO)	BINARY HARDWARE OUTPUT (BO)	SOFTWARE POINT (SFT)	HARDWARE INTERLOCK (HDW)	WIRELESS (WLS)	NETWORK (NET)	HIGH ANALOG LIMIT	LOW ANALOG LIMIT	BINARY	LATCH DIAGNOSTIC	SENSOR FAIL	COMMUNICATION FAIL
COMPRESSOR 1 COMMAND **CMP1**	X				X										
COMPRESSOR 2 COMMAND **CMP2**	X				X										
COMPRESSOR 3 COMMAND **CMP3**	X				X										
COMPRESSOR 4 COMMAND **CMP4**	X				X										
COMPRESSOR 5 COMMAND **CMP5**	X				X										
COOLING OUTPUT COMMAND **CLG**	X			X											
DISCHARGE AIR STATIC PRESSURE LOCAL **DA SP**		X								X	X		X		
DISCHARGE AIR TEMPERATURE **DAT**	X	X												X	
DX COIL FROST STAT **FROSTAT**	X		X									X			
HEATING OUTPUT 1 **HT1**	X				X										
HEATING OUTPUT 2 **HT2**	X				X										
MIXED AIR DAMPER **MAD**	X			X											
OUTSIDE AIR DAMPER COMMAND **OAD**	X			X											
OUTSIDE AIR FLOW LOCAL **OA FLW**	X	X													

OUTSIDE AIR HUMIDITY LOCAL **OAH**	X	X												X	
OUTSIDE AIR TEMPERATURE LOCAL **OAT**	X	X												X	
PRIMARY FILTER STATUS LOCAL **FIL**	X		X									X			
RETURN AIR CO2 LOCAL **RA CO2**		X								X				X	
RETURN AIR DAMPER COMMAND **RAD**	X			X											
RETURN AIR HUMIDITY LOCAL **RAH**	X	X												X	
RETURN AIR SMOKE DETECTION LOCAL **RA SD**							X								
RETURN AIR TEMPERATURE LOCAL **RAT**	X	X												X	
SUPPLY AIR SMOKE DETECTION LOCAL **SA SD**							X								
SUPPLY FAN SPEED **SAF**				X											
SUPPLY FAN START/STOP **SAF**	X				X										
SUPPLY FAN STATUS LOCAL **SAF**	X		X												
APPLICATION MODE **APP MODE**						X									
BAS COMMUNICATION STATE **BAS COM**						X									X
COMPRESSOR ENABLE **CMP ENA**	X					X									
COMPRESSOR LOCKOUT STATUS **CMP LCK**						X									
COOL OUTPUT **CLG**						X									
DISCHARGE AIR STATIC PRESSURE SETPOINT **DA SP SPT**	X					X									
ECONOMIZER ENABLE **ECON ENA**						X									
ECONOMIZER MINIMUM POSITION SETPOINT **ECON MIN POS SP**	X					X									
FAN MODE COMMAND **FAN MODE**						X									
FILTER TIMER HOURS **FIL HRS**						X									
HEAT / COOL MODE REQUEST **H/C REQ**	X					X									
HEAT OUTPUT **HTG**						X									
OCCUPANCY **OCC**	X					X									
OCCUPIED COOLING SETPOINT **OCC CLG SP**	X					X									
SPACE CO2 HIGH LIMIT **SP CO2 HL**						X									
TIMED OVERRIDE STATUS **TOV**						X									
UNOCCUPIED COOLING SETPOINT **UNOCC CLG SP**	X					X									

UNOCCUPIED HEATING SETPOINT **UNOCC HTG SP**	X					X									

B. VAV Terminal Units (typical)

System Point Description	POINTS									ALARMS					
	GRAPHIC	ANALOG HARDWARE INPUT (AI)	BINARY HARDWARE INPUT (BI)	ANALOG HARDWARE OUTPUT (AO)	BINARY HARDWARE OUTPUT (BO)	SOFTWARE POINT (SFT)	HARDWARE INTERLOCK (HDW)	WIRELESS (WLS)	NETWORK (NET)	HIGH ANALOG LIMIT	LOW ANALOG LIMIT	BINARY	LATCH DIAGNOSTIC	SENSOR FAIL	COMMUNICATION FAIL
AIR VALVE DRIVE OPEN COMMAND **AIR VLV OPN**	X				X										
AIR VALVE DRIVE CLOSE COMMAND **AIR VLV CLS**	X				X										
DISCHARGE AIR TEMPERATURE **DAT**	X	X								X	X			X	
SPACE TEMPERATURE LOCAL **SPT**	X							X							
SPACE TEMPERATURE SETPOINT LOCAL **SPT SP**	X							X							
SUPPLY AIRFLOW **DA FLW**	X	X								X	X				
BAS COMMUNICATION STATE **BAS COM**						X									X
MAXIMUM COOLING AIRFLOW SETPOINT **MAX CLG FLW SP**						X									
MINIMUM COOLING AIRFLOW SETPOINT **MIN CLG FLW SP**						X									
MAXIMUM HEATING AIRFLOW SETPOINT **MAX HTG FLW SP**						X									
MINIMUM HEATING AIRFLOW SETPOINT **MIN HTG FLW SP**						X									
OCCUPIED BYPASS TIMER **OCC TMR**	X					X									
OCCUPIED COOLING SETPOINT **OCC CLG SP**	X					X									

OCCUPIED HEATING SETPOINT **OCC HTG SP**	X					X									
UNOCCUPIED COOLING SETPOINT **UNOCC CLG SP**	X					X									
UNOCCUPIED HEATING SETPOINT **UNOCC HTG SP**	X					X									
SUPPLY FAN COMMAND **SF CMD**	X				X										

END OF SECTION