SECTION 250000

BUILDING AUTOMATION SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. Air handler AHU-8 was installed in 2020 and serves approximately 13,000 ft2 of the music department and classrooms across levels 2 (Sector 5B) and 3 (Section 13) of the College Complex building at Los Medanos College. The air distribution primarily dates to the early 1970s. The level 2 areas were gutted and retrofitted in 2015 with new VAV terminals and digital direct controls (DDC). The original pneumatically controlled constant volume reheat terminals serving level 3 were converted to variable flow with the addition of slide-in retrofit terminals by an undated project, but these areas remain pneumatically controlled.

B. Furnish and install a digital Building Automation System (BAS) as specified herein.

1.2 INTEGRATION WITH EXISTING SYSTEM

A. Include all services required to integrate this building into existing BAS for a fully operational system.

B. Procedure

1. Obtain a copy of the campus database with access privileges.

2. Perform a database review with the Owner’s Representative to ensure uniformity of point naming, graphic layout and style, BACnet device instance numbering scheme, IP addresses, BACnet Distribution Tables and BACnet Broadcast Management Devices.

3. BACnet devices

a. Create new building database following the BACnet device instance numbering scheme specified under Paragraph 3.12B.4.

b. Double check existing database to ensure there are no duplicate BACnet device instance numbers. This includes 3rd party equipment such as VFDs.

4. Graphics

a. For standard applications, such as VAV boxes and VAV box summary pages, use the campus standard graphics file template, including using the same file template name.

b. For new or modified graphics custom to the new building, ensure file template name do not duplicate any existing file names.

5. Programming

a. For standard sequences covered by ASHRAE Guideline 36, use the programming provided by Automated Logic, first ensuring they have been updated by the manufacturer to reflect the latest issue and all addenda published when programming work is initiated.

b. For other typical applications, first review those used for similar applications in other campus buildings to use as a starting point, then edit to reflect sequences specified herein. The intent is to have standard programming throughout the campus to the extent possible.

c. Double check existing database to ensure program file names do not duplicate any existing file names.

6. If a BACnet/IP Broadcast Management Device (BBMD) router is required, check the existing Broadcast Distribution Tables (BDT) to ensure that a BBMD router is not already assigned to the relevant network before adding a new one.

7. Install building database and control programming on a temporary portable operator's terminal provided by the Contractor. The POT shall be used for start-up, testing, and commissioning. The POT shall remain the property of the Contractor after final completion of the project.

8. Once the building BAS has been fully commissioned and accepted by the College:

    a. Create a new backup of the existing campus database.

    b. Merge the new building database with the existing campus database.

    c. Confirm that no communication issues (in the building and across the campus) have resulted from the merge.

    d. Confirm that all new controllers have successfully bound to the server and that alarms and trends are being sent to the server.

    e. Configure alarm page-out notifications (e.g. e-mail, SMS, etc.) per Paragraph 3.12F.

    f. Make another backup of the merged database.

    g. Load the merged database onto the campus Control System Server.

    h. Integrate graphic screens into the Central Plant graphics including adding appropriate hyperlinks so that the system operates as one integrated system.

    i. Confirm that the merge was successful by sample testing points and sequences

    j. Perform a post-merge review 4 to 8 weeks following the merge. Review general system operation, problematic areas, alarms and trend histories. Identify and remediate any issues.

    k. Receive College approve of the final installation in writing.

9. Provide high level password for College operator access to the system only at this point; College will not have access to the system prior to system acceptance and integration.

1.3 CONTRACTOR PROPOSALS

A. The system requirements described in this specification are generally performance based. Where requirements are prescriptive, the intent is to provide minimum quality, not to give unfair advantage to any given manufacturer or product. If a contractor finds that a certain requirement is unduly difficult or expensive to meet, contact the Engineer prior to bid due date and an addendum modifying the requirement will be considered.

B. Where requirements are unclear, the contractor shall clarify the requirements with the Engineer before the bid due date. Where requirements continue to be unclear, the contractor's proposal must accurately describe what is included and excluded.

C. By submitting a proposal, contractor guarantees that their proposal is in full compliance with these specifications and is complete and turnkey, except as specifically excluded in their proposal. Do not exclude work that is required – this is a turnkey project with no other contractors involved.

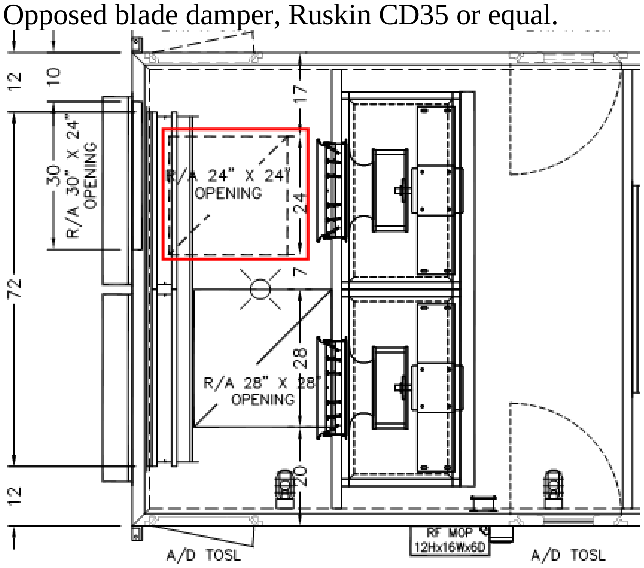
D. Base Bid Scope

1. Conversion of existing pneumatic and DDC systems to ALC as specified herein.

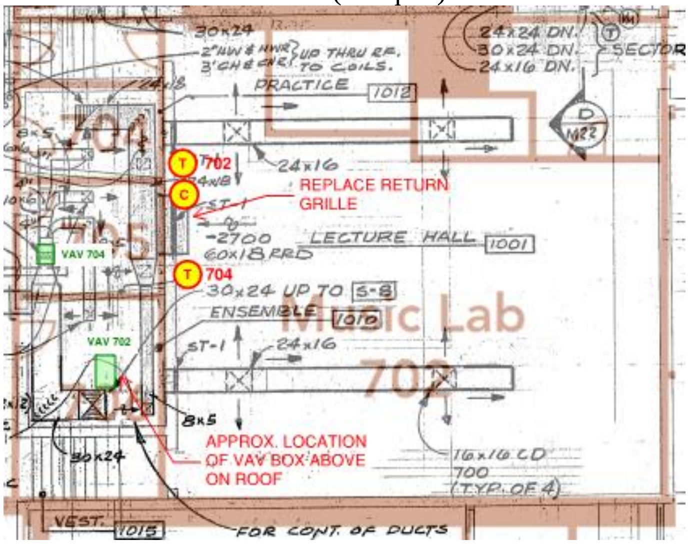
2. Testing, adjusting, and balancing as specified herein

3. Room 702 pressure and sound remediation

a. Installation of manual volume damper at return air opening in floor of inlet side of return fan, opposed blade dampers, mounted below existing floor grate. The airflow from this return branch currently exceeds design but there is no balancing device. Opposed blade damper, Ruskin CD35 or equal.



b. Replacement of 60x18 return air register in room 702 with Price 500 series grille (or equal) with parallel fixed blades set at 0 degree deflection and concealed fasteners and RAS return air silencer (or equal).



4. Provide and install slide-in retrofit VAV box for zone 8131 serving Level 3 restrooms. Price SRDV or equal, not including controls, for design flow of 1375 cfm. Branch originates from above Level 2 restrooms with an existing DDC reheat coil to serve Level 3 restrooms. Terminal may be installed on Level 2 or Level 3 at contractor’s choice. Include any work to access concealed ductwork, provide access door, and repair wall/ceiling to existing condition.

E. Alternates

1. Clearing duct obstructions. Investigate and clear any obstructions from coils, turning vanes, and dampers in AHU-8 supply air distribution. Cleaning shall be supervised by an Air System Cleaning Specialist and comply with standards set forth by the National Air Duct Cleaning Association, including debris containment and HEPA filtration. Duct to be cleared of obstructions shall extend from roofline down through duct distribution across levels 2 and 3 and as far as terminal reheat coils. Coil cleaning shall consist of 12 existing pneumatically controlled reheat coils serving level 3 zones (cleaning not required at newer DDC coils). Where existing access is not available, cut in new access panels. Coordinate with the College to complete work during normal business hours. Provide post project report.

2. MS/TP to Level 2 Zones. The nine zones on level 2 (VAV-5B.1 through 5B.9) are relatively new with Andover controllers and MS/TP communication. The base scope is to use Ethernet for the primary network and peer to peer communication. This deductive alternate is to reuse the existing twisted pair wiring instead for the nine zones with MS/TP.

3. All work during business hours. For the base bid, assume that work in and serving classrooms and music labs shall be done after-hours. For this deductive alternate, assume that work shall be performed during normal business hours when spaces are not in use, e.g. during spring break.

F. Unit Prices. Unit prices shall include all equipment, material, labor, design engineering, start-up and testing costs necessary to provide a complete operational system. Prices are based on normal design and construction schedule; for compression, additional costs may be added.

1. Slide-in retrofit VAV box. Price SRDV or equal, not including controls.
2. Replacement of hot water reheat coil with new 2-row coil.
3. Add/deduct controls for each VAV reheat box using TS-3A sensor
4. Add/deduct each TS-3C sensor in lieu of TS-3A sensor
5. Add/deduct each TS-3CC (CO2) sensor in lieu of TS-3A sensor
6. Relocate existing thermostat within 20 feet, including patching and painting
7. Demolish abandoned pneumatic thermostat, including patching and painting.

1.4 REFERENCE STANDARDS

A. Nothing in Contract Documents shall be construed to permit Work not conforming to applicable laws, ordinances, rules, and regulations. When Contract Documents differ from requirements of applicable laws, ordinances, rules and regulations, comply with documents establishing the more stringent requirement.

B. The latest published or effective editions, including approved addenda or amendments, of the following codes and standard shall apply to the BAS design and installation as applicable.

C. State, Local, and City Codes

1. CBC − California Building Code
2. CMC − California Mechanical Code
3. CEC – California Electrical Code
4. Local City and County Codes

D. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

1. ANSI/ASHRAE 135 – BACnet - A Data Communication Protocol for Building Automation and Control Networks
2. ANSI/ASHRAE Standard 135.1− Method of Test for Conformance to BACnet
3. ANSI/ASHRAE Standard 15 – Safety Standard for Refrigeration Systems

E. Electronics Industries Alliance

1. EIA-232 – Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.

2. EIA-458 – Standard Optical Fiber Material Classes and Preferred Sizes.

3. EIA-485 – Standard for Electrical Characteristics of Generator and Receivers for use in Balanced Digital Multipoint Systems.

4. EIA-472 – General and Sectional Specifications for Fiber Optic Cable.

5. EIA-475 – Generic and Sectional Specifications for Fiber Optic Connectors and all Sectional Specifications.

6. EIA-573 – Generic and Sectional Specifications for Field Portable Polishing Device for Preparation Optical Fiber and all Sectional Specifications.

7. EIA-590 – Standard for Physical Location and Protection of Below-Ground Fiber Optic Cable Plant and all Sectional Specifications.

F. Underwriters Laboratories

1. UL 916 – Energy Management Systems.

G. National Electrical Manufacturers Association

1. NEMA 250 – Enclosure for Electrical Equipment.

H. Institute of Electrical and Electronics Engineers (IEEE)

1. IEEE 142 – Recommended Practice for Grounding of Industrial and Commercial Power Systems.

2. IEEE 802.3 – CSMA/CD (Ethernet – Based) LAN.

1.5 DEFINITIONS

A. Acronyms

AAC	Advanced Application Controller
AH	Air Handler
AHU	Air Handling Unit
AI	Analog Input
ANSI	American National Standards Institute
AO	Analog Output
ASC	Application Specific Controllers
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
A-to-D	Analog-to-Digital
BACnet	Data Communications Protocol for Building Automation and Control Systems
BC	Building Controller

BIBB	BACnet Interoperability Building Blocks
BTL	BACnet Testing Laboratory
CAD	Computer Aided Drafting
CHW	Chilled Water
CHWR	Chilled Water Return
CHWS	Chilled Water Supply
COV	Change of Value
CSS	Control Systems Server
CU	Controller or Control Unit
CV	Constant Volume
CW	Condenser Water
CWR	Condenser Water Return
CWS	Condenser Water Supply
DBMS	Database Management System
DDC	Direct Digital Control
DHW	Domestic Hot Water
DI	Digital Input
DO	Digital Output
D-to-A	Digital-to-Analog
BAS	Building Automation System
EMT	Electrical Metallic Tubing
EP	Electro-Pneumatic
ETL	Edison Testing Laboratories
GUI	Graphical User Interface
HHD	Hand Held Device
HOA	Hand-Off-Automatic
HVAC	Heating, Ventilating and Air-Conditioning
HTTP	Hyper-Text Transfer Protocol
I/O	Input/output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LAN	Local Area Network
LANID	LAN Interface Device
MAC	Medium Access Control
MHz	Megahertz
MS/TP	Master-Slave/Token-Passing
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
ODBC	Open Database Connectivity
OI	Operator Interface
OWS	Operator Workstation
P	Proportional
PC	Personal Computer
PI	Proportional-Integral
PICS	Protocol Implementation Conformance Statement
PID	Proportional-Integral-Derivative
POT	Portable Operators Terminal
PTP	Point-to-Point

RAM	Random Access Memory
SOO	Sequence of Operation
SQL	Standardized Query Language
SSL	Secure Socket Layers
TAB	Test, Adjust, and Balance
TDR	Time Delay Relay
UFT	Underfloor Fan Terminal Box
UL	Underwriters' Laboratories, Inc.
XML	Extensible Markup Language

B. Terms

Term	Definition
Accessible	Locations that can be reached with no more than a ladder to assist access and without having to remove permanent partitions or materials. Examples include inside mechanical rooms, mechanical equipment enclosures, instrument panels, and above suspended ceilings with removable tiles.
BACnet Interoperability Building Blocks	A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device in a specification.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Change of Value	An event that occurs when a digital point changes value or an analog value changes by a predefined amount.
Client	A device that is the requestor of services from a server. A client device makes requests of and receives responses from a server device.
Concealed	Embedded in masonry or other construction, installed in furred spaces, within double partitions, above hung ceilings, in trenches, in crawl spaces, or in enclosures.
Continuous Monitoring	A sampling and recording of a variable based on time or change of state (such as trending an analog value, monitoring a binary change of state).
Contract Documents	Specifications, drawings, and other materials provided with request for bids.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database.
Controller	Intelligent stand-alone control device. Controller is a generic reference to BCs, AACs, and ASCs.
Direct Digital Control	Microprocessor-based control including Analog/Digital conversion and program logic.
Building Automation System	The entire integrated building management and control system.

Term	Definition
Equal	Approximately equal in material types, weight, size, design, quality, and efficiency of specified product.
Exposed	Not installed underground or concealed.
Furnish	To purchase, procure, acquire and deliver complete with related accessories.
Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.
Hand Held Device	Manufacturer’s microprocessor based portable device for direct connection to a field Controller.
Inaccessible	Locations that do not meet the definition of accessible. Examples include inside furred walls, pipe chases and shafts, or above ceilings without removable tiles.
Indicated, shown or noted	As indicated, shown or noted on drawings or specifications.
Install	To erect, mount and connect complete with related accessories.
Instrumentation	Gauges, thermometers and other devices mounted in ductwork or piping that are not a part of the BAS.
College IT LAN	The Information Technology local area network furnished by the College, used for normal business-related communication and may be used for interconnecting some BAS controllers and gateways where specified.
LAN Interface Device	Device or function used to facilitate communication and sharing of data throughout the BAS.
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token Passing	Data link protocol as defined by the BACnet standard.
Motor Controllers	Starters, variable speed drives, and other devices controlling the operation of motors.
Native BACnet Device	A device that uses BACnet for communication. A device may also provide gateway functionality and still be described as a Native BACnet device.
Native BACnet System	A network composed only of Native BACnet Devices without gateways.
Open Database Connectivity	An open standard application-programming interface for accessing a database developed. ODBC compliant systems make it possible to access any data from any application, regardless of which database management system is handling the data.

Term	Definition
Open Connectivity	OPC is an interoperability standard developed for industrial applications. OPC compliant systems make it possible to access or exchange data from any application, regardless of which database management system is handling the data.
Operator Interface	A device used by the operator to manage the BAS including OWSs, POTs, and HHDs.
Operator Workstation	The user's interface with the BAS system. As the BAS network devices are stand-alone, the OWS is not required for communications to occur.
College	The College or their designated representatives.
Piping	Pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation and related items.
Points	All physical I/O points, virtual points, and all application program parameters.
Point-to-Point	Serial communication as defined in the BACnet standard.
Portable Operators Terminal	Laptop PC used both for direct connection to a controller and for remote dial up connection.
Primary LAN	High speed, peer-to-peer controller LAN connecting BCs, AACs, and ASCs as well as some gateways. See System Architecture below.
Protocol Implementation Conformance Statement	A written document that identifies the particular options specified by BACnet that are implemented in a device.
Provide	Furnish, supply, install and connect up complete and ready safe and regular operation of particular work referred to unless specifically noted.
Protocol Translator	A device that converts BACnet from one network protocol to another.
Reviewed, approved, or directed	Reviewed, approved, or directed by or to College's Representative.
Router	A device that connects two or more networks at the network layer.
Secondary LAN	LAN connecting some gateways and networked sensors. See System Architecture below.
Server	A device that is a provider of services to a client. A client device makes requests of and receives responses from a server device.
Standardized Query Language	SQL - A standardized means for requesting information from a database.
Supervisory LAN	Ethernet-based LAN connecting Primary LANs with each other and OWSs, CSS, and THS. See System Architecture below.

Term	Definition
Supply	Purchase, procure, acquire and deliver complete with related accessories.
Wiring	Raceway, fittings, wire, boxes and related items.
Work	Labor, materials, equipment, apparatus, controls, accessories and other items required for proper and complete installation.

1.6 QUALITY ASSURANCE

A. Materials and Equipment

1. Manufacturer's Qualifications: See 2.1 for approved manufacturers.

B. Installer

1. The following are approved BAS contractors:

    a. Sunbelt. Marc Annicchero mannicchero@sunbeltcontrols.com

    b. Air Systems. Mike Putich Mike.Putich@airsystemsinc.com

    c. ASG: Tony Skibinski tskibinski@asgbms.com

2. BAS Contractor's Project Manager Qualifications: Individual shall specialize in and be experienced with direct digital control system installation for not less than 3 years. Project Manager shall have experience with the installation of the proposed direct digital control equipment product line for not less than 2 projects of similar size and complexity. Project Manager must have proof of having successfully completed the most advanced training offered by the manufacturer of the proposed product line.

3. BAS Contractor's Programmer Qualifications: Individual(s) shall specialize in and be experienced with direct digital control system programming for not less than 3 years and with the proposed direct digital control equipment product line for not less than 1.5 years. Programmers must show proof of having successfully completed the most advanced programming training offered by the vendor of the programming application on the proposed product line.

4. BAS Contractor's Lead Installation Technician Qualifications: Individual(s) shall specialize in and be experienced with direct digital control system installation for not less than 3 years and with the proposed direct digital control equipment product line for not less than 1.5 years. Installers must show proof of having successfully completed the installation certification training offered by the vendor of the proposed product line.

5. BAS Contractor's Service Qualifications: The installer must be experienced in control system operation, maintenance and service. BAS Contractor must document a minimum 5-year history of servicing installations of similar size and complexity. Installer must also document at least a 1-year history of servicing the proposed product line.

6. Installer's Response Time and Proximity

a. Installer must maintain a fully capable service facility within 50 miles of the subject Project. Service facility shall manage the emergency service dispatches and maintain the inventory of spare parts.

b. Installer must demonstrate the ability to meet the emergency response times listed in Paragraph 1.14B.1.

7. Electrical installation shall be by manufacturer-trained electricians

   a. Exception: Roughing in wiring and conduit and mounting panels may be subcontracted to any licensed electrician.

1.7 SUBMITTALS

A. No work may begin on any segment of this Project until the related submittals have been reviewed for conformity with the design intent and the Contractor has responded to all comments to the satisfaction of the College's Representative.

B. Submit drawings and product data as hereinafter specified. Conditions in this Section take precedence over conditions in Division 1.

C. Submittal Schedule: Submittal schedule shall be as follows unless otherwise directed by the College's Representative:

1. Allow 10 working days for approval, unless College's Representative agrees to accelerated schedule.
2. Submittal Package 0 (Qualifications) shall be submitted with bid.
3. Submittal Package 1 (Hardware and Shop Drawings) shall be submitted in accordance with schedule established by the College in bid documents.
4. Submittal Package 2 (Programming, Graphics, and Pre-Test TAB Report) and shall be submitted no less than 30 days before software is to be installed in field devices and no less than 30 days before TAB field work commences.
5. Submittal Package 2.5 (Final TAB Report) shall be submitted no less than 15 days prior to Contractor's request for final inspection.
6. Submittal Package 3 (Pre-Functional Test Forms) shall be submitted no less than 30 days prior to conducting tests.
7. Submittal Package 4 (Pre-Functional Test Report) shall be submitted no less than 14 after conducting tests.
8. Submittal Package 5 (Post-Construction Trend Points List) shall be submitted 14 days prior to the start of the trend collection period.
9. Submittal Package 6 (Functional Test Report) shall be submitted no more than 7 days after conducting tests.

10. Submittal Package 7 (Training Materials) shall be submitted no less than 14 days prior to conducting first training class.

11. Submittal Package 8 (Post-Construction Trend Logs) shall be submitted after demonstration tests are accepted and systems are in full automatic operation.

D. Submission and Resubmission Procedure

1. Optional Pre-Submittals. At Contractor’s option, electronic submittals indicated below may be submitted unofficially via email directly to the Engineer for review and comment prior to formal submission. Comments provided by the Engineer are not official and may be changed or additional comments may be provided on the formal submittal. The intent of pre-submittals is to reduce paperwork and review time.

2. Each submittal shall have a unique serial number that includes the associated specification section followed by a number for each sub-part of the submittal for that specification section, such as SUBMITTAL 250000-01.

3. Each resubmittal shall have the original unique serial number plus unique revision number such as SUBMITTAL 250000-01 REVISION 1.

4. Submit one copy of submittal in electronic format specified under each submittal package below. Submissions made in the wrong format will be returned without action.

5. Submittals shall have bookmarks for each subsection (e.g. Materials, Drawings) and for each drawing including drawing number and name.

6. College’s Representative will return a memo or mark-up of submittal with comments and corrections noted where required.

7. Make corrections

   a. Revise initial submittal to resolve review comments and corrections.

   b. Clearly identify resubmittal by original submittal number and revision number.

   c. The cover page of resubmittals shall include a summary of prior comments and how they were resolved in the resubmittal.

   d. Indicate any changes that have been made other than those requested.

8. Resubmit revised submittals until no exceptions are taken.

   a. The cost of the Engineer’s review of submittals after first resubmittal will be borne by Contractor at Taylor Engineering standard billing rates.

9. Once submittals are accepted with no exceptions taken, provide

   a. Complete submittal of all accepted drawings and products in a single electronic file.

   b. Photocopies or electronic copies for coordination with other trades, if and as required by the General Contractor or College’s Representative.

E. Submittals Packages

1. Submittal Package 0 (Qualifications)

a. Provide Installer and Key personnel qualifications as specified in Paragraph 1.6B.

b. Provide Testing, Adjusting, and Balancing (TAB) contractor qualifications as specified in Paragraph 3.14B.1.

c. Format: Word-searchable format per Paragraph 1.10C.3.

2. Submittal Package 1 (Hardware and Shop Drawings)

a. Hardware

1) Organize by specification section and device tags as tagged in these specifications.

2) Do not submit products that are not used even if included in specifications.

3) Include a summary table of contents listing for every submitted device:

a) Tab of submittal file/binder where submittal is located

b) Device tag as tagged in these specifications (such as TS-1A, FM-1)

c) Specification section number (down to the lowest applicable heading number)

d) Whether device is per specifications and a listed product or a substitution

e) Manufacturer

f) Model number

g) Device accuracy (where applicable)

h) Accuracy as installed including wiring and A/D conversion effects (where applicable)

4) Submittal shall include manufacturer’s description and technical data, such as performance data and accuracy, product specification sheets, and installation instructions for all control devices and software.

5) When manufacturer’s 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. Each submitted piece of literature and drawings shall clearly reference the specification or drawing that the submittal is to cover. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements.

6) A BACnet Protocol Implementation Conformance Statement (PICS) for each type of controller and operator interface.

7) Format: Word-searchable format per Paragraph 1.10C.3.

b. Shop Drawings

1) System architecture one-line diagram indicating schematic location of all control units, workstations, LAN interface devices, gateways, etc. Indicate address and type for each control unit. Indicate media, protocol, baud rate, and type of each LAN.

2) Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and control devices. The schematics provided on Drawings shall be the basis of the schematics with respect to layout and location of control points.

3) All physical points on the schematic flow diagram shall be indicated with names, descriptors, and point addresses identified as listed in the point summary table.

4) Label each input and output with the appropriate range.

5) Device table (Bill of Materials). With each schematic, provide a table of all materials and equipment including:

a) Device tag as indicated in the schematic and actual field labeling (use tag as indicated in these specifications where applicable and practical)

b) Device tag as indicated in these specifications where applicable and if it differs from schematic device tag

c) Description

d) Proposed manufacturer and model number

e) Range

f) Quantity

6) With each schematic or on separate valve sheet, provide valve and actuator information including pipe size, valve size, C_v, design flow, target pressure drop, actual design pressure drop, manufacturer, model number, close off rating, etc. Indicate normal positions of fail-safe valves and dampers.

7) Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.

8) Details of control panels, including controllers, instruments, and labeling shown in plan or elevation indicating the installed locations.

9) Floor plans: None required.

10) Format

a) Sheets shall be consecutively numbered.

b) Each sheet shall have a title indicating the type of information included and the mechanical/electrical system controlled.

c) Table of Contents listing sheet titles and sheet numbers.

d) Legend and list of abbreviations.

e) Schematics

1. Word searchable pdf format.

2. 21 inch x 15 inch or 17 inch x 11 inch.

c. Do not include sequence of controls on shop drawings or equipment submittals; they are included in Submittal Package 2.

3. Submittal Package 2 (Programming, Graphics, and Pre-Test TAB Report)

a. A detailed description of point naming convention conforming to Paragraph 3.12B to be used for all software and hardware points, integrated with existing database convention.

b. A list of all hardware and software points identifying their full text names, device addresses and descriptions.

c. Control Logic Documentation

1) Submit control logic program listings (graphical programming) consistent with specified English-language Sequences of Operation for all control units.

2) Control logic shall be annotated to describe how it accomplishes the sequence of operation. Annotations shall be sufficient to allow an operator to relate each program component (block or line) to corresponding portions of the specified Sequence of Operation.

3) Include a MS Word file of the specified English-language Sequences of Operation of each control sequence updated to reflect any suggested changes made by the Contractor to clarify or improve the sequences. Changes shall be clearly marked. Also merge Guideline 36 sequences, where referenced, verbatim into the file; see Section 259000 Building Automation Sequences of Operation. SOOs shall be fully consistent with the graphical programming.

4) Include control settings, setpoints, throttling ranges, reset schedules, adjustable parameters and limits.

5) Submit one complete set of programming and operating manuals for all digital controllers concurrently with control logic documentation.

d. Graphic screens of all required graphics, provided in final colors.

e. Provide the pre-test TAB report as required by Paragraph 3.14B.2.

f. Format

1) Points list: Word-searchable format per Paragraph 1.10C.3.

2) Programming: Native ALC Eikon.

3) Control sequences: MS Word

4) Programming and operating manual: Word-searchable format per Paragraph 1.10C.3.

5) Graphics: Graphical electronic format (pdf, png, etc.).

6) Pre-test TAB report: Word-searchable format per Paragraph 1.10C.3.

4. Submittal Package 2.5 (Final TAB Report)

a. Provide final TAB report as required by Paragraph 3.14B.3.

b. Format: Word-searchable format per Paragraph 1.10C.3.

5. Submittal Package 3 (Pre-Functional Test Forms)

a. Provide pre-functional test forms as required by Paragraph 3.15C.2.a.

b. Format: Word-searchable format per Paragraph 1.10C.3.

6. Submittal Package 4 (Pre-Functional Test Report)

a. Provide Pre-Functional Test Report as required by Paragraph 3.15C.2.

b. Format: Word-searchable format per Paragraph 1.10C.3.

7. Submittal Package 5 (Post-Construction Trend Points List)

a. Provide a list of points being trended along with trend interval or change-of-value per Paragraph 3.15G.2.d.

b. Format: See Paragraph 2.13C.3.

8. Submittal Package 6 (Functional Test Report)

a. Provide completed functional test forms as required by Paragraph 3.15E.4.

b. Format: Word-searchable format per Paragraph 1.10C.3.

9. Submittal Package 7 (Training Materials)

a. Provide training materials as required by Paragraph 3.16.

b. Format: Word-searchable format per Paragraph 1.10C.3.

10. Submittal Package 8 (Post-Construction Trend Logs)

a. Provide trend logs as required by Paragraph 3.15G.

b. Format: See Paragraph 2.13C.3.

1.8 USE OF PREMISES

A. BAS Contractor shall become fully informed of, and shall fully comply with, the College's site security requirements and provisions.

B. BAS Contractor shall limit the storage of materials and equipment on-site to specific areas approved by College. The College may also limit the type of material stored. At no time during the work under the contract shall the BAS Contractor place, or cause to be placed, any material or equipment at any location that would impede or impair access to or from the present facilities.

C. BAS Contractor shall send proper notices, make all necessary arrangements, and perform all services required in the care and maintenance of building utilities to the extent that these utilities may be affected and/or interrupted by the BAS installation work. Building utilities include telephone / telecommunications, electrical service, central cooling, water, and other utilities necessary for building operation and occupant comfort.

D. All work that has the potential for interrupting building usage, utilities, and/or maintenance services shall be scheduled to occur during campus breaks, evenings and/or weekends and coordinated with College. This includes all VAV box upgrade work, all work in public areas, offices, etc. Work in mechanical rooms, roof, and other areas not generally inhabited by building occupants (including vacant suites) may be conducted during normal work hours except any cutting and drilling work from which dissipated noise and vibration may impact the normal work of building occupants

E. The building will remain operational during construction. Changes to systems that affect these areas must be minimal in impact and time out-of-service. The functions of the existing BAS must be migrated in a manner that keeps all systems operational throughout the duration of this work. All down-times must be scheduled in advance with approval of College.

1. The air handling system shall be operational during normal campus hours, except they may be shut off for occasional periods not exceeding 15 minutes and shall be operational for at least 45 minutes between outages.

2. Work in and serving private offices, restrooms, and small meeting rooms may be done during normal campus hours when scheduled in advance with approval of College. Work in classrooms and music labs must be done after-hours or when no classes are scheduled.

1.9 REUSE OF EXISTING SYSTEMS AND EQUIPMENT

A. Unless otherwise directed, the Controls Contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers, or actuators that are designated to be reused. Should the Contractor find existing equipment that requires maintenance, the College shall be notified immediately.

B. Patch and paint at demolished wall sensors visible to occupants.

C. Wiring

1. All existing control conduit and wiring may be reused.

2. Where wiring is allowed to be reused, its integrity and suitability to the new application is the responsibility of the Contractor. Wiring shall be properly identified and tested.

3. Unused or redundant wiring and conduit shall be removed.

D. Pneumatic Controls

1. Demolish all pneumatic actuators (see Control Points list) and replace with electric. The new system will contain no pneumatic actuators or controls except at fire dampers, where applicable.

2. Demolish pneumatic VAV controllers and cap and demo pneumatic tubing as far back as possible. Use pneumatic tubing at thermostats to pull new wiring where possible; when impractical to route concealed wiring in wall, use new surface-mount raceway for new wiring. Reuse VAV box damper and velocity pressure probe.

E. Controllers

1. Salvage existing DDC controllers for future reuse by the College.

F. Control Panels

1. The Contractor may reuse any existing local control panels to locate new equipment. (E) panel for AHU-8 is located on roof adjacent to variable speed drives.

2. All unused existing equipment within these panels must be removed and shall not be reused.

3. Existing control transformers may be reused if they are sufficiently sized for new duty, otherwise provide new transformers.

4. All unused panels shall be removed.

G. Dampers

1. Reuse existing dampers and actuators.

H. Valves

1. Reuse existing ball valves with electric actuators at air handling unit and DDC reheat zones on level 2. Replace existing globe valves and actuators at pneumatically controlled reheat zones. See VAV schedule.

I. Temperature Sensors

1. Reuse existing temperature sensors.

2. Salvage existing DDC room temperature sensors for future reuse by the College.

J. Differential Pressure Sensor

1. Building Static Pressure: Existing differential pressure sensor shall be reused.

2. Duct Differential Pressure: Existing differential pressure sensor shall be reused.

3. Existing static pressure tips and pneumatic tubing may be used provided their location is found and noted on drawings.

K. Starters and variable speed drives.

1. Reuse existing starters; repair of same is not part of this project.

2. Reuse existing variable speed drives.

L. Safeties and Fire Alarm Controls

1. The existing Andover control system intercepts the signals from the smoke detector and fire alarm system, and shuts down the fans in programming.

2. Revise to hardwire the smoke detector and fire alarm signals directly to the VFD, through new relays in series that interrupt the enable command.

M. Other Mechanical Equipment

1. All other mechanical equipment shall continue to be used, except as otherwise noted.

1.10 COMPLETION REQUIREMENTS

A. Procedure

1. Until the documents required in this Section are submitted and approved, the system will not be considered accepted and final payment to Contractor will not be made.

2. Before requesting acceptance of Work, submit one set of completion documents for review and approval of College.

3. After review, furnish quantity of sets indicated below to College.

B. Completion Documents

1. Operation and Maintenance (O & M) Manuals. Provide in both paper and electronic format per Paragraph 1.10C.

   a. Include the as-built version of all submittals (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) in maintenance manual. Submittal data shall be located in tabs along with associated maintenance information.

   b. Engineering, Installation, and Maintenance Manual(s) that explain how to design and install new points, panels, and other hardware; preventive maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.

   c. Complete original issue documentation, installation, and maintenance information for all third-party hardware and software provided, including computer equipment and sensors.

   d. A list of recommended spare parts with part numbers and suppliers.

   e. Operators Manual with procedures for operating the control systems, including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.

   f. Programming Manuals with a description of the programming language, control block descriptions (including algorithms and calculations used), point database creation and modification, program creation and modification, and use of the programming editor.

   g. Recommended preventive maintenance procedures for all system components, including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

   h. A listing and documentation of all custom software for the Project created using the programming language, including the set points, tuning parameters, and point and object database.

   i. English language control sequences updated to reflect final programming installed in the BAS at the time of system acceptance. See Section 259000 Building Automation Sequences of Operation.

2. Complete original issue electronic copy for all software provided, including operating systems, programming language, operator workstation software, and graphics software.

3. Complete electronic copy of BAS database, user screens, setpoints and all configuration settings necessary to allow re-installation of system after crash or replacement of server, and resume operations with the BAS in the same configuration as during College sign-off.

4. Project Record Drawings

   a. As-built versions of the submittal drawings in reproducible paper and electronic format per Paragraph 1.10C.

   b. As-built network architecture drawings showing all BACnet nodes including a description field with specific controller and device identification, description and location information.

5. Commissioning Reports. Completed versions of all Pre-functional, Functional, and Demonstration Commissioning Test reports, calibration logs, etc., per Paragraph 3.15A.9.

6. Copy of inspection certificates provided by the local code authorities.

7. Written guarantee and warranty documents for all equipment and systems, including the start and end date for each.

8. Training materials as required by Paragraph 3.16.

9. Contact information. Names, addresses, and 24-hour telephone numbers of contractors installing equipment, and the control systems and service representatives of each.

C. Format of Completion Documents

1. Provide the type and quantity of media listed in table below.

2. Project database, programming source files, and all other files required to modify, maintain, or enhance the installed system shall be provided in their source format and compiled format (where applicable).

3. Where electronic copies are specified, comply with the following:

   a. Provide in word-searchable electronic format; acceptable formats are MS Word, Adobe Acrobat (pdf), and HTML; submit other formats for review and approval prior to submission; scanned paper documents not acceptable.

   b. For submittals, provide separate file for each type of equipment.

   c. Control sequences shall be in MS Word.

	Document	Paper (binder or bound)	Electronic	
			Loaded onto Flash Drive	Loaded onto CSS
1.	O&M Manual	2	1	1
2.	Original issue software	–	1	1

	Document	Paper (binder or bound)	Electronic	
			Loaded onto Flash Drive	Loaded onto CSS
3.	Project database including all source files	–	1	1
4.	Project Record Drawings	2	1	1
5.	Control sequences	1	1	1
6.	Commissioning Reports	2	1	1
7.	Inspection Certificates	1	–	–
8.	Warranty documents	1	–	–
9.	Training materials	1 per trainee	1	1
10.	Contact information	1	–	–

D. Permanent On-site Documentation

1. In each panel, provide the following stored in clear plastic sleeve taped to the back of the panel door:

a. 8.5x11 printout of as-built points list

b. 21 inch x 15 inch or 17 inch x 11 inch set of as-built shop drawings for devices in panel

1.11 BAS DESIGN

A. System Architecture

1. General

a. The system provided shall incorporate hardware resources sufficient to meet the functional requirements specified in this Section. Include all items not specifically itemized in this Section that are necessary to implement, maintain, and operate the system in compliance with the functional intent of this Section.

b. The system shall be configured as a distributed processing network(s) capable of expansion as specified herein.

c. The existing Campus BAS consists of a control system server interconnected by the College IT LAN to each campus building and facility. This project includes integrating building level BCs and other control devices into the campus system.

1) Within the building, the BAS shall be standalone and not rely on any 3rd party networks, such as the College IT LAN, except as specifically allowed herein.

2) To communicate with the central CSS (and internet via VPN), the building Primary LAN shall connect via managed switches, provided by the College, to the College IT LAN. Arrange with College IT administrators for final connection and IP addresses. Contractor to provide patch panels.

3) Managed switches are located in Electrical Room 1024 on Level 3 (near restrooms) and IDF room 253 on Level 2.

d. All control products provided for this Project shall comprise an interoperable Native BACnet System. All control products provided for this Project shall conform to ANSI/ASHRAE Standard 135.

e. Power-line carrier systems are not acceptable for BAS communications.

2. BAS Network Architecture

a. College IT LAN. Ethernet-based, 100 or 1000 Mbps BACnet/IP network.

b. Supervisory LAN: The LAN is owner-provided and shall be an Ethernet-based, 100 or 1000 Mbps network interconnecting the server and OWS(s) to the owner-provided managed switch as specified herein. LAN shall be IEEE 802.3 Ethernet with switches and routers that support 100 Mbps minimum throughput.

c. Primary LAN: High-speed, peer-to-peer communicating LAN used to connect BCs, AACs, ASCs, and certain gateways and sensors where specified herein. Acceptable technologies are limited to Ethernet (IEEE802.3) per the Supervisory LAN. This network shall be BACnet/IP as defined in the BACnet standard, and shall share a common network number for the Ethernet backbone, as defined in BACnet.

d. Secondary LAN: Network used only to connect certain gateways and sensors where specified herein. It shall <u>not</u> be used to interconnect BCs, AACs, and ASCs. Network speed versus the number of devices on the LAN shall be dictated by the response time and trending requirements. Acceptable technologies include but are not limited to:

1) BACnet over Master Slave/ Token Passing (MS/TP)

2) Modbus RTU over RS-485

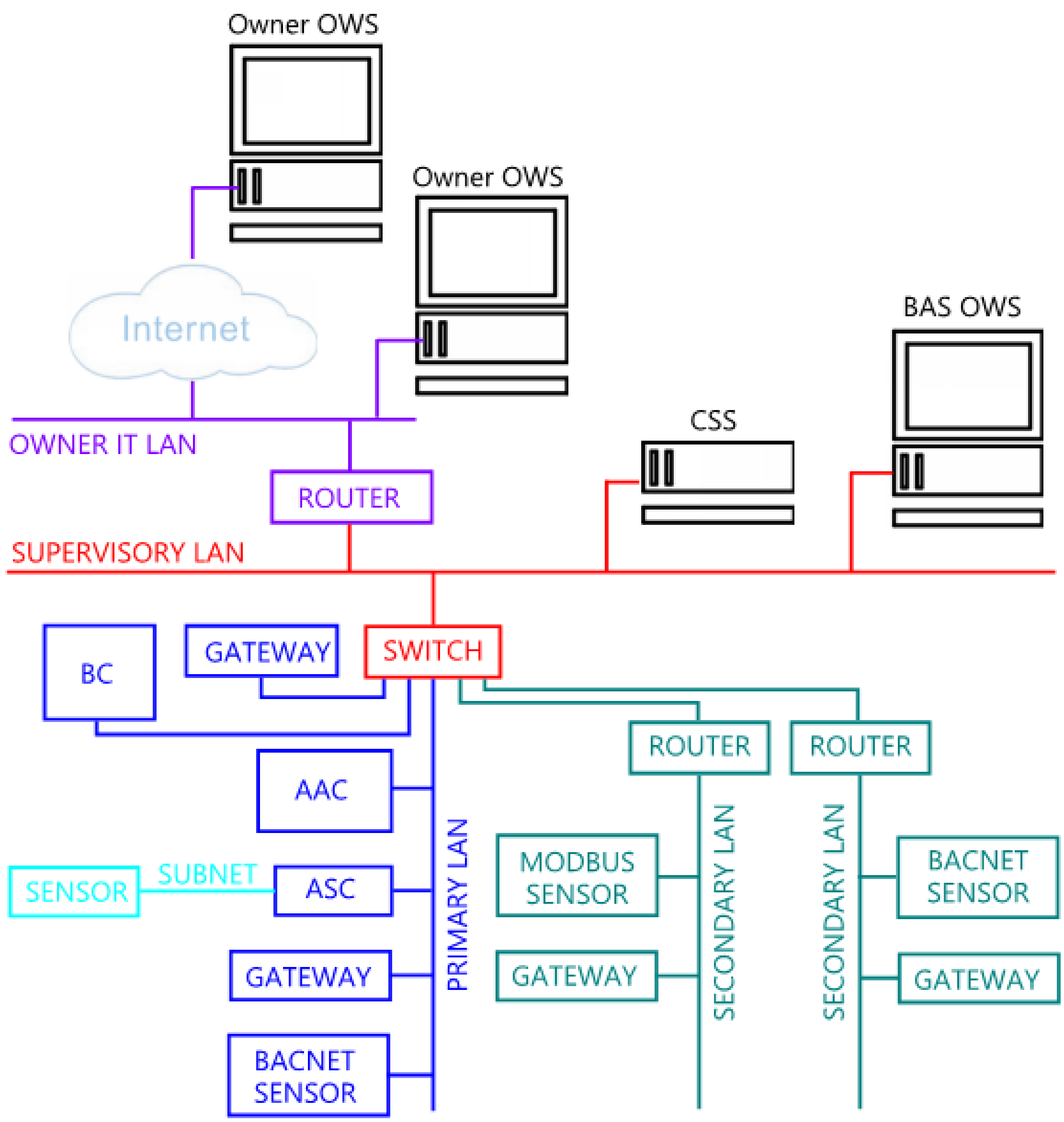
e. Subnets: Networks used to connect sensors and thermostats to AACs and ASCs. This network may as above for Secondary LANs or may be proprietary the manufacturer.

3. The figure below shows an example schematic of the desired network architecture. Note:

a. Not all devices shown will exist for this project.

b. Ethernet network installer shall be responsible for assigning IP addresses to all devices on the network.

c. If gateways are specified to be directly connected to the College IT LAN in Paragraph 2.4C, the gateway supplier shall also provide and install a BBMD Router (both shown dashed in the schematic) including all configuration and programming.



4. Operator Interfaces and Servers

   a. The Control Systems Server (CSS) is existing. See Paragraph 1.2B.7 for temporary CSS requirements.

   b. OWSs or POTs are either existing or will be provided by the College.

   c. Remote monitoring and control shall be through use of a web browser through the College IT LAN and via the internet through the College IT LAN.

5. Controllers. The BCs, AACs, and ASCs shall monitor, control, and provide the field interface for all points specified.

6. Gateways

a. See Paragraph 2.4C for a list of gateways and routers.

b. Where gateways are used, critical points may also be hardwired from the BAS to the controlled device, rather than using the gateway, to avoid problems with gateway failures. Where listed in Hardware Points tables, these points shall be hardwired even when available through gateway.

B. System Performance

1. The communication speed between the controllers, LAN interface devices, and operator interface devices shall be sufficient to ensure fast system response time under any loading condition. This includes when system is collecting trend data for commissioning and for long term monitoring. (See Paragraph 3.15G.) In no case shall delay times between an event, request, or command initiation and its completion be greater than those listed herein, assuming no other simultaneous operator activity. Reconfigure LAN as necessary to accomplish these performance requirements. This does not apply to gateways and their interaction with non-BAS-vendor equipment.

a. Object Command: The maximum time between an operator command via the operator interface to change an analog or binary point and the subsequent change in the controller shall be less than 5 seconds.

b. Object Scan: All changes of state and change of analog values will be transmitted over the network such that any data used or displayed at a controller or workstation will have been current within the previous 10 seconds.

c. Graphics Scan: The maximum time between an operator’s selection of a graphic and it completely painting the screen and updating at least 10 points shall be less than 10 seconds.

d. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation or broadcast (where so programmed) shall not exceed 10 seconds for a Level 1 alarm, 20 seconds for alarm levels 2 and 3, and 30 seconds for alarm levels 4 and 5. All workstations on the onsite network must receive alarms within 5 seconds of each other.

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

f. Control Loop Performance: Programmable controllers shall be able to execute DDC PID control loops at a selectable frequency of at least once per second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

2. Sensor selection, wiring method, use of transmitters, A-to-D conversion bits, etc. shall be selected and adjusted to provide end-to-end (fluid to display) accuracy at or better than those listed in the following table.

Measured Variable	Reported Accuracy
Space drybulb temperature	±1ºF
Ducted Air drybulb temperature	±0.5ºF

Measured Variable	**Reported Accuracy**
Mixed Air drybulb temperature	±1ºF
Outside Air drybulb temperature	±0.5ºF
Water and Gas Flow	±1% of reading
Airflow (terminal)	±10% of reading
Airflow (measuring stations)	±5% of reading
Air Pressure (ducts)	±0.05 inches
Air Pressure (space)	±0.01 inches
Water Pressure	±2% of reading
Electrical power	1% of reading
Carbon Dioxide (CO_2)	±75 ppm

1.12 OWNERSHIP OF PROPRIETARY MATERIAL

A. All project-developed software and documentation shall become the property of the College. These include, but are not limited to:

1. Project graphic images

2. Record drawings

3. Project database

4. Project-specific application programming code

5. All documentation

1.13 WARRANTY

A. At the successful completion of the final testing, commissioning, and demonstration phase in accordance with the terms of this specification, if equipment and systems are operating satisfactorily to the College and if all completion requirements per Paragraph 1.10B have been fulfilled, the College shall certify in writing that the control system has been accepted. The date of acceptance shall be the start of the warranty period.

B. Guarantee all materials, equipment, apparatus and workmanship (including programming) to be free of defective materials and faulty workmanship for the following periods from date of acceptance:

1. BCs, AACs, and ASCs: two years

2. Valve and damper actuators: five years

3. All else: one year

C. Provide new materials, equipment, apparatus and labor to replace that determined by College to be defective or faulty.

D. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the College. Contractor shall respond to the College’s request for warranty service within 24 hours during normal business hours.

E. Operator workstation software, project-specific software, graphic software, database software, and firmware updates that resolve known software deficiencies shall be provided at no cost to the College during the warranty period.

F. Sequence of operation programming bugs (both due to programming misinterpretations and sequence errors) shall be corrected and any reasonable control sequence changes required to provide proper system operation shall be provided at no additional cost to the College during this period.

1.14 WARRANTY MAINTENANCE

A. The College reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. The Contractor shall warrant parts and installation work regardless of any such changes made by the College, unless the Contractor provides clear and convincing evidence that a specific problem is the result of such changes to the BAS.

B. At no cost to the College, provide maintenance services for software and hardware components during the warranty period as specified below:

1. Emergency Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following notification by the College to the Contractor.

    a. Response by telephone or via internet connection to the BAS to any request for service shall be provided within two hours of the College’s initial request for service.

    b. In the event that the malfunction, failure, or defect is not corrected, at least one technician, trained in the system to be serviced, shall be dispatched to the College’s site within eight hours of the College’s initial request for such services.

2. Normal Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would not result in property damage or loss of comfort control shall be corrected and repaired following notification by the College to the Contractor.

    a. Response by telephone to any request for service shall be provided within eight working hours (contractor specified 40 hr. per week normal working period) of the College’s initial request for service.

    b. In the event that the malfunction, failure, or defect is not, at least one technician, trained in the system to be serviced, shall be dispatched to the College’s site within three working days of the College’s initial request for such services, as specified.

3. College’s Telephonic Request for Service: Contractor shall specify a maximum of three telephone numbers for College to call in the event of a need for service. At least one of the lines shall be attended continuously (24/7). Alternatively, pagers/SMS can be used for technicians trained in system to be serviced. One of the three paged/texted technicians shall respond to every call within 15 minutes.

4. Technical Support: Contractor shall provide technical support by telephone throughout the warranty period.

5. Documentation: Record drawings and software documentation shall be updated as required to reflect any and all changes made to the system or programming during the warranty period.

PART 2 PRODUCTS

2.1 PRIMARY BAS MANUFACTURER

A. Automated Logic Corp.

B. No Equal

2.2 GENERAL

A. Materials shall be new, the best of their respective kinds without imperfections or blemishes and shall not be damaged in any way.

B. To the extent practical, all equipment of the same type serving the same function shall be identical and from the same manufacturer.

C. All controllers, associated hardware (repeaters, routers, etc.), sensors, and control devices shall be fully operational and maintain specified accuracy at the anticipated ambient conditions of the installed location as follows:

1. Outdoors or in harsh ambient conditions: -20°C to 55°C (-4°F to 130°F), 10% RH to 90% RH noncondensing.

2. Conditioned spaces or mechanical rooms: 0°C to 40°C (32°F to 104°F), 10% RH to 80% RH noncondensing.

2.3 CONTROLLERS

A. Building Controller (BC)

1. ALC OptiFlex line

B. Advanced Application Controller (AAC)

1. ALC OptiFlex line

C. Application Specific Controller (ASC)

1. ALC OptiFlex line

2.4 COMMUNICATION DEVICES

A. Supervisory LAN Protocol Translators

1. ALC Optiflex line

B. BACnet Gateways & Protocol Translators

1. Gateways shall be provided to link non-BACnet control products to the BACnet internetwork. All of the functionality described in this Paragraph is to be provided by using the BACnet capabilities. Each Gateway shall have the ability to expand the number of BACnet objects of each type supported by 20% to accommodate future system changes.

2. Each Gateway shall provide values for all points on the non-BACnet side of the Gateway to BACnet devices as if the values were originating from BACnet objects. The Gateway shall also provide a way for BACnet devices to modify (write) all points specified by the Points List using standard BACnet services.

C. Gateways and Protocol Translators

1. Provide wiring for new network connections to AHU-8 supply and return fan VFDs (there are no existing network connections to ABB ACH550 drives).

Equipment/System	Interface			
	Type	Specified Under Division:	Location	Connect to this Network:
Variable Speed Drives	BACnet/MSTP	23	Each VFD	Secondary

2.5 BAS INTERFACE HARDWARE

A. Not required (existing)

2.6 AIR TUBING

A. Seamless copper tubing, Type L-ACR, ASTM B 88; with cast-bronze solder joint fittings, ANSI B1.18; or wrought-copper solder-joint fittings, ANSI B16.22; except brass compression-type fittings at connections to equipment. Solder shall be 95/5 tin antimony, or other suitable lead free composition solder.

B. Virgin polyethylene non-metallic tubing type FR, ASTM D 2737, and with flame-retardant harness for multiple tubing. Use compression or push-on brass fittings.

2.7 ELECTRIC WIRING AND DEVICES

A. Communication Wiring

1. Provide all communication wiring between Building Controllers, Protocol Translators, Gateways, AACs, ASCs and local and remote peripherals (such as operator workstations and printers).

2. Ethernet LAN: Use Fiber or Category 6 of standard TIA/EIA 68 (10baseT). Network shall be run with no splices and separate from any wiring over 30 volts.

B. Analog Signal Wiring

1. Input and output signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, current or voltage analog outputs, etc. shall be twisted pair, 100% shielded if recommended or required by controller manufacturer, with PVC cover. Gauge shall be as recommended by controller manufacturer.

2.8 CONTROL CABINETS

A. Existing control cabinets may be reused. This section applies to new cabinets.

B. All control cabinets shall be fully enclosed with hinged door.

1. For panels in mechanical rooms and other spaces that are secure and accessible only to BAS/MEP operators, provide quarter-turn slotted latch.

2. For panels located in electrical rooms, IDF rooms, and other spaces that may be accessible by persons other than BAS/MEP operators, provide key-lock latch. A single key shall be common to all panels within each building. Provide 3 keys.

C. Construction

1. Indoor:

a. Mechanical or electrical rooms etc.: NEMA 1

b. Air plenums: NEMA 12

2. Outdoor: NEMA 4

D. Interconnections between internal and face-mounted devices shall be pre-wired with color-coded stranded conductors neatly installed in plastic troughs or tie-wrapped. Terminals for field connections shall be UL Listed for service, individually identified per control-interlock drawings, with adequate clearance for field wiring. All control tubing and wiring shall be run neatly and orderly in open slot wiring duct with cover. Control terminations for field connection shall be individually identified per control Shop Drawings.

E. Provide ON/OFF power switch with over-current protection for control power sources to each local panel.

F. Provide with

1. Framed, plastic-encased point list for all points in cabinet.

2. Nameplates for all devices on face.

2.9 SENSORS AND MISCELLANEOUS FIELD DEVICES

A. The listing of several sensors or devices in this section does not imply that any may be used. Refer to points list in Paragraph 2.14 Points List for device specification. Only where two or more devices are specifically listed in points list (such as “FM-1 or FM-4”) may the Contractor choose among listed products.

B. Control Valves

1. Manufacturers
   a. Belimo
   b. Siemens
   c. Schneider
   d. Delta
   e. JCI
   f. Bray
   g. Or equal
2. Modulating Characterized Ball Valves
   a. Valves shall be specifically designed for modulating duty in control application with guaranteed average leak-free life span over 200,000 full stroke cycles.
   b. Industrial quality with nickel plated forged brass body and female NPT threads.
   c. Blowout proof stem design, glass-reinforced Teflon thrust seal washer and stuffing box ring with minimum 600 psi rating (2-way valves) or 400 psi rating (3-way valves). The stem packing shall consist of 2 lubricated O-rings designed for modulating service and requiring no maintenance.
   d. Valves suitable for water or low-pressure steam shall incorporate an anti-condensation cap thermal break in stem design.
   e. Close off rating: Bubble-tight shutoff greater or equal to 125% of pump shut-off head.
   f. Characterizing disk held securely by a keyed ring providing equal percentage characteristic
   g. Ball: stainless steel
   h. Stem: stainless steel
3. Two Position Ball Valves
   a. Same as Modulating Characterized Ball Valves except no characterization disks
4. Minimum valve assembly pressure ratings
   a. Hot water: 125 psi at 200ºF
5. Valve Selection
   a. Valve type

1) Modulating 2-way or 3-way valves

a) 6 inch and less: characterized ball type

b. Valve Characteristic

1) 2-way valves: equal percentage or modified equal percentage.

2) 3-way valves controlling heating coils: equal percentage or modified equal percentage.

3) Two-position valves: not applicable. For ball valves used for two-position duty, do not include characterizing disk.

c. Valve Sizing

1) Modulating Water: Size valve to achieve the following full-open pressure drop

a) Minimum pressure drop: equal to half the pressure drop of coil or exchanger.

b) Maximum pressure drop

1. Hot water at coils: 2 psi

c) 3-way valves shall be selected for near minimum pressure drop. 2-way valves shall be selected near maximum pressure drop.

d) Flow coefficient (C_v) shall not be less than 1.0 (to avoid clogging)

e) Valve size shall match as close as possible the pipe size where C_v is available in that size.

2) Two-position valves: Line size unless otherwise indicated on Drawings.

C. Control Dampers

1. None

D. Actuators

1. Manufacturers

a. Belimo

b. No equal

2. Warranty: Valve and damper actuators shall carry a manufacturer's 5-year warranty.

3. Electric Actuators

a. Entire actuator shall be UL or CSA approved by a National Recognized Testing Laboratory.

b. Enclosure shall meet NEMA 4X weatherproof requirements for outdoor applications.

c. Dampers. The actuator shall be direct coupled over the shaft, enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The clamp shall be steel of a V-bolt design with associated V-shaped, toothed cradle attaching to the shaft for maximum strength and eliminating slippage via cold weld attachment. Single bolt or set screw type fasteners are not acceptable. Aluminum clamps are unacceptable.

d. Valves. Actuators shall be specifically designed for integral mounting to valves without external couplings.

e. Actuator shall have microprocessor-based motor controller providing electronic cut off at full open so that no noise can be generated while holding open. Holding noise level shall be inaudible.

f. Noise from actuator while it is moving shall be inaudible through a tee-bar ceiling.

g. Actuators shall provide protection against actuator burnout using an internal current limiting circuit or digital motor rotation sensing circuit. Circuit shall insure that actuators cannot burn out due to stalled damper or mechanical and electrical paralleling. End switches to deactivate the actuator at the end of rotation or use of magnetic clutches are not acceptable.

h. Modulating Actuators. Actuators shall accept a 0 to 10 VDC or 0 to 20 mA control signal and provide a 2 to 10 VDC or 4 to 20 mA operating range. Actuators shall have positive positioning circuit so that controlled device is at same position for a given signal regardless of operating differential pressure. Actuators that internally use a floating actuator with an analog signal converter are not acceptable.

i. Where indicated on Drawings or Points List, actuators shall include

   1) 2 to 10 VDC position feedback signal

   2) Limit (end) position switches

j. All 24 VAC/DC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC. Actuators operating on 120 VAC power shall not require more than 10 VA. Actuators operating on 230 VAC power shall not require more than 11 VA.

k. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.

l. Actuators shall be provided with a conduit fitting an a minimum three-foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.

m. Where fail-open or fail-closed (fail-safe) position is required by Paragraph 2.9D.4, an internal mechanical, spring return mechanism shall be built into the actuator housing. Electrical capacitor type fail-safe are also acceptable. All fail-safe actuators shall be capable of both clockwise or counterclockwise spring return operation by simply changing the mounting orientation. Spring return 2-position fail-safe valves shall not be used in noise sensitive locations; use either electronic fail-safe where available, or use floating point type actuator with drive-open and drive-close wiring for normal open/close operation (spring shall only be used to cause valve to drive to fail-safe position upon a loss of power) including position feedback.

n. Actuators shall be capable of being mechanically and electrically paralleled to increase torque where required.

o. 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 inch-pound torque capacity shall have a manual crank for this purpose.

p. Actuators shall be designed for a minimum of 60,000 full cycles at full torque and be UL 873 listed.

q. Actuators shall provide clear visual indication of damper/valve position.

4. Normal and Fail-Safe Position

a. Except as specified otherwise herein, the normal position (that with zero control signal) and the fail-safe position (that with no power to the actuator) of control devices and actuators shall be as indicated in table below. "Last" means last position. Actuators with a fail-safe position other than "Last" must have spring or electronic fail-safe capability.

Device	**Normal Position**	**Fail-Safe Position**
Hot water reheat coil valves	CLOSED	LAST
VAV box dampers	OPEN	LAST

5. Valve Actuator Selection

a. Modulating actuators for valves shall have minimum rangeability of 50 to 1.

b. Water

1) 2-way, and two-position valves

a) Tight closing against 125% of system pump shut-off head.

b) Modulating duty against 90% of system pump shut-off head.

2) 3-way shall be tight closing against twice the full open differential pressure for which they are sized.

6. Damper Actuator Selection

a. Actuators shall be direct coupled. For multiple sections, provide one actuator for each section; linking or jack-shafting damper sections shall not be allowed.

b. Provide sufficient torque as velocity, static, or side seals require per damper manufacturer's recommendations and the following:

1) Torque shall be a minimum 5 inch-pound per square foot for opposed blade dampers and 7 inch-pound per square foot for parallel blade dampers.

2) The total damper area operated by an actuator shall not exceed 80% of the manufacturer's maximum area rating.

E. General Field Devices

1. Provide field devices for input and output of digital (binary) and analog signals into controllers (BCs, AACs, ASCs). Provide signal conditioning for all field devices as recommended by field device manufacturers and as required for proper operation in the system.

2. It shall be the Contractor's responsibility to assure that all field devices are compatible with controller hardware and software.

3. Field devices specified herein are generally two-wire type transmitters, with power for the device to be supplied from the respective controller. If the controller provided is not equipped to provide this power, or is not designed to work with two-wire type transmitters, or if field device is to serve as input to more than one controller, or where the length of wire to the controller will unacceptably affect the accuracy, provide a transmitter and necessary regulated DC power supply, as required.

4. For field devices specified hereinafter that require signal conditioners, signal boosters, signal repeaters, or other devices for proper interface to controllers, furnish and install proper device, including 120V power as required. Such devices shall have accuracy equal to, or better than, the accuracy listed for respective field devices.

5. Accuracy: As used in this Section, accuracy shall include combined effects of nonlinearity, non-repeatability and hysteresis. Sensor accuracy shall be at or better than both that specifically listed for a device and as required by Paragraph 1.11B.2.

F. Temperature Sensors (TS)

1. General

a. Unless otherwise noted, sensors may be platinum RTD, thermistor, or other device that is commonly used for temperature sensing and that meets accuracy, stability, and resolution requirements.

b. When matched with A/D converter of BC, AAC, or ASC, sensor range shall provide a resolution of no worse than 0.3ºF (0.16 °C) (unless noted otherwise herein).

c. Sensors shall drift no more than 0.3ºF and shall not require calibration over a five-year period.

d. Manufacturers

1) Mamac

2) Kele Associates

3) Building Automation Products Inc.

4) Automated Logic Corp.

5) Or equal

2. Duct temperature sensors: Shall consist of sensing element, junction box for wiring connections and gasket to prevent air leakage or vibration noise.

a. TS-1A: Single point (use where not specifically called out to be averaging in points list). Sensor probe shall be 304 stainless steel.

b. TS-1B: Not used

c. TS-1C: Averaging, rigid. Sensor length shall be at least 2/3 the width of the duct and include at least four sensing elements, or one per 6 inches, whichever is greater.

3. Room Sensors

a. Thermostat tags refer to the following:

Type:	Tag	
ALC model	ZS2 Standard	ZS2 Pro
Distech model	EC-SmartAir	EC-SmartVue
Display	Blank	LCD
Temperature only	TS-3A	TS-3C
With motion	TS-3AM	TS-3CM
With CO_2	TS-3AC	TS-3CC

1) Display

a) Blank: Blank cover (or LCD display with display configured to be shut off and touchpad or keypad disabled)

b) LCD: LCD display of all sensors, temperature setpoint adjustment buttons, and schedule override button

2) CO2 Sensor

a) 400 to 1250 PPM/ ±30PPM or 3% of reading, whichever is greater.

b) The sensor shall include automatic background calibration (ABC) logic to compensate for the aging of the infrared source and shall not require recalibration for a minimum of 5 years, guaranteed. If sensor is found to be out of calibration, supplier shall recalibrate at no additional cost to the Owner within 5 years of purchase date.

c) Meet Title 24 requirements including calibration interval

3) For room sensors connected to terminal box controllers (such as at VAV boxes) that require calibration: Include a USB port or some other means for connection of POT for terminal box calibration. Alternative means of terminal calibration are acceptable provided they result in no cost to Work performed for Testing, Adjusting, and Balancing.

b. See equipment schedules for thermostat type.

4. Temperature Transmitters: Where required by the Controller or to meet specified end-to-end accuracy requirements, sensors as specified above shall be matched with transmitters outputting 4-20 mA linearly across the specified temperature range. Transmitters shall have zero and span adjustments, an accuracy of 0.1°F when applied to the sensor range.

G. Differential Pressure Transmitters (DPT)

1. DPT-1: Not used

2. DPT-2: Not used

3. DPT-3: Air, Duct Pressure:

a. General: Loop powered two-wire differential capacitance cell-type transmitter.

b. Output: two wire 4-20 mA output with zero adjustment.

c. Overall Accuracy: ±1% of range (not of maximum range/scale)

d. Switch selectable range:

1) ≥ 0.5 inches water column

2) ≤10 inches water column

3) Select range as specified in points list or, if not listed for specified setpoint to be between 25% and 75% full-scale.

e. Housing: Polymer housing suitable for surface mounting.

f. Static Sensing Element: Pitot-type static pressure sensing tips similar to Dwyer model A-301, Davis Instruments, or equal, with connecting tubing.

g. Manufacturers.

1) Setra

2) Modus

3) Dwyer

4) Or equal

4. DPT-4: Not used

5. DPT-5: VAV Velocity Pressure

    a. General: Loop powered two-wire differential capacitance cell type transmitter.

    b. Output: Two-wire, 4-20 mA output with zero adjustment.

    c. Flow transducer (including impact of A-to-D conversion) shall be capable of stably controlling to a setpoint of 0.004 inches differential pressure or lower, shall be capable of sensing 0.002 inches differential pressure or lower, and shall have a ±0.001 inches or lower resolution across the entire scale.

    d. Calibration software shall use a minimum of two field measured points, minimum and maximum airflow, with curve fitting airflow interpolation in between.

    e. Range: 0 to 1 in.w.c.

    f. Housing: Polymer housing suitable for surface mounting.

    g. Manufacturer

        1) Automated Logic

        2) No equal

H. Differential Pressure Switches (DPS)

1. DPS-1: Not used

2. DPS-2: Air: Diaphragm with adjustable setpoint and differential and snap acting form C contacts rated for the application. Automatic reset. Provide manufacturer’s recommended static pressure sensing tips and connecting tubing.

I. Current Switches (CS-1)

1. Clamp-on or solid-core

2. Range: as required by application

3. Trip Point: Automatic or adjustable

    a. Exception: Fixed setpoint (Veris H-600 or equal) may be used on direct drive constant speed fans that do not have backdraft or motorized shutoff dampers.

4. Switch: Solid state, normally open, 1 to 135 Vac or Vdc, 0.3 Amps. Zero off state leakage

5. Lower Frequency Limit: 6 Hz

6. Trip Indication: LED

7. Approvals: UL, CSA

8. May be combined with relay for start/stop

9. Where used for single-phase devices, provide the CS/CR in a self-contained unit in a housing with override switch. Kele RIBX, Veris H500, or equal

10. Manufacturers

    a. Veris Industries H-608/708/808/908

    b. Senva C-2320L

    c. RE Technologies SCS1150A-LED

    d. Or equal

J. Current Transformers (CT-1)

1. Clamp-On Design Current Transformer (for Motor Current Sensing)

2. Range: 1-10 amps minimum, 20-200 amps maximum

3. Trip Point: Adjustable

4. Output: 0-5 Vdc or 0-10 Vdc,

5. Accuracy: ±0.2% from 20 to 100 Hz.

6. Amperage range sizing and switch settings in accordance with the following and per manufacturer's instructions:

Motor HP	120V	277V	480V
≤1/2	0-10A	0-10A	−
3/4 – 1.5	−	0-10A	0-10A
2 – 5	−	−	0-10A
7.5 − 10	−	−	0-20A
15 − 20	−	−	0-30A
25 − 30	−	−	0-40A

7. Manufacturers

    a. Veris Hx22 series

    b. Kele SC100

    c. Or equal

K. Electric Control Components

1. Control Relays: All control relays shall be UL listed, with contacts rated for the application, and mounted in minimum NEMA-1 enclosure for indoor locations, NEMA-4 for outdoor locations.

    a. Control relays for use on electrical systems of 120 volts or less shall have, as a minimum, the following:

        1) AC coil pull-in voltage range of +10%, -15% or nominal voltage.

        2) Coil sealed volt-amperes (VA) not greater than 4 VA.

        3) Silver cadmium Form C (SPDT) contacts in a dustproof enclosure, with 8 or 11 pin type plug.

        4) Pilot light indication of power-to-coil and coil retainer clips.

    b. Relays used for across-the-line control (start/stop) of 120V motors, 1/4 HP, and 1/3 HP, shall be rated to break minimum 10 Amps inductive load.

    c. Relays used for stop/start control shall have low voltage coils (30 VAC or less), and shall be provided with transient and surge suppression devices at the controller interface.

2. General Purpose Power Contactors: NEMA ICS 2, AC general-purpose magnetic contactor. ANSI/NEMA ICS 6, NEMA type 1 enclosure. Manufacturer shall be Square D, Cutler-Hammer, or equal.

3. Control Transformers and Power Supplies

    a. Control transformers shall be UL Listed. Furnish Class 2 current-limiting type, or furnish over-current protection in both primary and secondary circuits for Class 2 service per NEC requirements. Mount in minimum NEMA-1 enclosure.

    b. Transformer shall be proper size for application. Limit connected loads to 80% of rated capacity.

    c. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100 microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection, and shall be able to withstand a 150% current overload for at least 3 seconds without trip-out or failure.

    d. Separate power transformer shall be used for controllers and for actuators and other end devices that use half wave rectification.

    e. 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.

    f. Line voltage units shall be UL Recognized and CSA Approved.

4. Electric Push Button Switch: Switch shall be momentary contact, oil tight, push button, with number of N.O. or N.C. contacts as required. Contacts shall be snap-action type, and rated for minimum 120 Vac operation. Switch shall be 800T type, as manufactured by Allen Bradley, Kele, or equal.

5. Pilot Light: Panel-mounted pilot light shall be NEMA ICS 2 oil tight, transformer type, with screw terminals, push-to-test unit, LED type, rated for 120 VAC. Unit shall be 800T type, as manufactured by Allen-Bradley, Kele, or equal.

2.10 DAMPERS

A. Volume Dampers

1. Conform to requirements of SMACNA HVAC Duct Construction Standards.

2. General

a. Blades of same material as duct where damper is located

b. Damper Hardware

1) Ventlok 400 and 4000 series or equal; for low pressure systems 2 inch SMACNA pressure class and less

c. Bearing at one end of damper rod: Ventlok No. 609 or equal

d. Sealed bushings installed at both ends to avoid duct leakage

e. Accessible quadrant at other end of damper rod

1) With lever and lock screw: Ventlok No. 635 or equal

3. Multi-blade Dampers

a. Low Pressure/Low Velocity Systems (2 inch water column or less static pressure class and 1500 fpm or less face velocity)

1) Opposed blade damper

2) Ruskin Model CD35 or equal

2.11 DIFFUSERS

A. MANUFACTURERS

1. Named manufacturer model numbers used as example of item and establish minimum level of quality and minimum standard options. Equivalent models of listed manufacturers are acceptable.

2. Price

3. Titus

4. Krueger

5. Nailor

6. Or equal

B. GENERAL

1. Diffuser frame

   a. No visible screw allowed on diffusers or frames, unless otherwise indicated on Drawings or in this Section.

2. Outlets may be steel or aluminum.

3. Color

   a. Face and frame:

      1) General: Factory-baked #26 white enamel

   b. Internal parts of grille visible from occupied space, including all visible parts behind the diffuser face such as pattern controllers, back pans of perforated diffusers, and visible parts of plenums: flat black

C. STYLES

1. Sidewall

   a. Price 500 series

   b. Return/exhaust

      1) Parallel fixed blades set at a deflection of 45 degrees or 0 degrees from horizontal as scheduled

   c. Drywall frame with concealed fasteners

2.12 CALIBRATION & TESTING INSTRUMENTATION

A. Provide instrumentation required to verify readings, calibrate sensors, and test the system and equipment performance.

B. All equipment used for testing and calibration shall be NIST/NBS traceable and calibrated within the preceding 6-month period. Certificates of calibration shall be submitted.

C. Test equipment used for testing and calibration of field devices shall be at least twice as accurate as respective field device (for example if field device is ±0.5% accurate, test equipment shall be ±0.25% accurate over same range).

2.13 SOFTWARE

A. General

1. System software shall be the latest version of ALC WebCTRL.

B. Licensing

1. Include licensing and hardware keys for all software packages at all workstations (OWSs and POTs) and servers.

2. Within the limitations of the server, provide licenses for any number of users to have web access to the CSS at any given time.

3. All operator interface, programming environment, networking, database management and any other software used by the Contractor to install the system or needed to operate the system to its full capabilities shall be licensed and provided to the College.

4. All operator software, including that for programming and configuration, shall be available on all workstations. Hardware and software keys to provide all rights shall be installed on all workstations.

C. Graphical User Interface Software

1. Graphics

a. The GUI shall make extensive use of color in the graphic pane to communicate information related to setpoints and comfort. Animated graphics and active setpoint graphic controls shall be used to enhance usability.

b. Graphics tools used to create Web Browser graphics shall be non-proprietary and provided and installed on each OWS.

c. Graphical display shall be 1280 x 1024 pixels or denser, 256 color minimum.

d. Links

1) Graphics shall include hyperlinks which when selected (clicked on with mouse button) launch applications, initiate other graphics, etc.

2) Screen Penetration: Links shall be provided to allow user to navigate graphics logically without having to navigate back to the home graphic. See additional discussion in Paragraph 3.12E.

3) Information Links

a) On each MEP system and subsystem graphic, provide links to display in a new window the information listed below.

1. English-language as-built control sequence associated with the system. See Paragraph 1.10B.

2. O&M and submittal information for the devices on the graphic. See Paragraph 1.10B. This includes links to electronic O&M and submittal information for mechanical equipment.

b) The display shall identify the target of the link by file name/address.

c) Information shall be displayed in electronic format that is text searchable.

d) Window shall include software tools so that text, model numbers, or point names may be found. Source documents shall be read-only (not be editable) with this software.

e. Point Override Feature

1) Every real output or virtual point displayed on a graphic shall be capable of being overridden by the user (subject to security level access) by mouse point-and-click from the graphic without having to open another program or view.

2) When the point is selected to be commanded

a) Dialog box opens to allow user to override the point (Operator Mode) or release the point (Automatic Mode). Operator Mode will override automatic control of the point from normal control programs.

b) Dialog box shall have buttons (for digital points) or a text box or slide bar (for analog points) to allow user to set the point's value when in operator mode. These are grayed out when in automatic mode.

c) When dialog box is closed, mode and value are sent to controller.

d) Graphic is updated upon next upload scan of the actual point value.

3) A list of points that are currently in an operator mode shall be available through menu selection.

f. Point override status (if a digital point is overridden by the supervised manual override per Paragraph 2.3A or if a point is in operator mode per Paragraph 2.13C.1.e) shall be clearly displayed on graphics for each point, such as by changing color or flag.

g. The color of symbols representing equipment shall be able to change color or become animated based on status of binary point to graphically represent on/off status.

2. Alarms

a. ALC WebCTRL Enterprise Integration advanced alarm package configured as indicated below.

3. Trends

a. ALC WebCTRL Enterprise Integration trend package configured as indicated below.

b. Trend Data Storage

1) The database shall allow applications to access the data while the database is running. The database shall not require shutting down in order to provide read-write access to the data. Data shall be able to be read from the database without interrupting the continuous storage of trend data being carried by the BAS using SQL queries.

2) Data shall be stored in an SQL compliant database format and shall be available through the College’s intranet or internet (with appropriate security clearance) without having to disable BAS access to the database.

3) The database shall not be inherently limited in size, e.g. due to software limitations or lack of a correct license. Database size shall be limited only by the size of the provided storage media (hard drive size).

4. Security Access

a. Standard ALC WebCTRL security package

5. Report Software

a. ALC WebCTRL Enterprise Integration advanced reporting package.

b. Standard reports. Prepare the following standard reports, accessible automatically without requiring definition by user.

1) Tenant or department after-hour usage. System must be capable of monitoring tenant override requests and generating a monthly report showing the daily total time in hours that each tenant has requested after-hours HVAC services.

2) Monthly and annual energy usage and cost. See Utility cost calculation in Paragraph 3.12.

3) Alarm events and status.

4) Points in Hand (Operator Override) via Workstation command (including name of operator who made the command) or via supervised HOA switch at output, including date and time.

D. Control Programming Software

1. Standard ALC WebCTRL Eikon programming.

E. Miscellaneous Software

1. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide relevant data for the application or object that help is being called from.

2. Provide software for viewing (but not editing) electronic versions of as-built shop drawings of

a. Mechanical, electrical, and plumbing systems in Adobe pdf format

b. BAS drawings in Adobe pdf format

3. Automatic Demand Response (ADR) Control Software

a. Provide ALC WebCTRL Automated Demand Response Add-on or other certified OpenADR 2.0a or OpenADR 2.0b Virtual End Node (VEN) software, as specified under Clause 11, Conformance, in the applicable OpenADR 2.02 Specification.

b. The software shall allow OpenADR communication from PG&E's Demand Response Automation Server through the College's LAN to the CSS.

2.14 CONTROL POINTS

A. Table Column Definitions

1. Point description

2. Type (number in point schedule after each type refers to tag on schematics)

a. AO: analog output

b. AI: analog input

c. DO: digital or binary output

d. DI: digital or binary input

3. Device description

a. See Paragraph 2.9 for device definition.

4. Trend Logging

a. Commissioning: Where listed, point is to be trended at the basis listed for commissioning and performance verification purposes.

b. Continuous: Where listed, point is to be trended at the basis listed continuously, initiated after system acceptance, for the purpose of future diagnostics.

c. Trend Basis

1) Where range of engineering units is listed, trend on a change of value (COV) basis (in other words record time stamp and value when point value changes by engineering unit listed).

2) Where time interval is listed, trend on a time basis (in other words record time stamp and value at interval listed). All points relating to a specific piece of equipment shall be trended at the same initiation time of day so data can be compared in text format.

5. Calibration

a. F = factory calibration only is required (no field calibration)

b. HH = field calibrate with handheld device. See Paragraph 3.15C.6.a.2)

B. Note that points lists below are for each system of like kind. Refer to drawings for quantity of each.

C. Points mapped through gateways and network interfaces. Note that points listed herein are intended to indicate the level of effort required for point mapping for bid purposes; the points lists are not exclusive and exhaustive. The exact point names and types may vary since the points available vary by equipment manufacturer and model. A final list of available points must be obtained from the manufacturer during the shop drawing development phase. If the available points differ from the points lists herein, the desired points to be mapped shall be confirmed by the Engineer prior to issuing Submittal Package 2. Unless the quantity of points is significantly different from those shown herein, the changes shall be made at no additional costs to the College.

1. Variable speed drives

Description	**Type**	**Device**	**Trend Logging**		**Calibra-tion**
			Comm-issioning	**Contin-uous**	
Fault reset	DO	Through network	COV	COV	–
On/off status	DI	Through network	COV	COV	–
Fault (critical alarm)	DI	Through network	COV	COV	–
Minor alarm	DI	Through network	COV	COV	–
Fault text	AI	Through network (convert code to plain English text)	COV	COV	–
Alarm text	AI	Through network (convert code to plain English text)	COV	COV	–
Keypad in hand/auto	DI	Through network	COV	COV	–
Minimum frequency setpoint	AO	Through network	±5%	±5%	–
Maximum frequency setpoint	AO	Through network	±5%	±5%	–
Acceleration rate	AO	Through network	±5%	±5%	–
Deceleration rate	AO	Through network	±5%	±5%	–
Actual frequency	AI	Through network	1 min	15 min	–
DC bus voltage	AI	Through network	±10%	±10%	F
AC output voltage	AI	Through network	±10%	±10%	F
Current	AI	Through network	15 min	60 min	F
VFD temperature	AI	Through network	60 min	60 min	F
Power, kW	AI	Through network	1 min	15 min	F
Energy, MWh	AI	Through network	15 min	60 min	–

D. Hardwired Points

1. VAV Box with reheat (existing DDC)

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Supply Airflow	AI	DPT-5 connected to existing flow cross	X		1 min	15 min	HH (see §230593)
Discharge Air Temperature	AI	(E) sensor			1 min	15 min	
Zone Temperature	AI	TS-3x – where applicable (see Paragraph 2.9F).	X		1 min	15 min	
VAV Box Damper Position	AO	Modulating actuator			1 min	15 min	
HW valve signal	AO	(E) valve and actuator			1 min	15 min	
Zone Occupancy Status	DI	TS-3x – where applicable (see Paragraph 2.9F).	X	X	COV	COV	
Local Override	DI	TS-3x – where applicable (see Paragraph 2.9F).	X	–	COV	COV	–
Zone Temperature Setpoint Adjustment	AI	TS-3x – where applicable (see Paragraph 2.9F).	X	–	15 min	60 min	F
Zone CO_2 Concentration	AI	TS-3xC – where applicable (see Paragraph 2.9F).	X	–	5 min	15 min	F

2. VAV Box with reheat (existing pneumatic)

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Supply Airflow	AI	DPT-5 connected to existing flow cross	X	X	1 min	15 min	
Discharge Air Temperature	AI	TS-1A	X	X	1 min	15 min	F
Zone Temperature	AI	TS-3x – where applicable (see Paragraph 2.9F).	X	X	1 min	15 min	F
VAV Box Damper Position	AO	Modulating actuator	X	X	1 min	15 min	
HW valve signal	AO	New 2-way valve and electric actuator	X	X	1 min	15 min	
Zone Occupancy Status	DI	TS-3x – where applicable (see Paragraph 2.9F).	X	X	COV	COV	
Local Override	DI	TS-3x – where applicable (see Paragraph 2.9F).	X	X	COV	COV	–
Zone Temperature Setpoint Adjustment	AI	TS-3x – where applicable (see Paragraph 2.9F).	X	X	15 min	60 min	F
Zone CO_2 Concentration	AI	TS-3xC – where applicable (see Paragraph 2.9F).	X	X	5 min	15 min	

3. VAV Air Handler with Return Fan (AHU-8)

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Supply Fan Start/Stop	DO	Connect to VFD run			COV	COV	
Return Fan Start/Stop	DO	Connect to VFD run			COV	COV	
Return Fan High Static Alarm Reset	DO	Dry contact to 120V or 24V control circuit		X	COV	COV	–
Supply Fan High Static Alarm Reset	DO	Dry contact to 120V or 24V control circuit	X	X	COV	COV	–
CHW Pump Start/Stop	DO	(E) motor starter			COV	COV	
Supply Fan Speed	AO	Connect to VFD speed			1 min	15 min	
Return Fan Speed	AO	Connect to VFD speed			1 min	15 min	
Outside Air Damper	AO	(E) actuator			1 min	15 min	
Return Air Damper	AO	(E) actuator			1 min	15 min	
Exhaust Air Damper	AO	(E) actuator			1 min	15 min	
Chilled Water Valve	AO	(E) actuator			1 min	15 min	
Hot Water Valve	AO	(E) actuator			1 min	15 min	
Supply Fan 1 Status	DI	Connect to (E) current switch			COV	COV	
Supply Fan 2 Status	DI	Connect to (E) current switch			COV	COV	
Supply Fan 3 Status	DI	Connect to (E) current switch			COV	COV	
Supply Fan 4 Status	DI	Connect to (E) current switch			COV	COV	
Supply Fan VFD Fault	DI	Connect to VFD fault			COV	COV	
Return Fan 1 Status	DI	Connect to (E) current switch			COV	COV	
Return Fan 2 Status	DI	Connect to (E) current switch			COV	COV	
Return Fan 3 Status	DI	Connect to (E) current switch			COV	COV	
Return Fan 4 Status	DI	Connect to (E) current switch			COV	COV	
Return Fan VFD Fault	DI	Connect to VFD fault			COV	COV	
CHW Booster Pump Status	DI	Connect to (E) current switch			COV	COV	
Supply Air Temperature	AI	(E) sensor			1 min	15 min	
Mixed Air Temperature	AI	(E) sensor			1 min	15 min	
Outside Air Temperature	AI	(E) sensor			1 min	15 min	
Return Air Temperature	AI	(E) sensor			1 min	15 min	
Supply Airflow	AI	(E) sensor			1 min	15 min	
Outside Airflow	AI	(E) sensor			1 min	15 min	
Return Airflow	AI	(E) sensor			1 min	15 min	
Supply Duct Static Pressure	AI	(E) sensor			1 min	15 min	

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Building Static Pressure, Room 257	AI	(E) sensor			1 min	15 min	
Building Static Pressure, Room 710	AI	(E) sensor			1 min	15 min	
Return Fan Static Pressure	AI	DPT-3, 0 to 1 inches	X	X	1 min	15 min	F
Filter Pressure Drop	AI	(E) sensor			-	60 min	
Return Fan VFD Feedback	AI	Connect to VFD speed feedback			1 min	15 min	
Supply Fan VFD Feedback	AI	Connect to VFD speed feedback			1 min	15 min	

4. Air-conditioning Unit (typ of two, serving Rms 253 and 1024)

   a. Provide and install Mitsubishi PAC-US444CN-1 thermostat adapter interface and ALC OptiPoint BACnet Plus thermostat for existing Mitsubishi AC units.

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Start Fan	DO	(N) thermostat card	X		COV	COV	–
Cooling	DO	(N) thermostat card	X		COV	COV	–
Supply fan status	DI	(N) thermostat card	X		COV	COV	–
Supply air temperature	AI	TS-1A	X		1 min	15 min	F
Zone Temperature	AI	ALC OptiPoint BACnet Plus	X		1 min	15 min	F

5. Single Speed Exhaust Fans (EF-131)

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Fan Start/Stop	DO	Dry contact to 120V starter control circuit	X	X	COV	COV	–
Fan Status	DI	CS-1 OR CT-1	X	X	COV	COV	See 3.11F

PART 3 EXECUTION

3.1 INSTALLATION - GENERAL

A. Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details indicated on Drawings.

B. Coordinate Work and Work schedule with other trades prior to construction.

C. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.2 DELIVERY, STORAGE, AND HANDLING

A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons during shipping, storage and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment.

B. Store equipment and materials inside and protect from weather.

3.3 IDENTIFICATION

A. General

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

2. Identifiers shall match record documents.

3. All plug-in components shall be labeled such that removal of the component does not remove the label.

B. Wiring and Tubing

1. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 2 inches of termination with the BAS address or termination number.

2. Permanently label or code each point of field terminal strips to show the instrument or item served.

3. All pneumatic tubing shall be labeled at each end within 2 inches of termination with a descriptive identifier.

C. Equipment and Devices

1. Valve and damper actuators: None required.

2. Sensors: Provide 1 inch x 3 inches x 1/8 inches black micarta or lamacoid labels with engraved white lettering, ¼ inches high. Indicate sensor identifier and function (for example "CHWS Temp").

3. Panels

a. Provide 2 inches x 5 inches 1/8 inches black micarta or lamacoid labels with engraved white lettering, ½ inches high. Indicate panel identifier and service.

b. Provide permanent tag indicating the electrical panel and circuit number from which panel is powered.

4. Identify room sensors relating to terminal box or valves with indelible marker on sensor hidden by cover.

3.4 CUTTING, CORING, PATCHING AND PAINTING

A. Penetrations through rated walls or floors shall be filled with a listed material to provide a code compliant fire-stop.

B. All damage to and openings in ductwork, piping insulation, and other materials and equipment resulting from Work in this Section shall be properly sealed, repaired, or re-insulated by experienced mechanics of the trade involved. Repair insulation to maintain integrity of insulation and vapor barrier jacket. Use hydraulic insulating cement to fill voids and finish with material matching or compatible with adjacent jacket material.

C. Where work is to be done above inaccessible ceilings, cut new openings as necessary, provide access doors for future, and repair and paint to original finish.

D. At the completion of Work, all equipment furnished under this Section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired and repainted to original finish.

3.5 CLEANING

A. Clean up all debris resulting from its activities daily. Remove all cartons, containers, crates, and other debris generated by Work in this Section as soon as their contents have been removed. Waste shall be collected and legally disposed of.

B. Materials stored on-site shall be protected from weather and stored in an orderly manner, neatly stacked, or piled in the designated area assigned by the College’s Representative.

C. At the completion of work in any area, clean all work and equipment of dust, dirt, and debris.

D. Use only cleaning materials recommended by the manufacturer of the surfaces to be cleaned and on surfaces recommended by the cleaning material manufacturer.

3.6 CONTROLLERS

A. General

1. Install systems and materials in accordance with manufacturer’s instructions, specifications roughing-in drawings and details indicated on Drawings.

2. Regardless of application category listed below, each Control Unit shall be capable of performing the specified sequence of operation for the associated equipment. Except as listed below, all physical point data and calculated values required to accomplish the sequence of operation shall reside within the associated CU. Listed below are point data and calculated values that shall be allowed to be obtained from other CUs via LAN.

a. Global points such as outdoor air temperature

b. Requests, such as heat/cool requests, used to request operation or for setpoint reset from zones to systems and systems to plants

c. Modes, such as system modes, used to change operating logic from plants to systems and systems to zones

3. Where associated control functions involve functions from different categories identified below, the requirements for the most restrictive category shall be met.

B. Controller Application Categories

1. Controllers shall comply with the application table below (X under controller type indicates acceptable controller type).

Application Category	Examples	Acceptable Controller		
		ASC	AAC	BC
0	Monitoring of variables that are not used in a control loop, sequence logic, or safety, such as status of sump pumps or associated float switches, temperatures in monitored electrical rooms.	X	X	X
1	Miscellaneous heaters Constant speed exhaust fans and pumps	X	X	X
2	Fan Coil Units Terminal Units (such as VAV Boxes) Unitary AC and HP units	X		
3	"Slow" Lab Zone –Non-Hood Dominated	X (note 1)	X	X
4	Air Handling Units Central Hot Water Plant "Fast" Lab Zone –Hood Dominated Air-Cooled Chilled Water Plant		X (note 1)	X
5	Water-Cooled Chilled Water Plant			X
Notes: Controller may be used only if all control functions and physical I/O associated with a given unit resides in one AAC/ASC				

2. ASC Installation

a. ASCs that control equipment located above accessible ceilings shall be mounted on the equipment in an accessible enclosure and shall be rated for plenum use if ceiling attic is used as a return air plenum.

b. ASCs that control equipment mounted in a mechanical room may either be mounted in or on the equipment, or on the wall of the mechanical room at an adjacent, accessible location.

c. ASCs that control equipment mounted outside or in occupied spaces shall either be located in the unit or in a proximate mechanical/utility space or NEMA1 enclosure.

3. AAC and BC Installation

a. AACs/BCs shall be located in a temperature control cabinets constructed per Paragraph 2.8.

3.7 COMMUNICATION DEVICES

A. General

1. Install systems and materials in accordance with manufacturer’s instructions, roughing-in drawings and details indicated on Drawings.

2. Provide all interface devices and software to provide an integrated system.

B. LANID and LAN Routers

1. Provide as required

2. Connect networks to both sides of device

3. Thoroughly test to ensure proper operation

4. Interruptions or fault at any point on any Primary LAN shall not interrupt communications between other nodes on the network. If a LAN is severed, two separate networks shall be formed and communications within each network shall continue uninterrupted. The system shall automatically monitor the operation of all network devices and annunciate any device that goes off-line because it is failing to communicate.

C. Gateways and Protocol Translators to Equipment Controllers

1. See Paragraph 2.4C for network connection of Gateways and Protocol Translators.

2. Wire to networks on both sides of device.

3. Map across all monitoring and control points listed in Paragraph 2.14C.

4. Thoroughly test each point to ensure that mapping is accurate.

5. Initiate trends of points as indication in Paragraph 2.14C.

3.8 CONTROL AIR TUBING

A. Sensor air tubing shall be sized by the Contractor.

B. All control air piping shall be concealed except in equipment rooms or unfinished areas.

C. Installation methods and materials

1. Concealed and Inaccessible: Use copper tubing or FR plastic in metal raceway. Exception: Room thermostat drops in stud walls in areas with lay-in ceiling may be FR plastic tubing.

2. Concealed and Accessible tubing (including ceiling return air plenums) shall be copper tubing or FR plastic tubing, subject to the following limitations

    a. FR tubing shall be enclosed in metal raceway when required by local code.

    b. Quantity of FR tubing per cubic foot of plenum space shall not exceed manufacturer's published data for Class 1 installation.

3. Exposed to view or damage: Use hard-drawn copper or FR plastic in metal raceway.

    a. Where copper tubing is used, a section 12 inches or less of FR plastic tubing is acceptable at final connection to control device.

D. Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum 1 inch sleeves, extended 6 inches above floors and 1 inch below bottom surface of slabs.

E. Pneumatic tubing shall not be run in raceway containing electrical wiring.

F. Where FR tubing exits the end of raceway or junction box, provide a snap-in nylon bushing. Where pneumatic tubing exits control panels, provide bulkhead fittings. Where copper tubing exits junction boxes or panels, provide bulkhead fittings.

G. All tubing shall be number coded on each end and at each junction for easy identification.

H. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.

I. Piping above suspended ceilings shall be supported from or anchored to structural members or other piping or duct supports. Tubing shall not be supported by or anchored to electrical raceways or ceiling support systems.

J. Brass-barbed fittings shall be used at copper-to-FR tubing junctions. Plastic slipped-over copper tubing is not acceptable.

K. Number-code or color-code tubing, except local individual room control tubing, for future identification and servicing of control system. Code shall be as indicated on approved installation drawings.

3.9 CONTROL POWER

A. Power wiring and wiring connections required for Work in this Section shall be provided under this Section. Do not exclude this work – there is no other electrical contractor. Subcontract electrical work if required.

B. Extend power to all BAS devices, including 120V power to panels, from an acceptable power panel.

C. General requirements for obtaining power include the following:

1. Electrical service to controls panels and control devices shall be provided by isolated circuits, with no other loads attached to the circuit, clearly marked at its source. The location of the breaker shall be clearly identified in each panel served by it.

2. Obtain power from a source that feeds the equipment being controlled such that both the control component and the equipment are powered from the same panel. Where equipment is powered from a 460V source, obtain power from the electrically most proximate 120V source fed from a common origin.

3. Where control equipment is located inside a new equipment enclosure, coordinate with the equipment manufacturer and feed the control with the same source as the equipment. If the equipment's control transformer is large enough and of the correct voltage to supply the controls, it may be used. If the equipment's control transformer is not large enough or not of the correct voltage to supply the controls, provide separate transformer(s).

4. Where a controller controls multiple systems on varying levels of power reliability (normal, emergency, or interruptible), the controller, and any associated switches and devices necessary its operation, shall be powered by the highest level of reliability served.

D. Contractor shall provide transformers for all low voltage control devices including non-powered terminal units such as cooling-only VAV boxes and VAV boxes with hot water reheat. Transformer(s) shall be located in control panels in readily accessible locations such as Electrical Rooms.

E. Power line filtering. Provide transient voltage and surge suppression for all workstations and BCs either internally or as an external component.

3.10 CONTROL AND COMMUNICATION WIRING

A. Control and Signal Wiring

1. Line Voltage Wiring

a. All line-voltage wiring shall meet NEC Class 1 requirements.

b. All Class 1 wiring shall be installed in UL Listed approved raceway per NEC requirements and shall be installed by a licensed electrician.

c. Class 1 wiring shall not be installed in raceway containing pneumatic tubing.

2. Low Voltage Wiring

a. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.)

b. Class 2 wiring shall be installed in UL Listed approved raceway as follows:

1) Where located in unconcealed or inaccessible locations, such as:

a) Equipment rooms

b) Exposed to weather

c) Exposed to occupant view

d) Inaccessible locations such as concealed shafts and above inaccessible ceilings

2) Class 2 wiring shall not be installed in raceway containing Class 1 wiring.

c. Class 2 wiring need not be installed in raceway as follows:

1) Where located in concealed and easily accessible locations, such as:

a) Inside mechanical equipment enclosures and control panels

b) Above suspended accessible ceilings (e.g. lay-in and spline)

c) Above suspended drywall ceilings within reach of access panels throughout

d) In shafts within reach of access panels throughout

e) Nonrated wall cavities

2) Wiring shall be UL Listed for the intended application. For example, cables used in floor or ceiling plenums used for air transport shall be UL Listed specifically for that purpose.

3) Wiring shall be supported from or anchored to structural members neatly tied at 10 foot intervals and at least 1 foot above ceiling tiles and light fixtures. Support or anchoring from straps or rods that support ductwork or piping is also acceptable. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceilings.

4) Install wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

d. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two (for example relays and transformers).

3. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

4. All field wiring shall be properly labeled at each end, with self-laminating typed labels indicating device address, for easy reference to the identification schematic. All power wiring shall be neatly labeled to indicate service, voltage, and breaker source.

5. Use coded conductors throughout with different colored conductors.

6. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

7. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the Contractor shall provide step-down transformers.

8. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

9. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendation and NEC requirements.

10. Include one pull string in each raceway 1 inch or larger.

11. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

12. Conceal all raceways, except within mechanical, electrical, or service rooms, and to room temperature sensors mounted on concrete walls. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment (for example steam pipes or flues).

13. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

14. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.

15. Terminate all control or interlock wiring.

16. Maintain updated as-built wiring diagrams with terminations identified at the jobsite.

17. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than ½ inches electrical trade size shall not be used. In areas exposed to moisture liquid-tight, flexible metal raceways shall be used.

18. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings per code. Terminations must be made with fittings at boxes and ends not terminating in boxes shall have bushings installed.

19. Wire digital outputs to either the normally-closed or normally-open contacts of binary output depending on desired action in case of system failure. Unless otherwise indicated herein, wire to the NO contact except the following shall be wired to the NC contact

20. Hardwire Interlocks

a. The devices referenced in this Section are hardwire interlocked to ensure equipment shutdown occurs even if control systems are down. Do not use software (alone) for these interlocks.

b. Hardwire device NC contact to air handler fan starter upstream of HOA switch, or to VFD enable contact.

c. Where multiple fans (or BAS DI) are controlled off of one device and the device does not have sufficient contacts, provide a relay at the device to provide the required number of contacts.

d. Provide for the following devices where indicated on Drawings or in Sequences of Operation:

1) Duct smoke detector

2) High discharge static pressure

3) Low mixing plenum pressure

21. Shielded cable shield shall be grounded only at one end. Signal wiring shield shall be grounded at controller end only unless otherwise recommended by the controller manufacturer.

B. Communication Wiring

1. Adhere to the requirements of Paragraph 3.10A in addition to this Paragraph.

2. Communication and signal wiring may be run without conduit in concealed, accessible locations as permitted by Paragraph 3.10A only if noise immunity is ensured. Contractor is fully responsible for noise immunity and rewire in conduit if electrical or RF noise affects performance.

3. All cabling shall be installed in a neat and workmanlike manner. Follow all manufacturers' installation recommendations for all communication cabling.

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

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

6. Verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.

7. All runs of communication wiring shall be unspliced length when that length is commercially available.

8. All communication wiring shall be labeled to indicate origination and destination data.

9. Grounding of coaxial cable shall be in accordance with NEC regulations Article on Communications Circuits, Cable and Protector Grounding.

10. Power-line carrier signal communication or transmission is not acceptable.

3.11 SENSORS AND MISCELLANEOUS FIELD DEVICES

A. Install sensors in accordance with the manufacturer's recommendations.

B. Mount sensors rigidly and adequately for the environment within which the sensor operates.

C. Sensors used as controlled points in control loops shall be hardwired to the controller to which the controlled device is wired and in which the control loop shall reside.

D. Temperature Sensors

1. Room temperature sensors and thermostats shall be installed with back plate firmly secured to the wall framing or drywall anchors.

    a. For sensors mounted in exterior walls or columns, use a back plate insulated with foam and seal all junction box openings with mastic sealant.

    b. For sensors on exposed columns, use Wiremold or equal enclosures that are the smallest required to enclose wiring (e.g. Wiremold 400 BAC or equal) and Wiremold or equal junction boxes that are the narrowest required to enclose the temperature sensor and wiring connections (e.g. Wiremold 2348S/51 or equal). Color or raceway and boxes shall be per the architect; submit for approval prior to installation.

2. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.

3. Temperature sensors downstream of coils shall be located as far from the coil fins as possible, 12 inches minimum. Temperature sensors upstream of coils shall be a minimum of 6 inches away from the coil fins. No part of the sensor or its support elements or conduit shall be in contact with the coil, coil framing or coil support elements. Discharge temperature sensors on VAV boxes shall be mounted as far from the coil as possible but upstream of the first diffuser with the probe located as near as possible to the center of the duct both vertically and horizontally.

4. Unless otherwise noted on Drawings or Points List, temperature sensors/thermostats, CO_2 sensors, and other room wall mounted sensors shall be installed at same centerline elevation as adjacent electrical switches, 4 feet above the finished floor where there are no adjacent electrical switches, and within ADA limitations.

5. Unless otherwise noted on Drawings or Points List, install outdoor air temperature sensors on north wall where they will not be influenced by building exhaust, exfiltration, or solar insolation. Do not install near intake or exhaust air louvers.

E. Differential Pressure Sensors

1. Return Fan Discharge Plenum Pressure

    a. Mount transmitter in temperature control panel near or in BAS panel to which it is wired.

b. Low pressure port of the pressure sensor

1) Pipe to either

a) Building pressure (low) signal of the building static pressure transmitter.

b) Separate ambient static pressure probe located on the outside of the relief damper through a high-volume accumulator or otherwise protected from wind fluctuations.

c. High-pressure port of the pressure sensor

1) Pipe to the duct using a static pressure tip located at the discharge of the return fan.

2) Install pressure tips securely fastened with tip facing upstream in accordance with manufacturer's installation instructions.

2. High/Low Static Pressure Safeties

a. High static

1) Install DPS-2 on side of supply air duct in accessible location.

2) High port shall be open to supply air duct downstream of fan.

3) Reference low port pressure shall be that at DP location.

b. Low static

1) Install DPS-2 inside or outside of mixed air plenum whichever is most accessible.

2) Low port shall be open to mixed air plenum.

3) Reference high port pressure shall be pressure on other side of mixed air plenum with the highest pressure, e.g. ambient pressure for systems with relief fans or non-powered relief, or relief air plenum for systems with return fans.

3. All pressure transducers, other than those controlling VAV boxes, shall be located where accessible for service without use of ladders or special equipment. If required, locate in field device panels and pipe to the equipment monitored or ductwork.

4. The piping to the pressure ports on all pressure transducers (both air and water) shall contain a capped test port located adjacent to the transducer.

F. Current Switches and Current Transformers for Motor Status Monitoring

1. For CTs, create a software binary point for fan status triggered at a setpoint determined below and ~10% deadband.

2. Adjust the setpoint so that it is below minimum operating current and above motor no load current. For fans with motorized discharge dampers, adjust so that fan indicates off if damper is closed while fan is running. For pumps, adjust so that pump indicates off if valve is closed while pump is running.

G. Actuators

1. Type: All actuators shall be electric.

2. Mount and link control damper actuators per manufacturer’s instructions.

3. Control Valves: Install so that actuators, wiring, and tubing connections are accessible for maintenance. Where possible, mount the valve so that the position indicator is visible from the floor or other readily accessible location. However, do not install valves with stem below horizontal or down. The preferred location for the valve and actuator is on lowest point in the valve train assembly for ease of access and inspection. If this is on the coil supply piping, the control valve may be located there even if schematics (and standard practice) show valves located on the coil return piping. This comment applies to both 2-way valves and 3-way valves (which would become diverting valves rather than mixing valves in this location).

3.12 SOFTWARE INSTALLATION

A. System Configuration

1. Thoroughly and completely configure BAS system software, supplemental software, network software etc. on OWS, POTs, and servers.

B. Point Structuring and Naming

1. The intent of this Paragraph is to require a consistent means of naming points across the BAS. The following requirement establishes a standard for naming points and addressing Buildings, Networks, Devices, Instances, etc.

2. Point Summary Table

a. The term “Point” includes all physical I/O points, virtual points, and all application program parameters.

b. With each schematic, provide a Point Summary Table listing

1) Building number and abbreviation

2) System type

3) Equipment type

4) Point suffix

5) Full point name (see Point Naming Convention Paragraph)

6) Point description

7) Ethernet backbone network number

8) Network number

9) Device ID

10) Device MAC address

11) Object ID (object type, instance number)

12) Engineering units

13) Device make and model number; include range of device if model number does not so identify.

14) Device physical location description; include floor and column line intersection to one decimal place (for example line 6.2 and line A.3).

c. Point Summary Table shall be provided in both hard copy and in a relational database electronic format (ODBC-compliant).

d. Coordinate with the College's representative and compile and submit a proposed Point Summary Table for review prior to any object programming or Project startup.

e. The Point Summary Table shall be kept current throughout the duration of the Project by the Contractor as the Master List of all points for the Project. Project closeout documents shall include an up-to-date accurate Point Summary Table. The Contractor shall deliver to the College the final Point Summary Table prior to final acceptance of the system. The Point Summary Table shall be used as a reference and guide during the commissioning process.

3. Point Naming Convention

a. All point names shall adhere to the format as established below, unless otherwise agreed to by the College. New categories and descriptors may be created with approval of the College.

b. Format:

1) Building.Category.System.EquipmentTag.Component.Property.

2) Example: 001.HVAC.Heatplant.B-1.HWS.Temperature

Building	Category	System	Equipment Tag	Component	Property	Typical units
Building number	ELCT	Lighting Plug Generator Misc	(from equipment schedules)	SWITCH PHOTO CB	Command Status Light Power	On/off On/off Footcandles Watts

Building	Category	System	Equipment Tag	Component	Property	Typical units
		Airhandling		CWS	Voltage	Volts
		Exhaust		CWR	Current	Amps
	HVAC	Heatplant		HWS	ValvePos	%open
		Coolplant		HWR	DamperPos	%open
		Misc		CHWS	Temperature	°F
	PLMB	Domwater		CHWR	Humidity	%RH
		Air		OA	Pressure	Psig, “H_2O
		Natgas		SA	Flow	Cfm, gpm
		N2		RA	Energy	Btu
		O2		EA	Speed	%, Hz
		Irrigation			Signal	%
		Waste		GAS		
		Misc		FLUID		
	MISC	Weather				

4. Device Addressing Convention

    a. BACnet network numbers and Device Object IDs shall be unique throughout the network.

    b. All assignment of network numbers and Device Object IDs shall be coordinated with the College to ensure there are no duplicate BACnet device instance numbers.

    c. Each Network number shall be unique throughout all facilities and shall be assigned in the following manner: VVVNN, where: VVV = 0-999 for BACnet Vendor ID, NN = 00 - 99 for building network.

    d. Each Device Object Identifier property shall be unique throughout the system and shall be assigned in the following manner: VVVNNDD , where: VVV = number 0 to 999 for BACnet Vendor ID , NN = 00 - 99 for building network, DD = 01-99 for device address on a network.

    e. Coordinate with the College or a designated representative to ensure that no duplicate Device Object IDs occur.

    f. Alternative Device ID schemes or cross-project Device ID duplication if allowed shall be approved before Project commencement by the College.

5. I/O Point Physical Description

    a. Each point associated with a hardware device shall have its BACnet long-name point description field filled out with:

        1) The device manufacturer and model number. Include range of device if model number does not so identify.

        2) For space sensors, include room number in which sensor is located.

C. Point Parameters

1. Provide the following minimum programming for each analog input

   a. Name

   b. Address

   c. Scanning frequency or COV threshold

   d. Engineering units

   e. Offset calibration and scaling factor for engineering units

   f. High and low value reporting limits (reasonableness values), which shall prevent control logic from using shorted or open circuit values.

   g. Default value to be used when the actual measured value is not reporting. This is required only for points that are transferred across the Primary or Secondary networks and used in control programs residing in control units other than the one in which the point resides. Events causing the default value to be used shall include failure of the control unit in which the point resides or failure of any network over which the point value is transferred.

2. Provide the following minimum programming for each analog output

   a. Name

   b. Address

   c. Engineering units

   d. Offset calibration and scaling factor for engineering units

   e. Output Range

   f. Default value to be used when the normal controlling value is not reporting.

3. Provide the following minimum programming for each digital input

   a. Name

   b. Address

   c. Engineering units (on/off, open/closed, freeze/normal, etc.)

   d. Debounce time delay

   e. Message and alarm reporting as specified

   f. Reporting of each change of state, and memory storage of the time of the last change of state

g. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

4. Provide the following minimum programming for each digital output

a. Name

b. Address

c. Output updating frequency

d. Engineering units (on/off, open/closed, freeze/normal, etc.)

e. Direct or Reverse action selection

f. Minimum on-time

g. Minimum off-time

h. Status association with a DI and failure alarming (as applicable)

i. Reporting of each change of state, and memory storage of the time of the last change of state.

j. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

k. Default value to be used when the normal controlling value is not reporting.

D. Site-Specific Application Programming

1. All site specific application programming shall be written in a manner that will ensure programming quality and uniformity. Contractor shall ensure:

a. Programs are developed by one programmer, or a small group of programmers with rigid programming standards, to ensure a uniform style.

b. Programs for like functions are identical, to reduce debugging time and to ease maintainability.

c. Programs are thoroughly debugged before they are installed in the field.

2. Massage and tune application programming for a fully functioning system. It is the Contractor's responsibility to request clarification on sequences of operation that require such clarification.

3. All site-specific programming shall be fully documented and submitted for review and approval

a. Prior to downloading into the panel (see Submittal Package 2, Paragraph 1.7.)

b. At the completion of functional performance testing, and

c. At the end of the warranty period (see Warranty Maintenance, Paragraph 1.14).

4. All programming, graphics and data files must be maintained in a logical system of directories with self-explanatory file names. All files developed for the Project will be the property of the College and shall remain on the workstations/servers at the completion of the Project.

E. Graphic Screens

1. All site specific graphics shall be developed in a manner that will ensure graphic display quality and uniformity among the various systems.

2. Schematics of MEP systems

a. Schematics shall be 2-D or 3-D and shall be based substantially on the schematics provided on Drawings.

b. All relevant I/O points and setpoints being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units. Include appropriate engineering units for each displayed point value. Verbose names (English language descriptors) shall be included for each point on all graphics; this may be accomplished by the use of a pop-up window accessed by selecting the displayed point with the mouse.

c. Animation or equipment graphic color changes shall be used to indicate on/off status of mechanical components.

d. Indicate all adjustable setpoints and setpoint high and low limits (for automatically reset setpoints), on the applicable system schematic graphic or, if space does not allow, on a supplemental linked-setpoint screen.

3. Displays shall show all points relevant to the operation of the system, including setpoints.

4. The current value and point name of every I/O point and setpoint shall be shown on at least one graphic and in its appropriate physical location relative to building and mechanical systems.

5. Show weather conditions (local building outside air temperature and humidity) in the upper left hand corner of every graphic.

6. CAD Files: The contract document drawings will be made available to the Contractor in AutoCAD format upon request for use in developing backgrounds for specified graphic screens, such as floor plans and schematics. However the College does not guarantee the suitability of these drawings for the Contractor’s purpose.

7. Provide graphics for the following as a minimum

a. Site homepage: Background shall be a campus map, approximately to scale. Include links to each building, central plant, etc.

b. Building homepage: Background shall be a building footprint, approximately to scale, oriented as shown on the campus homepage. Include links to each floor and mechanical room/area, and to summary graphics described below.

c. Each occupied floor plan, to scale

1) HVAC: Floor plan graphics shall show heating and cooling zones throughout the buildings in a range of colors, which provide a visual display of temperature relative to their respective setpoints. The colors shall be updated dynamically as a zone's actual comfort condition changes. In each zone, provide links to associated terminal equipment.

2) If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views or plan views as necessary to graphically indicate the location of all of the larger scale floor plans. Link graphic building key plan to larger scale partial floor plans. Provide links from each larger scale graphic floor plan screen to the building key plan and to each of the other graphic floor plan screens.

d. Each equipment floor/area plan: To scale, with links to graphics of all BAS controlled/monitored equipment.

e. Each air handler: Provide link to associated HW and CHW plants where applicable.

f. Each trim & respond reset: Next to the display of the setpoint that is being reset, include a link to page showing all trim & respond points (see Section 259000) plus the current number of requests, current setpoint, and status indicator point with values "trimming," "responding," or "holding." Include a graph of the setpoint trend for the last 24 hours. Trim & respond points shall be adjustable from the graphic except for the associated device.

g. Each zone terminal

1) See Sample Graphics – VAV Reheat Zone

2) Include a non-editable graphic (picture) showing the design airflow setpoints from the design drawings adjacent to the editable airflows setpoints. The intent is that the original setpoints be retained over time despite "temporary" adjustments that may be made over the years.

h. Summary graphics: Provide a single text-based page (or as few as possible) for each of the following summary screens showing key variables listed in columns for all listed equipment. Include hyperlinks to each zone imbedded in the zone tag:

1) Air handling units: operating mode; on/off status; supply air temperature; supply air temperature setpoint; fan speed; duct static pressure; duct static pressure setpoint; outdoor air and return air damper position; coil valve positions; etc. (all key operating variables); Cooling CHWST Reset current requests, cumulative %-request-hours, and request Importance Multiplier; Heating HWST Reset current requests, cumulative %-request-hours, and request Importance Multiplier (if HW coil)

2) Zone Groups

a) Separate zone terminal summary for each Zone Group.

b) See Sample Graphics –Zone Group Summary

3) VAV Zone terminal units: operating mode; airflow rate; airflow rate setpoint; zone temperature; active heating setpoint; active cooling setpoint; damper position; HW valve position (reheat boxes); supply air temperature (reheat boxes); supply air temperature setpoint (reheat boxes); CO2 concentration and CO2 loop output (where applicable); Static Pressure Reset current requests, cumulative %-request-hours, and request Importance Multiplier; Cooling SAT Reset current requests, cumulative %-request-hours, and request Importance Multiplier; Heating HWST Reset current requests, cumulative %-request-hours, and request Importance Multiplier (HW reheat).

i. For all equipment with runtime alarms specified, show on graphic adjacent to equipment the current runtime, alarm setpoint (adjustable), alarm light, date of last runtime counter reset, and alarm reset/acknowledge button which resets the runtime counter.

j. For all equipment with lead/lag or lead/standby operation specified, show on graphic adjacent to equipment the current lead/lag order and manual buttons or switches to allow manual lead switching by the operator per Section 259000 Building Automation Sequences of Operation.

k. For all controlled points used in control loops, show the setpoint adjacent to the current value of the controlled point.

l. All other BAS controlled/monitored equipment.

m. On all system graphics, include a “note” block that allows users to enter comments relevant to system operation.

n. All equipment shall be identified on the graphic screen by the unit tag as scheduled on the drawings.

F. Alarm Configuration

1. Program alarms and alarm levels per Sequence of Operations.

2. Each programmed alarm shall appear on the alarm log screen and shall be resettable or acknowledged from those screens. Equipment failure alarms shall be displayed on the graphic system schematic screen for the system that the alarm is associated with (for example, fan alarm shall be shown on graphic air handling system schematic screen). For all graphic screens, display values that are in a Level 1 or 2 condition in a red color, Level 3 and higher alarm condition in a blue color, and normal (no alarm) condition in a neutral color (black or white).

3. For initial setup, Contractor shall configure alarms as follows:

	Level 1	**Level 2**	**Level 3**	**Level 4**
Criticality	Critical	Not Critical	Not Critical	Not Critical
Acknowledgement	Required	Required	Not Required	Not Required
Acknowledgement of Return to Normal	Not Required	Not Required	Not Required	Not Required
Email to building engineer(s)	Y	Y	Y	N
SMS text to building engineer(s)	Y	Y	N	N
Pop-up dialog box on OWS	Y	Y	N	N
Remove from alarm log	After Acknowledged	After Acknowledged	After 2 weeks	After 2 weeks

3.13 SEQUENCES OF OPERATION

A. See Section 259000 Building Automation Sequences of Operation.

3.14 TESTING, ADJUSTING, AND BALANCING

A. Testing, adjusting, and balancing (TAB) shall be performed in complete accordance with AABC or NEBB National Standards for Field Measurements and Instrumentation as applicable to air distribution and hydronic systems.

B. Submittals

1. Submit documentation that demonstrates

a. Contractor is a member of AABC, NEBB, or TABB

b. Contractor has satisfactorily balanced at least three systems of comparable type and size

2. Pre-Test Submittal

a. At least 30 days prior to starting field work, submit the following:

1) Set of final report forms

a) Complete with design conditions of all equipment and design flow rates for all equipment and devices to be tested.

b) Forms shall include blank entry space for all data requested in this Section. Carefully review requested data; standard balancing forms may not be acceptable.

c) Forms shall be in acceptable word-searchable electronic format.

2) Complete list of instruments proposed to be used

a) Organize in appropriate categories

b) Include data sheets for each

c) Show

1. Manufacturer and model number

2. Description and use when needed to further identify instrument

3. Size or capacity range

4. Latest calibration date

3) Provide certification that

a) All instruments have been calibrated prior to tests

b) Instruments comply with requirements of AABC, NEBB, or TABB for tests required

c) Contractor is currently certified by AABC, NEBB, or TABB

b. Do not proceed with field work until the above submittal has been approved by Owner’s Representative.

3. Final Test & Balance Report

a. At least 15 days prior to Contractor's request for final inspection, submit electronic copy of final reports on approved reporting forms for review and approval by Owner’s Representative. Once approved, provide paper and electronic copies.

b. Form of Final Reports

1) Completed forms shall be typed (not hand written) and be in acceptable word-searchable electronic format.

2) Fully completed report forms for all systems specified to be tested and balanced including at a minimum all data specified herein to be recorded

3) Each individual final reporting form must bear

a) Signature of person who recorded data

b) Signature of air balance supervisor of reporting organization

4) When more than one certified organization performs total air balance services, firm having managerial responsibility shall make submittals.

5) Identify instruments of all types that were used and last date of calibration of each.

C. Test Equipment

1. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified herein. If not otherwise noted, the following minimum requirements apply

    a. Ammeter: plus or minus 1 percent scale

    b. Flow sensors: plus or minus 2 percent of reading

    c. Temperature: plus or minus 0.4 degrees Fahrenheit

2. All equipment shall be calibrated within 6 months of use, or according to the manufacturer's recommended interval, whichever is shorter, and when dropped or damaged. Calibration tags shall be affixed or certificates readily available and proof of calibration shall be included reports.

D. General Execution

1. Report to Owner's Representative any discrepancies or items not installed in accordance with the Contract Drawings pertaining to proper balance and operation of air and water distribution systems.

2. Perform testing, adjusting and balancing in accordance with AABC, NEBB, or TABB standards.

3. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish.

4. Mark equipment settings with paint or other suitable, permanent identification material, including damper control positions, valve indicators, and similar controls and devices, to show final settings.

E. Air System Balancing

1. Check that the AHU filters are installed, oriented in the proper airflow direction, free of bypass, and clean.

2. Air Outlets

    a. Test and adjust each return grille and register to within plus or minus 10 percent of design requirements. Testing of supply diffusers is not required.

        1) Start with all dampers wide open.

        2) Adjust dampers, starting with nearest to terminal unit or fan. Make adjustments using duct mounted volume dampers rather than dampers at diffuser face (if any) unless absolutely required.

        3) At least one damper shall remain wide open at end of balance.

    b. Report

1) Tag each return grille and register and mark tag on copy of floor plan.

2) For each return grille and register, indicate tag, size, type, and effective area (where applicable).

3) Required velocity/cubic feet per minute

4) Initially tested velocity/cubic feet per minute

5) Finally tested cubic feet per minute after adjustments

3. Terminal Boxes

a. Balancing contractor shall provide laptop computer or other device for communicating with BAS system, using software provided by BAS installer.

b. Terminal box calibration procedure listed below may be modified based on specific features or limitations of digital controller and recommendations of the controller manufacturer. Submit revised procedure for approval by Owner’s Representative along with pre-test submittal per Paragraph B.2.

c. Use BAS terminal “commissioning” software where available and record all calibration and test data through the BAS.

d. Zero transmitter prior to each test.

e. Adjust/confirm balancing damper upstream of terminal is fully open.

f. Adjust BAS calibration constants so that the VAV box controller and measured air flow rate at air outlets matches BAS reading within range listed at all of the following conditions at a minimum:

1) Maximum airflow setpoint, ±5%

2) Controllable minimum airflow setpoint, ±10%. The controllable minimum value shall be that determined by the BAS contractor.

3) Zero flow

g. Report

1) Tag, manufacturer, and model

2) VAV maximum cooling flow rate, design and measured

3) VAV minimum flow rate, design and measured

4) BAS calibration coefficients at all calibration points

5) Terminals with reheat coils, with HW valve wide open

a) Entering air drybulb temperature to reheat coil

b) Leaving air drybulb temperature from reheat coil

c) Entering HW temperature to reheat coil

d) Leaving HW temperature from reheat coil

e) Differential pressure across reheat coil at design flow

4. Air Handling Unit Airflow Rate Readings

a. Total supply air quantities shall be determined at all of the following where applicable

1) Pitot traverse in the supply duct downstream, positive pressure side of the fan

2) Pitot traverse at coil or filter bank

3) Totaling the readings of individual terminals as read through the BAS

4) Supply fan airflow sensor reading as read through the BAS (if there is a supply AFMS at the AHU)

b. Total return air quantities shall be determined at all of the following where applicable

1) Pitot traverse in the return air duct or damper entering air handler

2) Totaling the readings of individual air outlets, if ducted return system

3) Totaling reading of each return air shaft inlet, if multi-story plenum return system

4) Return fan airflow sensor reading as read through the BAS (if there is a return AFMS at the AHU)

c. Outside air quantities shall be determined by all of the following where applicable

1) Subtracting pitot traverses of supply and return ducts

2) Pitot traverse of outdoor air intake duct

3) Outdoor airflow sensor reading as read through the BAS

4) Note: Balance by measurement of return air, outside air, and mixed air temperatures shall not be used due to inherent inaccuracy.

5. BAS airflow measuring stations (AFMS)

a. For supply air, return air, and outdoor air AFMS associated with a VAV box system

1) Test Conditions

a) Command all VAV boxes to design cooling maximum airflow setpoints.

b) Override the economizer to 100% outdoor air, i.e. configure the outdoor air damper to be 100% open and the return air damper to be 0% open.

c) Start supply fan and run it slowly from 10% speed up to 100% speed, in 30% increments with a pause at each step to allow time for the VAV boxes to communicate. At each 30% increment, measure and report:

1. Sum of VAV box airflows (should be displayed on BAS AHU graphic)

2. Airflow measurement station airflow readings

3. Traverses across supply air duct, filter bank, or other location where the most accurate airflow reading is possible. Include separate traverses to confirm return air flow.

2) Plot the speed vs. all three measured airflows. They should be linear and the three readings should be within 10% of each other.

b. For factory calibrated AFMS: If measured airflow and BAS readings differ by more than 10%, consult with Owner’s Representative for recalibration instructions. Do not change factory calibration without written direction.

c. For field calibrated AFMS: Coordinate with BAS installer to adjust calibration coefficients. Report coefficients in air balance report.

6. Variable Air Volume Air Handlers

a. Adjust fan speed using manual adjustment of variable speed drive for testing only. Do not change or adjust sheaves.

b. Supply fan DP Setpoint.

1) Establish maximum static pressure setpoint (DPmax) in conjunction with the BAS installer as follows. All adjustments made via the BAS, not field measurements except as noted.

2) Test Conditions

a) Set all boxes to operate at maximum airflow setpoints; allow controls to stabilize.

b) For cooling systems only to account for diversity: Shut off boxes, starting with boxes whose dampers are the most closed, as indicated by the BAS, and upstream of the DP sensor, until the airflow equals scheduled design airflow rate.

3) Procedure

a) Manually lower fan speed slowly while observing VAV box airflow rates downstream of the static pressure sensor. Stop lowering speed when one or more VAV box airflow rates drops 10 percent below maximum airflow rate setpoint.

b) Once flow condition in previous step is achieved, note the BAS system static pressure reading at the duct static pressure sensor.

1. This reading becomes the maximum static pressure setpoint.

2. Using pressure taps at differential pressure sensor and handheld digital pressure sensor, verify accuracy of BAS reading.

4) If there are multiple static pressure sensors, repeat steps above for each sensor. Each sensor will have its own setpoint.

5) Convey to the BAS installer

a) Static pressure setpoints

b) Any discrepancy between BAS differential pressure reading and handheld measurement

6) Report

a) Static pressure setpoint and concurrent reading of handheld measurement: Initials of BAS installer to indicate that the information was transmitted to them.

b) Tag of VAV boxes that dropped below design maximum airflow rate in tests above. These are the critical boxes, those requiring the largest static pressure.

c) Concurrent fan data

1. Volts and amps

2. Amps and kilowatts from variable speed drive

3. Variable speed drive speed in hertz

4. Entering and leaving fan static pressure

5. Flow rate, summed from BAS terminals

6. Fan airflow sensor reading from BAS, where applicable

c. Minimum outside air flow

1) Supply air fan and return air fan shall first be operating at design airflow. For VAV systems with diversity, close enough boxes close to fan to reduce supply airflow to scheduled design condition.

2) For systems with outdoor airflow measuring stations, see Paragraph 3.14E.5.

d. Test with system operating at design fan and minimum outside air flow conditions described above and report the following on a schematic of the system:

1) Tags of all equipment

2) Manufacturer and model of all fans and motors

3) Motor horsepower, rpm, volts, phase, full load amps

4) Sheave data at motor and fan; belt data

5) Fan airflow rate at all locations measured, as listed above

6) Final measured fan speed and amps

7) Amps and kilowatts from variable speed drives

8) Variable speed drive speed in hertz

9) Static pressures measured at

a) Return air plenum

b) Downstream of return fan

c) Mixed air plenum

d) Downstream of filter

e) Downstream of coil

f) Discharge of supply fans

g) At static pressure sensor

10) Concurrent airflow rate readings from BAS airflow sensors, including sum of VAV box airflow rates

11) Minimum BAS outdoor air control setpoints and signals as applicable

e. Supply airflow

1) With system at design airflow, measure and report supply airflow using traverses across the three supply duct branches from fan discharge. Report with values from AFMS, traverse of total supply airflow, and sum of VAV box airflow rates from BAS.

f. Return fan

1) Test 1: 100% Outdoor Air

a) Test Conditions

1. Economizer in 100% outdoor air position

2. Supply fan at design supply air rate

3. All doors and windows closed in area served by air handler

4. All exhaust fans on in area served by air handler

5. Relief damper fully open

b) Procedure

1. Measure building pressure using BAS sensor.

2. Manually adjust return fan speed at variable speed drive to achieve 0.05” building pressure.

   a. Fan speed may exceed 60 Hz if necessary. Do not change or adjust sheaves.

3. At the above conditions

   a. Measure fan inlet and outlet pressures.

   b. Outlet pressure also shall be measured with BAS. This pressure is the return fan static pressure setpoint for Test 1.

2) Test 2: Design Minimum Outdoor Air

a) Test conditions:

1. Per Paragraph 3.14E.6.d.

2. Relief damper fully closed.

b) Procedure

1. Measure return airflow rate across return air damper and minimum outdoor air rate across minimum outdoor air damper

2. Manually adjust return fan speed at variable speed drive by 5Hz.

3. Repeat these two steps until return air rate drops below design return air rate by 5%, then increase return fan speed 5Hz.

4. At the above conditions

   a. Measure fan inlet and outlet pressures.

   b. Outlet pressure also shall be measured with BAS. This pressure is the return fan static pressure setpoint for Test 2.

3) Convey to the BAS installer

a) Return fan static pressure setpoints:

1. RFSPmin = Test 2 Outlet Pressure

2. RFSPmax = Larger of Test 1 and Test 2 Outlet Pressures

b) Return fan maximum speed if greater than 60 Hz.

4) Report

a) Amps and kilowatts from variable speed drive

b) Variable speed drive required speed in hertz

c) Inlet and outlet static pressure

d) Building static pressure

F. Provide one copy of TAB report to College in pdf format.

3.15 SYSTEM COMMISSIONING

A. Sequencing. The following list outlines the general sequence of events for submittals and commissioning:

1. Submit Submittal Package 0 (Qualifications) and receive approval.

2. Submit Submittal Package 1 (Hardware and Shop Drawings) and receive approval.

3. Initiate installation of BAS hardware, devices and wiring.

4. Develop point database and application software.

5. Simulate sequencing and debug programming off-line to the extent practical.

6. Submit Submittal Package 2 (Programming and Graphics) and receive approval.

7. Complete installation of BAS hardware, devices and wiring.

8. Install point database and application software in field panels.

9. Perform TAB.

10. Submit Submittal Package 2.5 (Final TAB Report) and receive approval.

11. Submit Submittal Package 3 (Pre-Functional Test Forms) and receive approval.

12. Perform BAS Pre-functional Tests (start up, calibration and tuning) and submit completed forms as Submittal Package 4 (Pre-Functional Test Report) for approval.

13. Receive BAS Pre-functional Test Report approval and approval to schedule Functional Tests.

14. Field test application programs prior to functional testing.

15. Submit Package 5 (Post-Construction Trend Points List) in format specified for review and approval.

16. Receive approval of successful Trend Log configuration, or reconfigure as required.

17. Prepare and initiate commissioning Trend Logs.

18. Perform and record functional tests and submit Submittal Package 6 (Functional Test Report) for approval.

19. Assist in TAB tests and determining setpoints as specified herein.

20. Submit Package 7 (Training Materials) and receive approval.

21. Receive BAS Functional Test Report approval and approval to schedule Demonstration Tests.

22. Perform Demonstration Tests to Commissioning Provider and College’s Representatives and submit Demonstration Test Report.

23. Receive acceptance of Demonstration Tests.

24. Train College personnel on BAS operation and maintenance.

25. Substantial Completion

26. Submit Package 8 (Post-Construction Trend Logs) in format specified for review and approval.

27. Receive approval of successful Trend Log tests, or retest as required.

28. Complete all items in Completion Requirements per Paragraph 1.10B.

29. Provide administration level password access to the College.

30. Final Acceptance

31. Begin Warranty Period.

32. Prepare and initiate continuous Trend Logs per Paragraph 2.14A.4.

33. Update all software as specified.

34. End of Warranty Period

B. Assist Commissioning Provider including attending commissioning meetings.

C. Pre-functional tests

1. General

a. Inspect the installation of all devices. Review the manufacturer's installation instructions and validate that the device is installed in accordance with them.

b. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.

c. Verify integrity/safety of all electrical connections.

d. Verify that shielded cables are grounded only at one end.

e. Verify that all sensor locations are as indicated on drawings and are away from causes of erratic operation.

2. Test Documentation

a. Prepare forms to document the proper startup of the BAS components.

b. All equipment shall be included on test forms including but not limited to

1) Wiring: End-to-end checkout of all wiring at terminations. Power to all controllers and actuators. Confirmation of emergency power where specified.

2) Digital Outputs: Proper installation, normal position, response to command at CU

3) Digital Inputs: Proper installation, device test, response at CU

4) Analog Outputs: Proper installation of devices, verification of maximum and minimum stroke.

5) Analog Inputs: Proper installation of sensors, calibration

6) Panels: Confirmation of location, power source (electrical circuit used), confirmation of emergency power where specified.

7) Alarms and Safeties: Verification of alarm routing to all specified devices and correct hierarchy. Example: confirm alarm routing to cell phones, email, servers, remote workstations. Confirm that appropriate alarm levels are routed to appropriate devices.

8) Loop Tuning: Document setting of P/I parameters for all loops, chosen setpoints, time delays, loop execution speed.

9) Network Traffic: Document speed of screen generation, alarm and signal propagation in system with all required commissioning trends active.

c. Each form shall have a header or footer where the technician performing the test can indicate his/her name and the date of the test.

d. Submit blank forms for approval in Submittal Package 3.

e. Complete work, document results on forms, and submit for approval as Submittal Package 4 (Pre-Functional Test Report).

3. Digital Outputs

   a. Verify that all digital output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.

4. Digital Inputs

   a. Adjust setpoints, where applicable.

      1) For current switches used as status on fans, adjust current setpoint so that fan status is OFF when fan discharge damper (if present) is fully closed and when belt is broken (temporarily remove belt).

      2) For current switches used as status on pumps, adjust current setpoint so that pump status is OFF when pump is dead-headed (temporarily close discharge valve).

      3) For differential pressure sensors on pumps and fans, set so that status is on when pump operating with all valves open (out on its curve).

5. Analog Outputs

   a. Verify start and span are correct and control action is correct.

   b. Check all control valves and automatic dampers to ensure proper action and closure. Make any necessary adjustments to valve stem and damper blade travel.

   c. Check all normal positions of fail-safe actuators.

   d. For outputs to reset other manufacturer's devices (for example, chiller setpoint) and for feedback from them, calibrate ranges to establish proper parameters.

6. Analog Input Calibration

   a. Sensors shall be calibrated as specified on the points list. Calibration methods shall be one of the following:

      1) Factory: Calibration by factory, to standard factory specifications. Field calibration is not required.

      2) Handheld: Field calibrate using a handheld device with accuracy meeting the requirements of Paragraph 2.10.

   b. The calibrating parameters in software (such as slope and intercept) shall be adjusted as required. A calibration log shall be kept and initialed by the technician indicating date and time, sensor and hand-held readings, and calibration constant adjustments and included in the Pre-functional Test Report.

c. Inaccurate sensors must be replaced if calibration is not possible.

7. Alarms and Interlocks

   a. A log shall be kept and initialed by the technician indicating date and time, alarm/interlock description, action taken to initiate the alarm/interlock, and resulting action, and included in the Pre-functional Test Report.

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

   c. 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.

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

8. Variable Frequency Drive Minimum Speed

   a. Minimum speed for VFD-driven fans and pumps shall be determined in accordance with this Paragraph. Tests shall be done for each piece of equipment, except that for multiple pieces of identical equipment used for identical applications, only one piece of equipment need be tested with results applied to all. Note that for fans and pumps, there is no minimum speed required for motor cooling. Power drops with cube of speed, causing motor losses to be minimal at low speeds.

   b. This work shall be done only after fan/pump system is fully installed and operational.

   c. Determine minimum speed setpoint as follows:

      1) Start the fan or pump.

      2) Manually set speed to 6 Hz (10%) unless otherwise indicated in control sequences. For cooling towers with gear boxes, use 20% or whatever minimum speed is recommended by tower manufacturer.

      3) Observe fan/pump in field to ensure it is visibly rotating.

         a) If not, gradually increase speed until it is.

      4) The speed at this point shall be the minimum speed setpoint for this piece of equipment.

      5) Record minimum speeds in log and store in software point as indicated in Guideline 36.

9. Tuning

   a. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in the Pre-functional Test Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted)

Controlled Variable	Control Accuracy
Duct Pressure	±0.1 inches w.g.
Building and relief plenum	±0.01 inches w.g.
Airflow and water flow	±10%
Space Temperature	±1.5ºF
Hot Water Temperature	±3ºF
Duct Temperature	±2ºF
Others	±2 times reported accuracy

10. Interface and Control Panels

    a. Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the Record Drawings.

    b. Ensure that terminations are safe, secure and labeled in accordance with the Record Drawings.

    c. Check power supplies for proper voltage ranges and loading.

    d. Ensure that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in trough.

    e. Check for adequate signal strength on communication networks.

    f. Check for standalone performance of controllers by disconnecting the controller from the LAN. Verify the event is annunciated at Operator Interfaces. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.

    g. Ensure that buffered or volatile information is held through power outage.

    h. With all system and communications operating normally, sample and record update and annunciation times for critical alarms fed from the panel to the Operator Interface.

    i. Check for adequate grounding of all BAS panels and devices.

11. Operator Interfaces

    a. Verify that all elements on the graphics are functional and are properly bound to physical devices or virtual points, and that hot links or page jumps are functional and logical.

    b. Verify that the alarm logging, paging, emailing etc. are functional and per requirements.

D. Testing, Adjusting, and Balancing (TAB) Coordination

1. Coordinate with Work performed for Testing, Adjusting, and Balancing. Some balancing procedures require the BAS to be operational and require Contractor time and assistance.

2. Calibration Software

    a. Software shall be provided free of charge on at least a temporary basis to allow calibration of terminal box airflow controls and other Work for Testing, Adjusting, and Balancing.

    b. Software shall be provided for installation on POT(s) provided by Others or Contractor shall loan a POT or handheld device with software installed for the duration of Work for Testing, Adjusting, and Balancing.

    c. Provide sufficient training to those performing Work for Testing, Adjusting, and Balancing to allow them to use the software for balancing and airflow calibration purposes. Contractor shall include a single training session for this purpose.

3. Setpoint Determination

    a. Perform pre-functional tests described in Paragraph 3.15C before assisting in setpoint determination.

    b. Coordinate with Work for Testing, Adjusting, and Balancing to determine fan differential pressure setpoints, outdoor air damper minimum positions and DP setpoints, etc..

E. Functional Tests

1. Test schedule shall be coordinated with the Commissioning Provider and College's Representative.

2. Functional tests may be witnessed by College's Representative at the College's option.

3. All approved Functional Tests shall be conducted by the Contractor with results confirmed and signed by the Contractor's start-up technician.

4. Test documentation

    a. College's Representatives will prepare functional testing forms after Submittal Package 2 has been reviewed and approved. Tests will be designed to test all sequences in a formal manner with simulations and expected outcomes.

    b. Review tests and recommend changes that will improve ease of testing or avoid possible system damage, etc. and provide to College's Representative.

    c. Complete work, document results on forms, and submit for approval as Submittal Package 6 Functional Test Report. Tutorials for using the functional test Excel workbook can be found here.

F. Demonstration Test

1. Demonstration tests consist of a small representative sample of functional tests and systems randomly selected by the Commissioning Provider. Tests will be designed to occur over no longer than 1 working day.

2. Schedule the demonstration with the Commissioning Provider and College's Representative at least 1 week in advance. Demonstration shall not be scheduled until the Functional Test Report has been approved.

3. The Contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, instruments, ladders, etc. Contractor-supplied personnel shall be those who conducted the Functional tests or who are otherwise competent with and knowledgeable of all project-specific hardware, software, and the HVAC systems.

4. The system will be demonstrated following procedures that are the same or similar to those used in the Pre-Functional and Functional Tests. The Commissioning Provider will supply the test forms at the site at the start of the tests.

5. Demonstration tests may be witnessed by College's Representative at the College's option.

6. Contractor shall conduct tests as directed by and in the presence of the Commissioning Provider and complete test forms. Commissioning Provider will document the test results as the Demonstration Test Report after tests are complete.

7. Demonstration Tests shall be successfully completed and approved prior to Substantial Completion.

G. Trend Log Tests

1. Trends shall be fully configured to record and store data to the server for the points and at the interval listed in Paragraph 2.13 as follows:

   a. Commissioning: Configure trends prior to functional testing phase. Retain configuration until post-construction commissioning trend review has been completed successfully and accepted by the College's representative. Trends shall be deactivated after acceptance.

   b. Continuous: After system acceptance, configure trends for the purpose of long term future diagnostics. Configure trends to overwrite the oldest trends at the longest interval possible without filling the server hard disk beyond 80%.

2. Post-Construction Trend Test

   a. Trend logging shall not commence until Demonstration Tests are successfully completed.

   b. Hardware Points. Contractor shall configure points to trend as indicated in the Commissioning Trend column listed in Paragraph 2.13 points.

c. Software Points. Include the following in trends of systems and zones whose hardware points are being trended as called for above. Time interval shall be the same as associated hardware point.

1) All setpoints and limits that are automatically reset, such as supply air temperature and fan static pressure setpoints, plus the points that are driving the reset, such as zone level cooling and static pressure requests

2) All setpoints that are adjustable by occupants

3) Outputs of all control loops, other than those driving a single AO point that is already being trended

4) System mode points (e.g. Warm-up, Occupied, etc.)

5) Global overrides such as demand shed signals

6) Calculated performance monitoring points, such as chiller efficiency

d. Submit for review and approval by the Commissioning Provider a table of points to be trended along with trend intervals or change-of-value a minimum of 14 days prior to trend collection period, as Submittal Package 5.

e. Trends shall be uploaded to the CSS in data format specified in Paragraph 2.13C.3.

f. Trend logs of all points indicated above shall be collected for a 3 week Trend Period.

g. At the completion of the Trend Period, data shall be reviewed by the Contractor to ensure that the system is operating properly. If so, data shall be submitted to the College in an electronic format agreed to by the College and Contractor (such as flash drive or via direct access to the CSS via the internet) as Submittal Package 8.

h. Data will be analyzed by the Commissioning Provider.

i. The system shall be accepted only if the trend review indicates proper system operation without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with these specifications. If any but very minor glitches are indicated in the trends, steps f to h above shall be repeated for the same Trend Period until there is a complete Trend Period of error free operation.

j. After successfully completing the Post-Construction Trend Tests, the Contractor shall configure all points to trend as indicated in the Continuous Trend column listed in Paragraph 2.13 points list.

H. Remedial Work

1. Repair or replace defective Work, as directed by College’s Representative in writing, at no additional cost to the College.

2. Restore or replace damaged Work due to tests as directed by College’s Representative in writing, at no additional cost to the College.

3. Restore or replace damaged Work of others, due to tests, as directed by College's Representative in writing, at no additional cost to the College.

4. Remedial Work identified by site reviews, review of submittals, demonstration test, trend reviews, etc. shall be performed to the satisfaction of the College's Representative, at no additional cost to the College.

5. Contractor shall compensate College's Representatives and Commissioning Provider on a time and material basis at standard billing rates for any additional time required to witness additional demonstration tests or to review additional BAS trends beyond the initial tests, at no additional cost to the College.

3.16 TRAINING

A. Coordinate schedule and materials with Commissioning Provider.

B. Interim Training

1. Provide minimal training so the operating staff can respond to occupant needs and other operating requirements during start-up and commissioning phase.

C. Formal Training

1. Training shall be conducted after all commissioning is complete and systems are fully operational.

2. Training materials, including slides, shall be submitted prior to any training in Submittal Package 7.

3. ALC Training

a. It may be assumed that College building engineers have been previously trained on the existing ALC system.

b. Include training on ALC system operations only for new features installed at CSS/OWS as a part of this project.

4. Jobsite Training

a. Include 24 hours total of on-site training to assist personnel in becoming familiar with job-specific issues, systems, control sequences, etc.

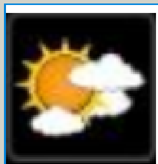
b. College shall be permitted to videotape training sessions.

5. Training may be in non-contiguous days at the request of the College.

6. During the warranty period, provide unlimited telephone support for all trained operators.

END OF SECTION 250000

ZONE GROUP SUMMARY



xx.x °F
xx %RH

Schedule

Zone Group Summary

Zone Group Name 1st Floor
Mode Occupied

AHU-x-x
SAT xx.x °F
DSP xx.x in.wg
Mode Occupied
Alarm OK

Heating Plant
HWST xxx °F
Status ON
Alarm OK

Chiller Plant
CHWST xxx °F
Status ON
Alarm OK

Mode Requests

Occupied xxx
Warmup xxx
Cooldown xxx
Setback xxx
Setup xxx

System/Plant Requests

Cooling SAT Reset xxx
Duct SP Reset xxx
HW Plant xxx
HWST Reset xxx
Min OA CFM xxx
Max CO2 DCV xxx

Total Airflow

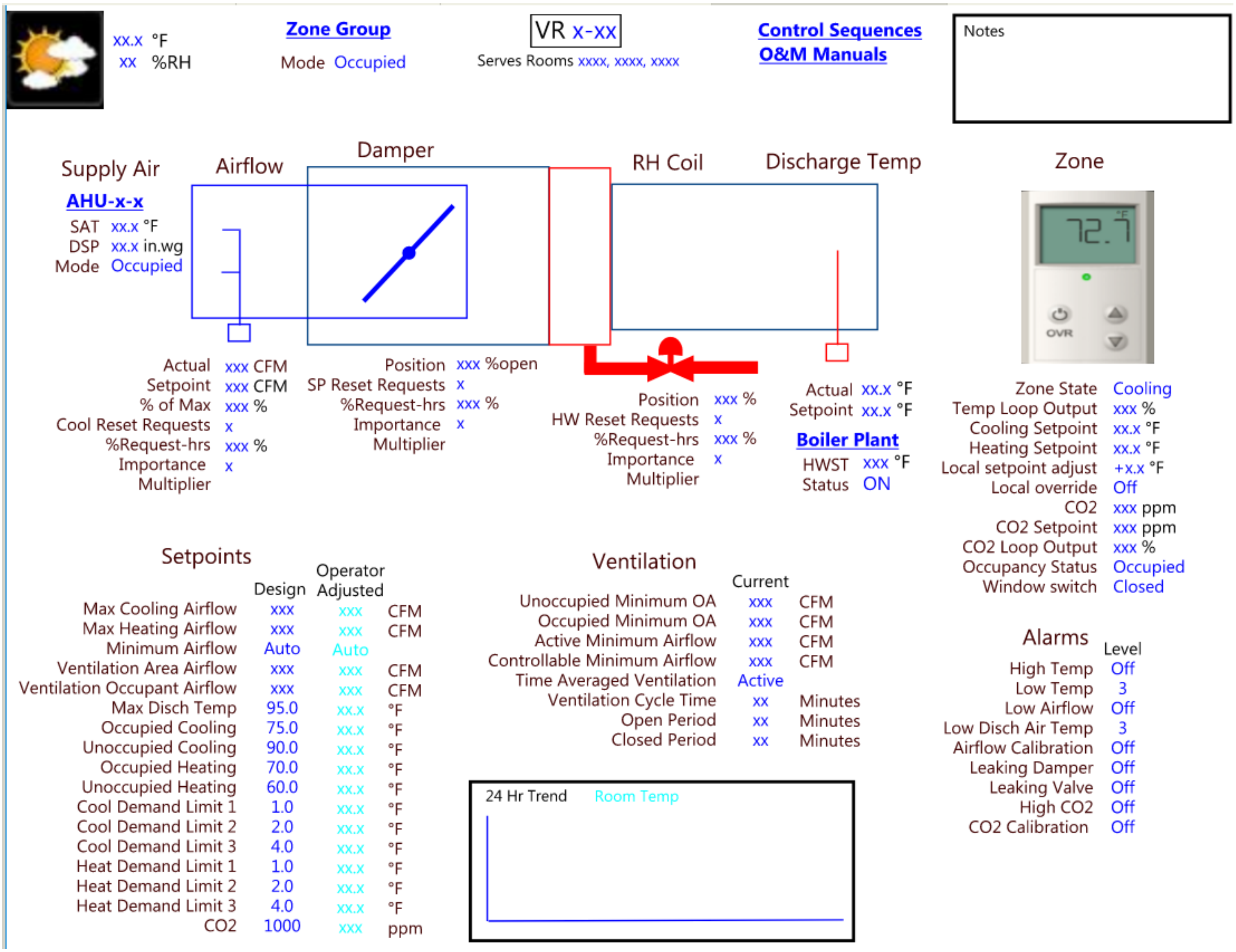
Airflow Setpoints xxx cfm
Actual Airflow xxx cfm
Occupant OA xxx cfm
Area OA xxx cfm
Total OA xxx cfm

Zone Alarms

High Temp xxx
Low Temp xxx
High CO2 xxx
CO2 Calibration xxx
Low Airflow xxx
Airflow Calibration xxx
Leaking Damper xxx
Rogue SATSP xxx
Rogue DSPSP xxx
Rogue HWSTSP xxx

Zone		Zone Temperature			Airflow			Discharge Air			CO2			Cool Reset Requests			Static Pressure Reset Requests			HWST Reset Requests		
Tag	State	Actual °F	Heat Setpoint °F	Cool Setpoint °F	Actual CFM	Setpoint CFM	Damper %open	Temp °F	Setpoint °F	HW Valve %open	Actual PPM	Setpoint PPM	Loop Output %	Requests	%-Req-hrs	Importance Multiplier	Requests	%-Req-hrs	Importance Multiplier	Requests	%-Req-hrs	Importance Multiplier
VR-2012	Heating	70	70	75	200	220	15	93	95	90	500	1000	0	0	21	1	0	14	1	1	30	1
VC-2013	Cooling	75	70	75	200	220	15							0	21	1	0	14	1			

VAV REHEAT ZONE



BUILDING AUTOMATION SEQUENCES OF OPERATION

PART 1 GENERAL

1.1 SUMMARY

A. Program and commission the Building Automation System (BAS) to execute the Sequences of Operation specified herein.

B. See Section 250000 Building Automation Systems for general requirements.

C. These control sequences include references to ASHRAE Guideline 36 and approved addenda. Where sequences are verbatim from Guideline 36, they are shown in green text. Not all informative text has been included. Sequences have been customized to include only Title 24 options where they take precedence over ASHRAE 90.1 and 62.1 requirements.

D. Guideline 36 sequences shall be programmed to exactly match the specified sequences verbatim. The Contractor may use “equivalent” alternative sequences only with formal approval by the Engineer. Proposed changes in sequences shall be clearly identified and included as a part of Submittal Package 2.

E. This file shall be maintained by the Contractor to include all approved changes to sequences made during testing and commissioning and shall become the final as-built sequences of operation installed on the CSS per Section 250000 Building Automation Systems.

1.2 INFORMATION PROVIDED BY DESIGNER

A. See equipment schedules on drawings for all setpoints unless otherwise noted below.

B. General Zone Information

1. Zone Temperature Setpoints

a. Default setpoints shall be based on zone type as shown in Table 3.1.1.1.

Table 3.1.1.1 Default Setpoints

	Occupied		Unoccupied	
Zone Type	Heating	Cooling	Heating	Cooling
General (unless listed below)	70ºF	75ºF	60ºF	90ºF
Restrooms	68ºF	78ºF	60ºF	90ºF

2. Outdoor Air Ventilation Setpoints

a. All zone minimum outdoor air setpoints are scheduled on Drawings.

1) Vocc-min. Zone minimum outdoor airflow for occupants.

2) Varea-min. Zone minimum outdoor airflow for building area.

3) Indicate where occupied-standby mode is allowed based on the zone occupancy category.

3. CO2 Setpoints

a. The CO2 setpoint for all occupancy types is 1000 ppm.

C. VAV Box Design Information

1. All VAV box setpoints are scheduled on Drawings except as indicated below.

2. VAV Cooling-Only Terminal Unit

a. Zone maximum cooling airflow setpoint (Vcool-max)

b. Zone maximum heating airflow setpoint (Vheat-max) = Vcool-max

c. Zone minimum airflow setpoint (Vmin). This is an optional entry. If no value is scheduled, or a value of “AUTO” is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

3. VAV Reheat Terminal Unit

a. Zone maximum cooling airflow setpoint (Vcool-max)

b. Zone minimum airflow setpoint (Vmin. This is an optional entry. If no value is scheduled, or a value of “AUTO” is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

c. Zone maximum heating airflow setpoint (Vheat-max)

d. Zone maximum DAT above heating setpoint (MaxΔT) = 25ºF

e. The heating minimum airflow setpoint (Vheat-min) = 0

D. Zone Group Assignments

1. Unless otherwise specified by Owner, the following Zone Groups shall be created:

Zone Group Name	AH Tag	Terminal Unit Tags	Miscellaneous Equipment Tags	Default Schedule
Second-floor	AH-1	VAV-5B.1 thru VAV-5B.9	EF-131	WD: 7 am to 7 pm SAT: 9 am to 2 pm SUN: off HOL: off
Third-floor	AH-1	VAV-701 thru VAV-714, 8131, 8136, 81311, 81312	EF-131	WD: 7 am to 7 pm SAT: 9 am to 2 pm SUN: off HOL: off

E. Multiple-Zone VAV Air-Handler Design Information

1. Temperature Setpoints

a. Min_ClgSAT, lowest cooling supply air temperature setpoint = scheduled cooling coil leaving air temperature plus 3°F

b. Max_ClgSAT, highest cooling supply air temperature setpoint = 65°F

c. OAT_Min, the lower value of the OAT reset range = 55°F

d. OAT_Max, the higher value of the OAT reset range = 70°F

2. Ventilation Setpoints

a. All AHU outdoor airflow setpoints are scheduled on Drawings.

1) AbsMinOA, the design outdoor air rate when all zones with CO2 sensors or occupancy sensors are unpopulated

2) DesMinOA, the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable

3. Economizer High Limit

a. California Title 24 economizer high limit

1) California climate zone = 12

2) High limit option:

a) Fixed dry bulb + differential dry bulb

4. DP100, filter high limit differential pressure at design airflow = 1 in.w.c. or value from manufacturer's submittal whichever is lower

5. Pressure Zone Group Assignments

Pressure Zone Group Name	AHU Tag	RF Tag	Building Pressure Sensor Location(s)
Pressure Zone	AHU-1	RF-1	Rm. 257, 710

1.3 INFORMATION PROVIDED BY (OR IN CONJUNCTION WITH) THE TESTING, ADJUSTING, AND BALANCING CONTRACTOR

A. Coordinate with Testing, Adjusting and Balancing (TAB) contractor for setpoint determination. Any TAB work not specifically listed in Section 250000 shall be provided under this Section.

B. Multiple-Zone Air-Handler Information

1. Duct Design Maximum Static Pressure, Max_DSP

2. Minimum Fan Speed

a. Minimum speed setpoints for all VFD-driven equipment shall be determined in accordance with Section 250000 Building Automation System specifications for the following, as applicable:

1) Supply fan

2) Return fan

3. Return-Fan Discharge Static Pressure Setpoints. (For return-fan direct building pressure control, see Section 3.8E.)

a. RFDSPmin. That required to deliver the design return air volume across the return air damper when the supply air fan is at design airflow and on minimum outdoor air. This setpoint shall be no less than 2.4 Pa (0.01 in. of water) to ensure outdoor air is not drawn backwards through the relief damper.

b. RFDSPmax. That required to exhaust enough air to maintain building static pressure at setpoint 12 Pa (0.05 in. of water) when the supply air fan is at design airflow and on 100% outdoor air.

1.4 INFORMATION DETERMINED BY CONTROL CONTRACTOR

A. VAV Box Controllable Minimum

1. This section is used to determine the lowest possible VAV box airflow setpoint (other than zero) allowed by the controls (Vm) used in VAV box control sequences. The minimums shall be stored as software points that may be adjusted by the user but need not be adjustable via the graphical user interface.

2. The minimum setpoint *Vm* shall be determined from the table below for the VAV box manufacturer from approved submittals:

Inlet	Titus	Krueger	Price	MetalAire High Gain	ETI	Greenheck
4	15	15	20	15	15	18
6	30	35	30	30	30	35
8	55	60	55	50	55	63
10	90	90	95	85	90	105
12	120	130	135	110	130	149
14	190	175	195	155	180	206
16	245	230	260	210	235	259
24x16	455	445	490	N/A	415	N/A

PART 2 PRODUCTS

2.1 NOT USED

PART 3 EXECUTION

3.1 GENERAL

A. Contractor shall review sequences prior to programming and suggest modifications where required to achieve the design intent. Contractor may also suggest modifications to improve performance and stability or to simplify or reorganize logic in a manner that provides equal or better performance. Proposed changes in sequences shall be clearly identified and included as a part of Submittal Package 2.

B. Include costs for minor program modifications if required to provide proper performance of the system.

C. Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent windup.

D. When a control loop is enabled or reenabled, it and all its constituents (such as the proportional and integral terms) shall be set initially to a neutral value.

E. A control loop in neutral shall correspond to a condition that applies the minimum control effect, i.e., valves/dampers closed, VFDs at minimum speed, etc.

F. When there are multiple outdoor air temperature sensors, the system shall use the valid sensor that most accurately represents the outdoor air conditions at the equipment being controlled.

1. Outdoor air temperature sensors at air-handler outdoor air intakes shall be considered valid only when the supply fan is proven on and the unit is in Occupied Mode or in any other mode with the economizer enabled.

2. The outdoor air temperature used for optimum start, plant lockout, and other global sequences shall be the average of all valid sensor readings. If there are four or more valid outdoor air temperature sensors, discard the highest and lowest temperature readings.

G. The term “proven” (i.e., “proven on”/“proven off”) shall mean that the equipment’s DI status point (where provided, e.g., current switch, DP switch, or VFD status) matches the state set by the equipment’s DO command point.

H. The term “software point” shall mean an analog variable, and “software switch” shall mean a digital (binary) variable, that are not associated with real I/O points. They shall be read/write capable (e.g., BACnet analog variable and binary variable).

I. The term “control loop” or “loop” is used generically for all control loops. These will typically be PID loops, but proportional plus integral plus derivative gains are not required on all loops. Unless specifically indicated otherwise, the guidelines in the following subsections shall be followed.

1. Use proportional only (P-only) loops for limiting loops (such as zone CO2 control loops, etc.).

2. Do not use the derivative term on any loops unless field tuning is not possible without it.

J. To avoid abrupt changes in equipment operation, the output of every control loop shall be capable of being limited by a user adjustable maximum rate of change, with a default of 25% per minute.

K. All setpoints, timers, deadbands, PID gains, etc. listed in sequences shall be adjustable by the user with appropriate access level whether indicated as adjustable in sequences or not. Software points shall be used for these variables. Fixed scalar numbers shall not be embedded in programs except for physical constants and conversion factors.

L. Values for all points, including real (hardware) points used in control sequences shall be capable of being overridden by the user with appropriate access level (e.g., for testing and commissioning). If hardware design prevents this for hardware points, they shall be equated to a software point, and the software point shall be used in all sequences. Exceptions shall be made for machine or life safety.

M. Alarms

1. There shall be 4 levels of alarm

a. Level 1: Life-safety message

b. Level 2: Critical equipment message

c. Level 3: Urgent message

d. Level 4: Normal message

2. Maintenance Mode. Operators shall have the ability to put any device (e.g., AHU) in/out of maintenance mode.

a. All alarms associated with a device in maintenance mode will be suppressed. Exception: Life safety alarms shall not be suppressed.

b. If a device is in maintenance mode, issue a Level 3 alarm at a scheduled date and time indicating that the device is still in maintenance mode.

3. Exit Hysteresis

a. Each alarm shall have an adjustable time-based hysteresis (default: 5 seconds) to exit the alarm. Once set, the alarm does not return to normal until the alarm conditions have ceased for the duration of the hysteresis.

b. Each analog alarm shall have an adjustable percent-of-limit-based hysteresis (default: 0% of the alarm threshold, i.e., no hysteresis; alarm exits at the same value as the alarm threshold) the alarmed variable required to exit the alarm. Alarm conditions have ceased when the alarmed variable is below the triggering threshold by the amount of the hysteresis.

4. Latching. A latching alarm requires acknowledgment from the operators before it can return to normal, even if the exit deadband has been met. A nonlatching alarm does not require acknowledgment. Default latching status is as follows:

a. Level 1 alarms: latching

b. Level 2 alarms: latching

c. Level 3 alarms: nonlatching

d. Level 4 alarms: nonlatching

5. Post-exit Suppression Period. To limit alarms, any alarm may have an adjustable suppression period such that once the alarm is exited, its post-exit suppression timer is triggered and the alarm may not trigger again until the post-exit suppression timer has expired. Default suppression periods are as follows:

a. Level 1 alarms: 0 minutes

b. Level 2 alarms: 5 minutes

c. Level 3 alarms: 24 hours

d. Level 4 alarms: 7 days

N. VFD Speed Points

To avoid operator confusion, the speed command point (and speed feedback point, if used) for VFDs should be configured so that a speed of 0% corresponds to 0 Hz, and 100% corresponds to maximum speed set in the VFD, not necessarily 60 Hz. The maximum speed may be limited below 60 Hz to protect equipment, or it may be above 60 Hz for direct drive equipment. Drives are often configured such that a 0% speed signal corresponds to the minimum speed programmed into the VFD, but that causes the speed AO value and the actual speed to deviate from one another.

1. The speed AO sent to VFDs shall be configured such that 0% speed corresponds to 0 Hz, and 100% speed corresponds to maximum speed configured in the VFD.

It is desirable that the minimum speed reside in the VFD to avoid problems when the VFD is manually controlled at the drive. But minimums can also be adjusted inadvertently in the VFD to a setpoint that is not equal to the minimum used in software. The following prevents separate, potentially conflicting minimum speed setpoints from existing in the BAS software and the drive firmware.

2. For each piece of equipment, the minimum speed shall be stored in a single software point; in the case of a hard-wired VFD interface, the minimum speed shall be the lowest speed command sent to the drive by the BAS. See Section 1.3 for minimum speed setpoints. The active minimum speed parameter shall be read every 60 minutes via the drive's network interface. When a mismatch between the drive's active minimum speed and the minimum speed stored in the software point is detected, the minimum speed stored in the software point shall be written to the VFD via the network interface to restore the active minimum speed parameter to its default value, and generate a Level 4 alarm.

The minimum speed parameter is read via the network interface to detect any changes in the minimum speed parameter. Upon detecting a change in the minimum speed setting, the correct minimum speed stored in a BAS software point is written back to the drive via the network interface to override any changes that are made locally to the minimum speed parameter at the VFD.

O. Trim & Respond Set-Point Reset Logic

1. T&R set-point reset logic and zone/system reset requests, where referenced in sequences, shall be implemented as described below.

2. A "request" is a call to reset a static pressure or temperature setpoint generated by downstream zones or air-handling systems. These requests are sent upstream to the plant or system that serves the zone or air handler that generated the request.

   a. For each downstream zone or system, and for each type of set-point reset request listed for the zone/system, provide the following software points:

      1) Importance-Multiplier (default = 1)

Importance-Multiplier is used to scale the number of requests the zone/system is generating. A value of zero causes the requests from that zone or system to be ignored. A value greater than one can be used to effectively increase the number of requests from the zone/system based on the critical nature of the spaces served.

      2) Request-Hours Accumulator. Provided SystemOK (see Section 3.1Q) is true for the zone/system, every x minutes (default 5 minutes), add x divided by 60 times the current number of requests to this request-hours accumulator point.

      3) System Run-Hours Total. This is the number of hours the zone/system has been operating in any mode other than Unoccupied Mode.

Request-Hours accumulates the integral of requests (prior to adjustment of Importance-Multiplier) to help identify zones/systems that are driving the reset logic. Rogue zone identification is particularly critical in this context, because a single rogue zone can keep the T&R loop at maximum and prevent it from saving any energy.

4) Cumulative%-Request-Hours. This is the zone/system Request-Hours divided by the zone/system run-hours (the hours in any mode other than Unoccupied Mode) since the last reset, expressed as a percentage.

5) The Request-Hours Accumulator and System Run-Hours Total are reset to zero as follows:

   a) Reset automatically for an individual zone/system when the System Run-Hours Total exceeds 400 hours.

   b) Reset manually by a global operator command. This command will simultaneously reset the Request-Hours point for all zones served by the system.

6) A Level 4 alarm is generated if the zone Importance-Multiplier is greater than zero, the zone/system Cumulative% Request Hours exceeds 70%, and the total number of zone/system run hours exceeds 40.

b. See zone and air-handling system control sequences for logic to generate requests.

c. Multiply the number of requests determined from zone/system logic times the Importance-Multiplier and send to the system/plant that serves the zone/system. See system/plant logic to see how requests are used in T&R logic.

3. For each upstream system or plant setpoint being controlled by a T&R loop, define the following variables. Initial values are defined in system/plant sequences below. Values for trim, respond, time step, etc. shall be tuned to provide stable control. See Table 5.1.14.3.

Table 5.1.14.3 Trim & Respond Variables

Variable	Definition
Device	Associated device (e.g., fan, pump)
SP0	Initial setpoint
SPmin	Minimum setpoint
SPmax	Maximum setpoint
Td	Delay timer
T	Time step
I	Number of ignored requests
R	Number of requests from zones/systems
SPtrim	Trim amount
SPres	Respond amount (must be opposite in sign to SPtrim)
SPres-max	Maximum response per time interval (must be same sign as SPres)

Informative Note: The number of ignored requests (I) should be set to zero for critical zones or air handlers.

4. Trim & Respond logic shall reset the setpoint within the range SPmin to SPmax. When the associated device is off, the setpoint shall be SP0. The reset logic shall be active while the associated device is proven on, starting Td after initial device start command. When active, every time step T, if R≤I, trim the setpoint by SPtrim. If there are more than I requests, respond by changing the setpoint by SPres*(R – I), (i.e., the number of requests minus the number of ignored requests) but no more than SPres-max. In other words, every time step T.

If R≤I, change Setpoint by SPtrim
If R > I, change setpoint by (R – I)*SPres but no larger than SPres-max

P. Air Economizer High Limits

1. Economizer shall be disabled whenever the outdoor air conditions exceed the economizer high-limit setpoint as specified. Setpoints shall be automatically determined by the control sequences (to ensure they are correct and meet code) based on energy standard, climate zone, and economizer high-limit-control device type selected by the design engineer in Section 1.2E.3. Setpoints listed below are for current California Energy Standards.

2. Title 24-2019

Device Type	California Climate Zones	Required High Limit (Economizer off when)
Fixed dry bulb	1, 3, 5, 11 to 16	TOA > 24°C (75°F)
Differential dry bulb	1, 3, 5, 11 to 16	TOA > TRA

Q. Hierarchical Alarm Suppression

1. For each piece of equipment or space controlled by the BAS, define its relationship (if any) to other equipment in terms of “source,” “load,” or “system.”

   a. A component is a “source” if it provides resources to a downstream component, such as a chiller providing chilled water (CHW) to an AHU.

   b. A component is a “load” if it receives resources from an upstream component, such as an AHU that receives CHW from a chiller.

   c. The same component may be both a load (receiving resources from an upstream source) and a source (providing resources to a downstream load).

   d. A set of components is a “system” if they share a load in common (i.e., collectively act as a source to downstream equipment, such as a set of chillers in a lead/lag relationship serving air handlers).

1) If a single component acts as a source for downstream loads (e.g., an AHU as a source for its VAV boxes), then that single-source component shall be defined as a "system" of one element.

2) For equipment with associated pumps (chillers, boilers, cooling towers):

a) If the pumps are in a one-to-one relationship with equipment they serve, the pumps shall be treated as part of the system to which they are associated (i.e., they are not considered loads), as a pump failure will necessarily disable its associated equipment.

b) If the pumps are headered to the equipment they serve, then the pumps may be treated as a system, which is a load relative to the upstream equipment (e.g., chillers) and a source relative to downstream equipment (e.g., air handlers).

2. For each system as defined in Section 3.1Q.1.d, there shall be a SystemOK flag, which is either true or false.

3. SystemOK shall be true when all of the following are true:

a. The system is proven on.

b. The system is achieving its temperature and/or pressure setpoint(s) for at least 5 minutes

c. The system is ready and able to serve its load

4. SystemOK shall be false while the system is starting up (i.e., before reaching setpoint) or when enough of the system's components are unavailable (in alarm, disabled, or turned off) to disrupt the ability of the system to serve its load. This threshold shall be defined by the design engineer for each system.

a. By default, Level 1 through Level 3 component alarms (indicating equipment failure) shall inhibit SystemOK. Level 4 component alarms (maintenance and energy efficiency alarms) shall not affect SystemOK.

b. The operator shall have the ability to individually determine which component alarms may or may not inhibit SystemOK.

5. The BAS shall selectively suppress (i.e., fail to announce; alarms may still be logged to a database) alarms for load components if SystemOK is false for the source system that serves that load.

a. If SystemOK is false for a cooling water system (i.e., chiller, cooling tower, or associated pump), then only high-temperature alarms from the loads shall be suppressed.

b. If SystemOK is false for a heating water system (i.e., boiler or associated pump), then only low temperature alarms from the loads shall be suppressed.

c. If SystemOK is false for an air-side system (air handler, fan coil, VAV box, etc.), then all alarms from the loads shall be suppressed.

6. This hierarchical suppression shall cascade through multiple levels of load-source relationship such that alarms at downstream loads shall also be suppressed.

7. The following types of alarms will never be suppressed by this logic:

a. Life/safety and Level 1 alarms

b. Failure-to-start alarms (i.e., equipment is commanded on, but status point shows equipment to be off)

c. Failure-to-stop/hand alarms (i.e., equipment is commanded off, but status point shows equipment to be on)

R. Time-Based Suppression

1. Calculate a time-delay period after any change in setpoint based on the difference between the controlled variable (e.g., zone temperature) at the time of the change and the new setpoint. The default time delay period shall be as follows:

a. For thermal zone temperature alarms: 18 minutes per °C (10 minutes per °F) of difference but no longer than 120 minutes

b. For thermal zone temperature cooling requests: 9 minutes per °C (5 minutes per °F) of difference but no longer than 30 minutes

c. For thermal zone temperature heating requests: 9 minutes per °C (5 minutes per °F) of difference but no longer than 30 minutes

S. Pandemic Mode

1. Provide a software switch on the Home Page graphic for Pandemic Mode on/off. The switch shall include a timer that can be manually set by the operator for a period of up to 60 weeks, after which the Mode shall be shut off and control logic and setpoints returned to normal.

2. When the Pandemic Mode timer is on:

a. All CO2 DCV setpoints shall be set to 800 ppm.

b. Occupancy sensors used for Occupied Standby logic shall be not reset zone ventilation rates; with respect to ventilation, the zone shall be considered "populated".

c. All Zone Group time schedules shall indicate Occupied Mode one hour prior to the scheduled time. This earlier time shall be reflected in optimum start logic.

T. Wildfire Mode

1. Provide a 2-position software switch on the Home Page graphic for Wildfire Mode:

a. Off. Locks Wildfire Mode off.

b. On. Turns Wildfire Mode on for a preset period of time, after which the Mode shall be shut off. The preset time shall be operator adjustable for up to 1 week.

2. When the Wildfire Mode timer is on:

a. Disable all economizers (lock High Limit to off).

3.2 ELECTRICITY DEMAND LIMITING

A. Demand Response

1. On home page, provide three software switches: Demand Limit Level 1 to 3.

a. These switches shall have AUTO, ON, and OFF positions. AUTO position shall set the Demand Limit Level's status to enabled or disabled based on an OpenADR 2.0 signal from the utility (see Section 250000 Building Automation Systems) or the Owner Initiated Electricity Demand Limiting logic below with enabled taking precedence; ON shall manually enable the Demand Limit Level; and OFF shall disable and lockout the Demand Limit Level.

b. The Highest Demand Limit Level signal currently enabled, either via an ON or AUTO command, shall be given priority.

c. These signals are used at the zone level (see Zone Control sequences) to adjust setpoints to reduce demand.

2. When any Demand Limit Level is on, generate a Level 4 alarm.

B. Owner-Initiated Electricity Demand Limiting

1. Sliding Window: The demand control function shall utilize a sliding window method selectable in increments of one minute, up to 60 minutes, 15 minute default.

2. Demand Levels: Demand time periods shall be set up as per utility rate schedule. For each On/Off/Partial-Peak period, three demand kW thresholds can be defined and mapped to the Demand Limit Levels, 1 to 3. When the measured demand exceeds a threshold, and the software switch described above for the associated Demand Limit Level is set to AUTO, the Demand Limit Level shall be enabled; when demand is more than 10% (adjustable) below the limit for a minimum of 15 minutes, or the time is no longer within the On/Off/Partial-Peak window, the Demand Limit Level command shall be disabled.

3.3 GENERIC VENTILATION ZONES

A. Zone Minimum Outdoor Air and Minimum Airflow Setpoints

1. For every zone that requires mechanical ventilation, the zone minimum outdoor airflows and setpoints shall be calculated depending on the governing standard or code for outdoor air requirements.

2. See Section 1.2C for zone minimum airflow setpoint Vmin.

3. For compliance with California Title 24, outdoor air setpoints shall be calculated as follows:

   a. See Section 1.2B.2 for zone ventilation setpoints.

   b. Determine the zone minimum outdoor air setpoints Zone-Abs-OA-min and Zone-Des-OA-min.

Zone-Abs-OA-min is used in terminal-unit sequences and air-handler sequences. Zone-Des-OA-min is used in air-handler sequences only.

      1) Zone-Abs-OA-min shall be reset based on the following conditions in order from highest to lowest priority:

         a) Zero if the zone has a window switch and the window is open.

         b) Zero if the zone has an occupancy sensor and is unpopulated and is permitted to be in occupied-standby mode per Section 1.2B.2.a.3).

         c) Varea-min if the zone has a CO2 sensor.

         d) Zone-Des-OA-min otherwise.

      2) Zone-Des-OA-min is equal to the following, in order from highest to lowest priority:

         a) Zero if the zone has a window switch and the window is open.

         b) Zero if the zone has an occupancy sensor, is unpopulated, and is permitted to be in occupied-standby mode per Section 1.2B.2.a.3).

         c) The larger of Varea-min and Vocc-min otherwise.

   c. Vmin

      1) Shall be equal to Zone-Abs-OA-min if Vmin in Section 1.2C is “AUTO”;

      2) Else shall be equal to Vmin as entered in Section 1.2C.

   d. The occupied minimum airflow Vmin* shall be equal to Vmin except as noted below, in order from highest to lowest priority:

      1) If the zone has an occupancy sensor and is permitted to be in occupied-standby mode per Section 1.2B.2.a.3), Vmin* shall be equal to zero when the room is unpopulated.

      2) If the zone has a window switch, Vmin* shall be zero when the window is open.

      3) If the zone has a CO2 sensor:

         a) See Section 1.2B.2.a.3) for CO2 setpoints.

b) During Occupied Mode, a P-only loop shall maintain CO2 concentration at setpoint; reset from 0% at setpoint minus 200 PPM and to 100% at setpoint.

c) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

d) For reheat VAV terminal units:

1. The CO2 control loop output shall reset the occupied minimum airflow setpoint Vmin* from the zone minimum airflow setpoint Vmin at 0% up to maximum cooling airflow setpoint Vcool-max at 50%, as shown in Figure 5.2.1.4-1. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

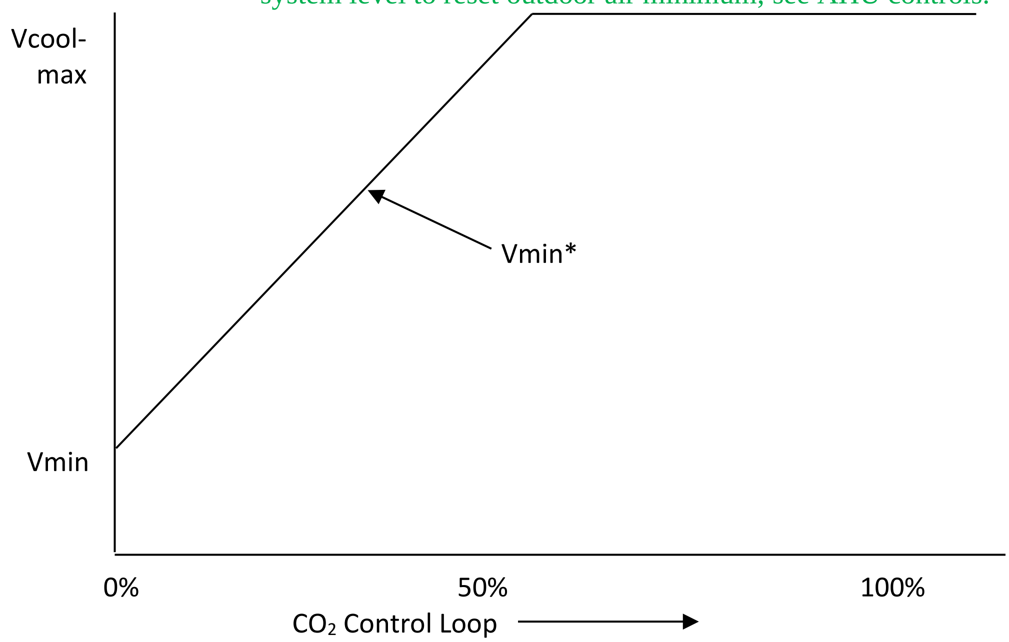


Figure 5.2.1.4-1 Vmin* reset with CO2 loop.

B. Time-Averaged Ventilation

ASHRAE Standard 62.1 and California Title 24 allow for ventilation to be provided based on average conditions over a specific period of time. This time-averaging method allows for zone airflows to effectively be controlled to values below the VAV box controllable minimum value, which may reduce energy use and the risk of overcooling when the zone ventilation requirement is less than the VAV box controllable minimum.

1. When the active airflow setpoint Vspt is nonzero and is less than the lowest possible airflow setpoint allowed by the controls (Vm), the airflow setpoint shall be pulse width modulated as follows:

a. The time-averaged ventilation (TAV) ratio shall be determined as TAVratio = Vspt/Vm

b. The total cycle time (TCT) shall be 15 minutes (adjustable)

c. Open period. During the open period, the TAV airflow setpoint Vspt* shall be equal to Vm for a period of time OP, which is the larger of the following:

d. 1.5 minutes or

e. TCT multiplied by TAVratio

f. Closed period. During the closed period, Vspt* shall be set to 0 for a period of time CP, where CP = TCT – OP. The VAV damper control loop shall be disabled with output set equal to 0 during the closed period. At the end of each closed period, the VAV damper shall be commanded to the last position from the previous open period prior to reenabling the control loop.

g. During TAV mode, each cycle shall consist of an open and closed period that alternate until Vspt is greater than Vm.

The following logic ensures that multiple zones do not enter TAV mode at the same time, avoiding the synchronized opening and closing of VAV dampers. Where there are a small number of zones and the majority may potentially be in TAV mode synchronously, avoiding this issue may be more reliably achieved by sequencing the VAV terminal units deterministically so that each VAV terminal unit always opens at a specific minute into the total cycle time. The aim of this sequencing is to ensure that the total airflow is as constant as possible over the total cycling time even if all of the VAV terminal units enter TAV mode at the same time (e.g., when a building-wide temperature setback occurs).
For example, the total open cycle for VAV terminal-unit A opens at minute 1 of the total cycle time, VAV terminal-unit B opens at minute x of the total cycle time, etc.
The random number for each terminal unit, RNDM, can be determined using a random number generator each time the unit enters TAV mode or set manually to a fixed value. If configured manually, set RNDM for each terminal unit to a unique value within the range of 0.0 to 1.0 such that the values are evenly distributed across the terminal units within a system.

h. When first entering TAV mode, start with an initial open period of duration RNDM*OP, where RNDM is a random number between 0.0 and 1.0.

2. When in TAV mode, the active airflow setpoint, Vspt, shall be overridden to Vspt*.

C. For zones with CO2 sensors:

1. If the CO2 concentration is less than 300 ppm, or the zone is in Unoccupied Mode for more than 2 hours and zone CO2 concentration exceeds 600 ppm, generate a Level 3 alarm. The alarm text shall identify the sensor and indicate that it may be out of calibration.

2. If the CO2 concentration exceeds setpoint plus 10% for more than 10 minutes, generate a Level 3 alarm.

3.4 GENERIC THERMAL ZONES

A. This section applies to all single-zone systems and subzones of air-handling systems, such as VAV boxes, etc.

B. Setpoints

1. See Section 1.2B.1 for zone temperature setpoints.

2. Each zone shall have separate occupied and unoccupied heating and cooling setpoints.

3. The active setpoints shall be determined by the operating mode of the Zone Group (see Section 3.5F).

The following is from addendum e to G36-2021:

   a. During occupied mode:

      1) The cooling set point shall be the occupied cooling set point.

      2) The heating set point shall be the occupied heating set point.

   b. During warm-up mode:

      1) The cooling set point shall be the unoccupied cooling set point.

      2) The heating set point shall be the unoccupied heating set point until the time remaining until the zone group's occupied start time is less than the zone's required warm-up time, tz-warmup, at which point the heating set point shall be the occupied heating set point.

   c. During cool-down mode:

      1) The cooling set point shall be the unoccupied cooling set point until the time remaining until the zone group's occupied start time is less than the zone's required cool-down time, tz-cooldown, at which point the cooling set point shall be the occupied cooling set point.

      2) The heating set point shall be the unoccupied heating set point.

   d. During setback mode:

      1) The cooling set point shall be the unoccupied cooling set point.

      2) The heating set point shall be 2°C (3°F) above the unoccupied heating set point.

   e. During setup mode:

      1) The cooling set point shall be 2°C (3°F) below the unoccupied cooling set point.

      2) The heating set point shall be the unoccupied heating set point.

   f. During unoccupied mode:

      1) The cooling set point shall be the unoccupied cooling set point.

      2) The heating set point shall be the unoccupied heating set point.

4. The software shall prevent the following:

a. The heating setpoint from exceeding the cooling setpoint minus 0.5°C (1°F) (i.e., the minimum difference between heating and cooling setpoints shall be 0.5°C [1°F]).

b. The unoccupied heating setpoint from exceeding the occupied heating setpoint.

c. The unoccupied cooling setpoint from being less than the occupied cooling setpoint.

5. Where the zone has a local setpoint adjustment knob/button:

a. The setpoint adjustment offsets established by the occupant shall be software points that are persistent (e.g., not reset daily), but the actual offset used in control logic shall be adjusted based on limits and modes as describe below.

b. The adjustment shall be capable of being limited in software.

These are absolute limits imposed by programming, which are in addition to the range limits (e.g., ±4°F) of the thermostat adjustment device.

1) As a default, the active occupied cooling setpoint shall be limited between 22°C (72°F) and 27°C (80°F).

2) As a default, the active occupied heating setpoint shall be limited between 18°C (65°F) and 22°C (72°F).

c. The active heating and cooling setpoints shall be independently adjustable, respecting the limits and anti-overlap logic described in Sections 3.4B.3.a and 3.4B.5.b. If zone thermostat provides only a single set-point adjustment, then the adjustment shall move both the active heating and cooling setpoints upward or downward by the same amount, within the limits described in Section 3.4B.5.b.

d. The adjustment shall only affect occupied setpoints in Occupied Mode, Warmup Mode, and Cooldown Mode and shall have no impact on setpoints in all other modes.

e. At the onset of demand limiting, the local set-point adjustment value shall be frozen. Further adjustment of the setpoint by local controls shall be suspended for the duration of the demand-limit event.

6. Cooling Demand Limit Set-Point Adjustment. The active cooling setpoints for all zones shall be increased when a demand limit is imposed on the associated Zone Group. The operator shall have the ability to exempt individual zones from this adjustment through the normal BAS user interface. Changes due to demand limits are not cumulative.

a. At demand-limit Level 1, increase setpoint by 0.5°C (1°F).

b. At demand-limit Level 2, increase setpoint by 1°C (2°F).

c. At demand-limit Level 3, increase setpoint by 2°C (4°F).

7. Heating Demand-Limit Set-Point Adjustment. The active heating setpoints for all zones shall be decreased when a demand limit is imposed on the associated Zone Group. The operator shall have the ability to exempt individual zones from this adjustment through the normal BAS user interface. Changes due to demand limits are not cumulative.

a. At demand-limit Level 1, decrease setpoint by 0.5°C (1°F).

b. At demand-limit Level 2, decrease setpoint by 1°C (2°F).

c. At demand-limit Level 3, decrease setpoint by 2°C (4°F).

Heating demand limits may be desirable in buildings with electric heat or heat pumps or in regions with limited gas distribution infrastructure.

8. Occupancy Sensors. For zones that have an occupancy switch:

a. When the switch indicates that the space has been unpopulated for 5 minutes continuously during the Occupied Mode, the active heating setpoint shall be decreased by 0.5°C (1°F) and the cooling setpoint shall be increased by 0.5°C (1°F).

b. When the switch indicates that the space has been populated for 1 minute continuously, the active heating and cooling setpoints shall be restored to their previous values.

9. Hierarchy of Set-Point Adjustments. The following adjustment restrictions shall prevail in order from highest to lowest priority:

a. Setpoint overlap restriction (Section 3.4B.3.a)

b. Absolute limits on local setpoint adjustment (Section 3.4B.5.b)

c. Window switches

d. Demand limit

1) Occupancy sensors. Change of setpoint by occupancy sensor is added to change of setpoint by any demand limits in effect.

2) Local set-point adjustment. Any changes to setpoint by local adjustment are frozen at the onset of the demand limiting event and remain fixed for the duration of the event. Additional local adjustments are ignored for the duration of the demand limiting event.

e. Scheduled setpoints based on Zone Group mode

C. Local Override. When thermostat override buttons are depressed, the call for Occupied Mode operation shall be sent to the Zone Group control for 60 minutes. Local Override shall be capable of being enabled and disabled separately for each thermostat via the graphical user interface; default to disabled.

Local overrides will cause all zones in the Zone Group to operate in Occupied Mode to ensure that the system has adequate load to operate stably.

D. Control Loops

1. Two separate control loops, the Cooling Loop and the Heating Loop, shall operate to maintain space temperature at setpoint.

a. The Heating Loop shall be enabled whenever the space temperature is below the current zone heating set-point temperature and disabled when space temperature is above the current zone heating setpoint temperature and the loop output is zero for 30 seconds. The loop may remain active at all times if provisions are made to minimize integral windup.

b. The Cooling Loop shall be enabled whenever the space temperature is above the current zone cooling set-point temperature and disabled when space temperature is below the current zone cooling set-point temperature and the loop output is zero for 30 seconds. The loop may remain active at all times if provisions are made to minimize integral windup.

2. The Cooling Loop shall maintain the space temperature at the active cooling setpoint. The output of the loop shall be a software point ranging from 0% (no cooling) to 100% (full cooling).

3. The Heating Loop shall maintain the space temperature at the active heating setpoint. The output of the loop shall be a software point ranging from 0% (no heating) to 100% (full heating).

4. Loops shall use proportional + integral logic or other technology with similar performance. Proportional-only control is not acceptable, although the integral gain shall be small relative to the proportional gain. P and I gains shall be adjustable by the operator.

5. See other sections for how the outputs from these loops are used.

E. Zone State

1. Heating. When the output of the space Heating Loop is nonzero and the output of the Cooling Loop is equal to zero.

2. Cooling. When the output of the space Cooling Loop is nonzero and the output of the Heating Loop is equal to zero.

3. Deadband. When not in either heating or cooling.

F. Zone Alarms

1. Zone Temperature Alarms

a. High-temperature alarm

1) If the zone is 2°C (3°F) above cooling setpoint for 10 minutes, generate a Level 4 alarm.

2) If the zone is 3°C (5°F) above cooling setpoint for 10 minutes, generate a Level 3 alarm.

b. Low-temperature alarm

1) If the zone is 2°C (3°F) below heating setpoint for 10 minutes, generate a Level 4 alarm.

2) If the zone is 3°C (5°F) below heating setpoint for 10 minutes, generate a Level 3 alarm.

Default time delay for zone temperature alarm (10 minutes) is intentionally long to minimize nuisance alarms. For critical zones, such as IT closets, consider reducing time delay or setting delay to zero.

c. Suppress zone temperature alarms as follows:

1) After zone setpoint is changed per Section 3.1R.

2) While Zone Group is in Warmup Mode or Cooldown Mode.

The following is from addendum e to G36-2021:

G. Zone Group Mode Requests

1. Zone Group Mode Requests shall be generated by the conditions in each zone and sent to the Zone Group of which the zone is a member.

2. Warm-up Mode Requests

a. An algorithm provided with the BAS shall calculate the required zone warm-up time, tz-warmup, which shall be less than 3 hours, based on the zone’s occupied heating set point, the current zone temperature, the outdoor air temperature, and a heating mass/capacity factor for each zone.

b. The heating mass/capacity factor may be either manually adjusted or automatically self-tuned by the BAS. If automatic, the tuning process shall be turned ON or OFF by a software switch to allow tuning to be stopped after the system has been trained.

c. If the zone group is in any mode other than occupied mode, zone window switch(es) indicate that all windows are closed, and the time remaining until the zone group’s occupied start time is less than the zone's required warm-up time, tz-warmup, send 1 Warm-up Mode Request; else, send 0 Warm-up Mode Requests.

3. Cooldown Mode Requests

a. An algorithm provided with the BAS shall calculate the required zone cool-down time, tz-cooldown, which shall be less than 3 hours, based on the zone’s occupied heating set point, the current zone temperature, the outdoor air temperature, and a cooling mass/capacity factor for each zone.

b. The cooling mass/capacity factor may be either manually adjusted or automatically self-tuned by the BAS. If automatic, the tuning process shall be turned ON or OFF by a software switch to allow tuning to be stopped after the system has been trained.

c. If the zone group is in any mode other than occupied mode, zone window switch(es) indicate that all windows are closed, and the time remaining until the zone group’s occupied start time is less than the zone's required cool-down time, t-cooldown, send 1 Cooldown Mode Request; else, send 0 Cooldown Mode Requests.

Warm-up and cooldown modes are used to bring the zone groups up to temperature based on their scheduled occupancy period. The algorithms used in these modes (often referred to as "optimal start") predict the shortest time to achieve occupied set point to reduce the central system energy use based on past performance.
It is recommended to use a global outdoor air temperature not associated with any AHU to determine warm-up start time. This is because unit-mounted OA sensors, which are usually placed in the outdoor air intake stream, are often inaccurate (reading high) when the unit is off due to air leakage from the space through the OA damper.

4. Setback Mode Requests

   a. If the zone group is in unoccupied or setback mode, zone window switch(es) indicate that all zone windows are closed, and zone temperature is less than the unoccupied heating setpoint for 5 minutes, send 1 Setback Mode Request; else, send 0 Setback Mode Requests.

5. Setup Mode Requests

   a. If the zone group is in unoccupied or setup mode, zone window switch(es) indicate that all zone windows are closed, and zone temperature is greater than the unoccupied cooling setpoint for 5 minutes, send 1 Setup Mode Requests; else, send 0 Setup Mode Requests.

3.5 ZONE GROUPS

Zone scheduling groups, or Zone Groups, are sets of zones served by a single air handler that operate together for ease of scheduling and/or in order to ensure sufficient load to maintain stable operation in the upstream equipment. A Zone Group is equivalent to an isolation area as defined in ASHRAE/IES Standard 90.1 and Title 24.

A. Each system shall be broken into separate Zone Groups composed of a collection of one or more zones served by a single air handler. See Section 1.2D for Zone Group assignments.

B. Each Zone Group shall be capable of having separate occupancy schedules and operating modes from other Zone Groups.

Note that, from the user's point of view, schedules can be set for individual zones, or they can be set for an entire Zone Group, depending on how the user interface is implemented. From the point of view of the BAS, individual zone schedules are superimposed to create a zone-group schedule, which then drives system behavior.
The schedule may govern operation of other integrated systems such as lights, daylighting, or other, in addition to the HVAC system.

C. All zones in each Zone Group shall be in the same zone-group operating mode as defined in Section 3.5F. If one zone in a Zone Group is placed in any zone-group operating mode other than Unoccupied Mode (due to override, sequence logic, or scheduled occupancy), all zones in that Zone Group shall enter that mode.

Occupied-standby mode applies to individual zones, is considered a zonal subset of Occupied Mode, and shall not be considered a zone-group operating mode.

D. A Zone Group may be in only one mode at a given time.

E. For each Zone Group, provide a set of testing/commissioning software switches that override all zones served by the Zone Group. Provide a separate software switch for each of the zone-level override switches listed under “Testing and Commissioning Overrides” in terminal unit sequences. When the value of a Zone Group’s override switch is changed, the corresponding override switch for every zone in the Zone Group shall change to the same value. Subsequently, the zone-level override switch may be changed to a different value. The value of the zone-level switch has no effect on the value of the zone-group switch, and the value of the zone-group switch only affects the zone-level switches when the zone-group switch is changed.

> *The testing and commissioning overrides will be specified for each type of terminal unit and system in subsequent sequences. These overrides allow a commissioning agent to, for example, force a zone into cooling or drive a valve all the way open or closed.*
> *Zone-group override switches allow a commissioning agent to apply a zone-level override to all zones in a Zone Group simultaneously. This greatly accelerates the testing and commissioning process.*

F. Zone-Group Operating Modes. Each Zone Group shall have the modes shown in the following subsections.

> *The modes presented in this section are to enable different setpoints and ventilation requirements to be applied to Zone Groups based on their operating schedule, occupancy status, and deviation from current setpoint.*
> *See ASHRAE Guideline 13 for best practices in locating zone-group operating mode programming logic based on network architecture.*

1. Occupied Mode. A Zone Group is in the Occupied Mode when any of the following is true:

    a. The time of day is between the Zone Group’s scheduled occupied start and stop times.

    b. Any zone local override timer (initiated by local override button) is nonzero.

> *The following is from addendum e to G36-2021:*

2. Warm-Up Mode. Warm-up mode shall start when the number of Warm-Up Mode Requests > I (I = ignores, default = 5), and shall end at the zone group’s scheduled occupied start time or Warm-Up Mode Requests <MT (MT=minimum threshold, default = 1) after a minimum of 10 minutes in this mode.

3. Cool-down Mode. Cool-down mode shall start when the number of Cool-down Mode Requests > I (I = ignores, default to 5), and shall end at the zone group’s scheduled occupied start time or Cool-down Mode Requests <MT (MT=minimum threshold, default = 1) after a minimum of 10 minutes in this mode.

4. Setback Mode. Setback mode shall start when the number of Setback Mode Requests > I (I = ignores, default to 4), and shall end when Setback Mode Requests <MT (MT=minimum threshold, default = 1) after a minimum of 10 minutes in this mode.

5. Setup Mode. Setup mode shall start when the number of Setup Mode Requests > I (I = ignores, default to 4), and shall end when Setup Mode Requests <MT (MT=minimum threshold, default = 1) after a minimum of 10 minutes in this mode.

Setback and setup modes are used to keep zone temperatures (and mass) from straying excessively far from occupied set points so that the cooldown and warm-up modes can achieve set point when initiated. The number of ignored zones (set at 4 here) are to ensure that the central systems (fans, pumps, heating sources, or cooling sources) can operate stably. Obviously, the size of the zones and the characteristics of the central systems are a factor in choosing the correct number of zones in each group.

6. When zones in one Zone Group are generating requests for different modes, the hierarchy in Section 5.15.1 shall be used to determine Zone Group Operating Mode.

3.6 VAV TERMINAL UNIT WITH REHEAT

A. See "Generic Thermal Zones" (Section 3.3C) for setpoints, loops, control modes, alarms, etc.

B. See "Generic Ventilation Zones" (Section 3.3) for calculation of zone minimum outdoor airflow.

C. See Section 1.2C.3 for zone minimum airflow setpoints Vmin, zone maximum cooling airflow setpoint Vcool-max, zone maximum heating airflow setpoint Vheat-max, zone minimum heating airflow setpoint Vheat-min, and the maximum DAT rise above heating setpoint MaxΔT.

D. Active endpoints used in the control logic depicted in Figure 5.6.5 shall vary depending on the mode of the Zone Group the zone is a part of (see Table 5.6.4).

Table 5.6.4 Endpoints as a Function of Zone Group Mode

Endpoint	Occupied	Cooldown	Setup	Warmup	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Cooling minimum	Vmin*	0	0	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating minimum	Max (Vheat-min, Vmin*)	Vheat-min	0	Vheat-max	Vheat-max	0
Heating maximum	Max (Vheat-max, Vmin*)	Vheat-max	0	Vcool-max	Vcool-max	0

E. Control logic is depicted schematically in Figure 5.6.5 (modified from Guideline 36) and described in the following subsections.

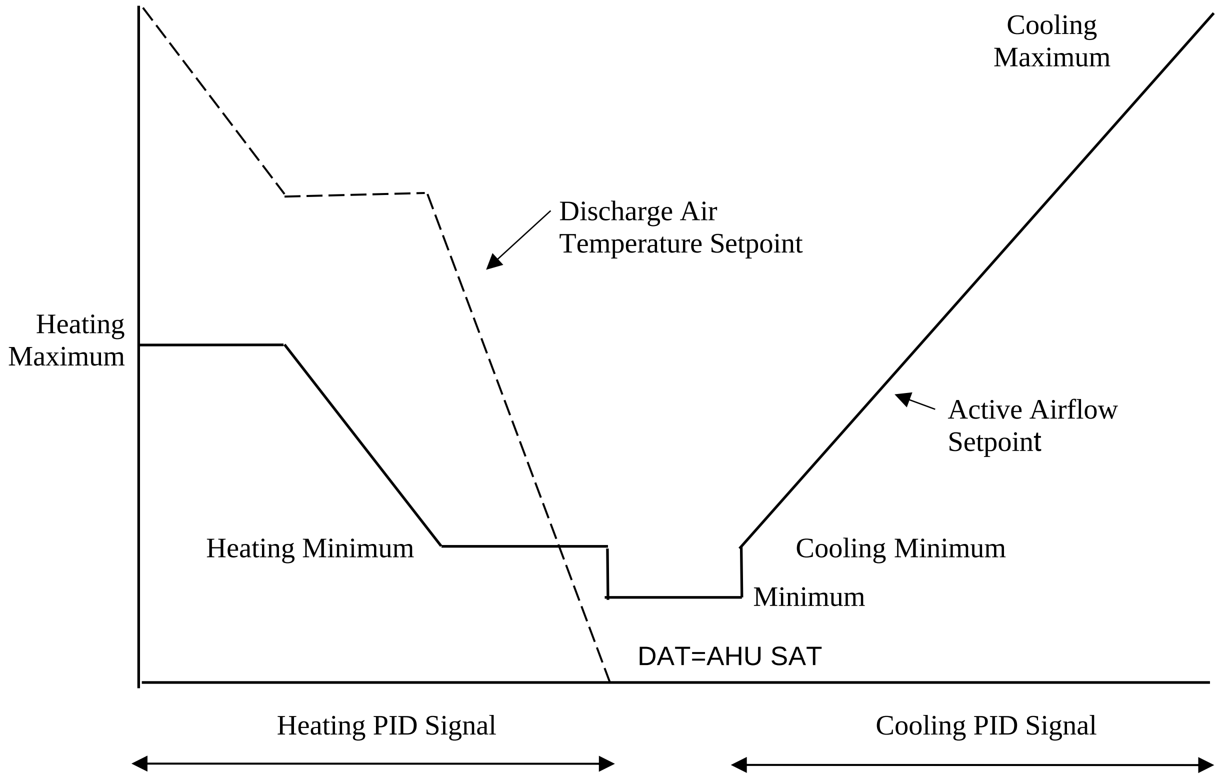


Figure 5.6.5 Control logic for VAV reheat zone modified from Guideline 36.

1. When the Zone State is cooling, the cooling-loop output shall be mapped to the active airflow setpoint from the cooling minimum endpoint to the cooling maximum endpoint. Heating coil is disabled unless the DAT is below the minimum setpoint (see Section 3.6E.4).

   a. If supply air temperature from the air handler is greater than room temperature, the active airflow setpoint shall be no higher than the minimum endpoint.

2. When the Zone State is deadband, the active airflow setpoint shall be the minimum endpoint. Heating coil is disabled unless the DAT is below the minimum setpoint (see Section 3.6E.4).

3. When the Zone State is heating, the Heating Loop shall maintain space temperature at the heating setpoint as follows:

   a. From 0 to 33%, the Heating Loop output shall reset the discharge air temperature DAT from the current AHU SAT setpoint to a setpoint equal to MaxΔT above space temperature setpoint. The airflow setpoint shall be the Heating Minimum.

   b. From 33% to 66%, if the DAT is greater than the room temperature plus 5ºF, the Heating Loop output shall reset the zone airflow setpoint from the Heating Minimum to the Heating Maximum endpoint.

   c. From 66% to 100%, the Heating Loop output shall reset the DAT setpoint to 115°F.

d. The heating coil shall be modulated to maintain the discharge temperature at setpoint. (Directly controlling heating off the zone temperature control loop is not acceptable).

1) When the airflow setpoint is pulse-width modulated per Section 3.3B, the heating coil and PID loop shall be disabled, with output set to 0 during closed periods.

4. In Occupied Mode, the heating coil shall be modulated to maintain a DAT no lower than 10°C (50°F).

5. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

F. Alarms

1. Low Airflow

a. If the measured airflow is less than 70% of setpoint for 10 minutes while setpoint is greater than zero, generate a Level 4 alarm.

b. If the measured airflow is less than 50% of setpoint for 10 minutes while setpoint is greater than zero, generate a Level 3 alarm.

c. If a zone has an Importance-Multiplier of 0 (see Section 3.1O.2.a.1)) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

2. Low-Discharge Air Temperature

a. If heating hot-water plant is proven on, and the DAT is 8.3°C (15°F) less than setpoint for 10 minutes, generate a Level 4 alarm.

b. If heating hot-water plant is proven on, and the DAT is 17°C (30°F) less than setpoint for 10 minutes, generate a Level 3 alarm.

c. If a zone has an Importance-Multiplier of 0 (see Section 3.1O.2.a.1)) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

3. Airflow Sensor Calibration. If the fan serving the zone is off and airflow sensor reading is above the larger of 10% of the cooling maximum airflow setpoint or 50 cfm for 30 minutes, generate a Level 3 alarm.

4. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow setpoint or 50 cfm for 10 minutes while the fan serving the zone is proven on, generate a Level 4 alarm.

5. Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 3°C (5°F), and the fan serving the zone is proven on, generate a Level 4 alarm.

G. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow setpoint to zero,

b. force zone airflow setpoint to Vcool-max,

c. force zone airflow setpoint to Vmin,

d. force zone airflow setpoint to Vheat-max,

e. force damper full closed/open,

f. force heating to off/closed, and

g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

H. System Requests

1. Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling setpoint by 3°C (5°F) for 2 minutes and after suppression period due to setpoint change per Section 3.1R, send 3 requests.

b. Else if the zone temperature exceeds the zone's cooling setpoint by 2°C (3°F) for 2 minutes and after suppression period due to setpoint change per Section 3.1R, send 2 requests.

c. Else if the Cooling Loop is greater than 95%, send 1 request until the Cooling Loop is less than 85%.

d. Else if the Cooling Loop is less than 95%, send 0 requests.

2. Static Pressure Reset Requests

a. If the measured airflow is less than 50% of setpoint while setpoint is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.

b. Else if the measured airflow is less than 70% of setpoint while setpoint is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.

c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.

d. Else if the damper position is less than 95%, send 0 requests.

3. Hot-Water Reset Requests

a. If the DAT is 17°C (30°F) less than setpoint for 5 minutes, send 3 requests.

b. Else if the DAT is 8°C (15°F) less than setpoint for 5 minutes, send 2 requests.

c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.

d. Else if the HW valve position is less than 95%, send 0 requests.

4. Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.

b. Else if the HW valve position is less than 95%, send 0 requests.

3.7 AIR-HANDLING UNIT SYSTEM MODES

A. AHU system modes are the same as the mode of the Zone Group served by the system. When Zone Group served by an air-handling system are in different modes, the following hierarchy applies (highest one sets AHU mode):

a. Occupied Mode

b. Cooldown Mode

c. Setup Mode

d. Warmup Mode

e. Setback Mode

f. Unoccupied Mode

3.8 MULTIPLE ZONE VAV AIR HANDLERS

A. Supply Fan Control

1. Supply Fan Start/Stop

a. Supply fan shall run when system is in the Cooldown Mode, Setup Mode, or Occupied Mode.

b. If there are any VAV-reheat boxes on perimeter zones, supply fan shall also run when system is in Setback Mode or Warmup Mode (i.e., all modes except unoccupied).

c. Totalize current airflow rate from VAV boxes to a software point Vps.

VAV box airflow rates are summed to obtain overall supply air rate without the need for an airflow measuring station (AFMS) at the air-handler discharge. This is used for ventilation rate calculations and may also be used for display and diagnostics.

2. Static Pressure Set-Point Reset

a. Static pressure setpoint. Setpoint shall be reset using T&R logic (see Section 3.1O) using the parameters shown in Table 5.16.1.2.

Table 5.16.1.2 Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	120 Pa (0.5 in. of water)
SPmin	25 Pa (0.1 in. of water)
SPmax	Max_DSP (see Section 1.3B.1)
Td	10 minutes
T	2 minutes
I	2
R	Zone static pressure reset requests
SPtrim	–12 Pa (–0.05 in. of water)
SPres	15 Pa (+0.06 in. of water)
SPres-max	32 Pa (+0.13 in. of water)

The T&R reset parameters in Table 5.16.1.2 are suggested as a starting point; they will most likely require adjustment during the commissioning/tuning phase.

3. Static Pressure Control

   a. Supply fan speed is controlled to maintain DSP at setpoint when the fan is proven on. Where the Zone Groups served by the system are small, provide multiple sets of gains that are used in the control loop as a function of a load indicator (such as supply-fan airflow rate, the area of the Zone Groups that are occupied, etc.).

High-pressure trips may occur if all VAV boxes are closed (as in Unoccupied Mode) or if fire/smoke dampers are closed (in some fire/smoke damper (FSD) designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors). Multiple sets of gains are used to provide control loop stability as system characteristics change.

B. Supply Air Temperature Control

1. Control loop is enabled when the supply air fan is proven on, and disabled and output set to deadband (no heating, minimum economizer) otherwise.

2. Supply Air Temperature Setpoint

The default range of outdoor air temperatures [21°C (70°F) –16°C (60°F)] used to reset the Occupied Mode SAT setpoint was chosen to maximize economizer hours. It may be preferable to use a lower range of OATs (e.g., 18°C [65°F] – 13°C [55°F]) to minimize fan energy if there is a 24/7 chiller plant that is running anyway; reheat is minimized, as in a VAV dual-fan dual-duct system, or the climate severely limits the number of available economizer hours.
If using this logic, the engineer should oversize interior zones and rooms with high cooling loads (design them to be satisfied by the warmest SAT) so these zones do not drive the T&R block to the minimum SAT setpoint.

a. See Section 1.2E.1 for Min_ClgSAT, Max_ClgSAT, OAT_Min, and OAT_Max setpoints.

b. During Occupied Mode and Setup Mode, setpoint shall be reset from Min_ClgSAT when the outdoor air temperature is OAT_Max and above, proportionally up to T-max when the outdoor air temperature is OAT_Min and below.

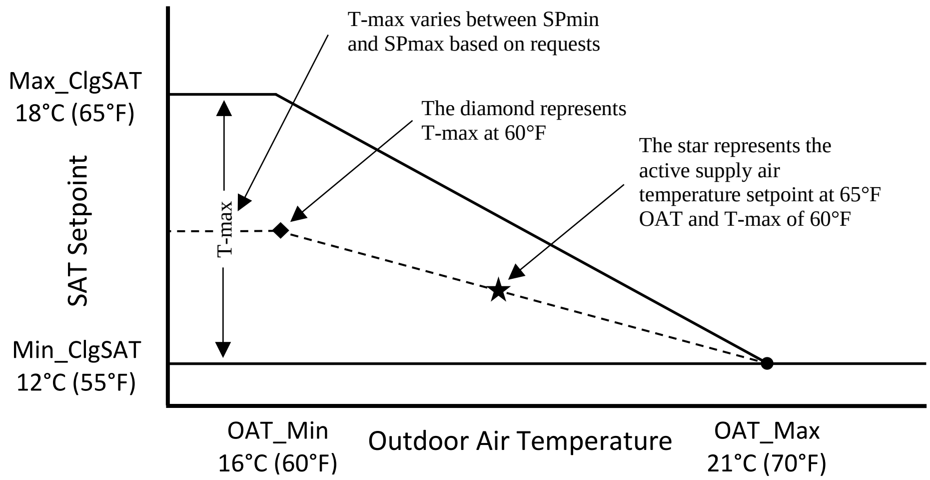
1) T-max shall be reset using T&R logic (see Section 3.1O) between Min_ClgSAT and Max_ClgSAT. The parameters shown in Table 5.16.2.2 are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

The T&R reset parameters in Table 5.16.2.2 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

Table 5.16.2.2 Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	SPmax
SPmin	Min_ClgSAT
SPmax	Max_ClgSAT
Td	10 minutes
T	2 minutes
I	2
R	Zone cooling SAT requests
SPtrim	+0.1°C (+0.2°F)
SPres	–0.2°C (–0.3°F)
SPres-max	–0.6°C (–1.0°F)

The net result of this SAT reset strategy is depicted in the Figure 5.16.2.2 for Min_ClgSAT = 12°C (55°F), Max_ClgSAT = 18°C (65°F), OAT_Max = 21°C (70°F), and OAT_Min = 16°C (60°F).



Informative Figure 5.16.2.2 Example supply air temperature reset diagram.

c. During Cooldown Mode, setpoint shall be Min_ClgSAT.

d. During Warmup Mode and Setback Mode, setpoint shall be 35°C (95°F).

Raising the SAT setpoint in warmup will effectively lock out the economizer and cooling coil, which is desirable for warmup even if there is no heating coil at the AHU to meet the higher SAT.
This does not apply in the case of a DFDD AHU or if all the zones are equipped with fan-powered boxes such that the AHU is off in warmup and setback.

3. Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to sequence the heating coil (if applicable), outdoor air damper, return air damper, and cooling coil as shown in Figure 5.16.2.3.

   a. For units with return fans

      1) Return air damper maximum position MaxRA-P is modulated to control minimum outdoor air volume (see Section 3.8D.2).

   b. The points of transition along the x-axis shown and described in Figure 5.16.2.3 are representative. Separate gains shall be provided for each section of the control map (heating coil, economizer, cooling coil) that is determined by the contractor to provide stable control. Alternatively, the contractor shall adjust the precise value of the x-axis thresholds shown in Figure 5.16.2.3 to provide stable control. Damper control depends on the type of building pressure control system.

For AHUs with return fans and direct building pressure controls, the SAT control loop makes the economizer outdoor air damper open fully whenever the AHU is on, while the return air damper modulates to maintain supply air temperature as shown below. Relief/exhaust damper position tracks inversely with the return damper position.
Outdoor air dampers on air handlers with return fans have no impact on the outdoor airflow rate into the mixing plenum. Instead, the return-fan and return-damper controls dictate outdoor air flow. See ASHRAE Guideline 16.
Note that the economizer damper will close (if there is a separate minimum outdoor air damper) or modulate to minimum position (if there is a single outdoor air damper) whenever minimum outdoor air control is active. See logic for Minimum Outdoor Air Control below.

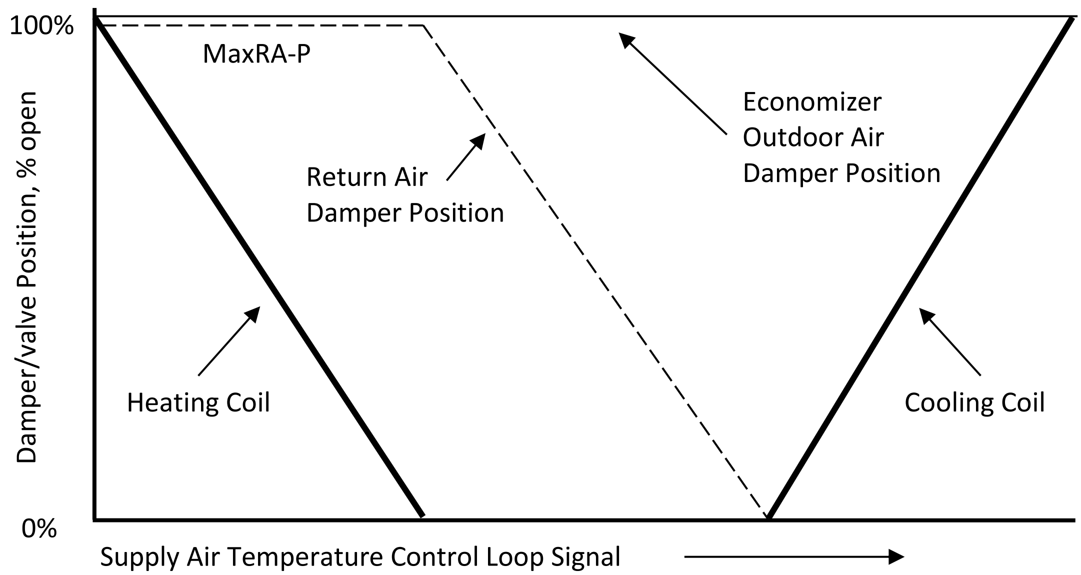


Figure 5.16.2.3 SAT loop mapping with return-fan control with direct building pressure controls.

4. Chilled water pump

   a. Start pump when chilled water valve has been commanded more than 10% open for 1 minute (adjustable). Disable pump when valve is commanded shut.

C. Minimum Outdoor Airflow Setpoints

1. Outdoor Airflow Setpoint for California Title 24 Ventilation

   a. See Section 3.3A.3 for zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.

   b. See Section 1.2E.2.a for setpoints AbsMinOA and DesMinOA.

   c. Effective outdoor air absolute minimum and design minimum setpoints are recalculated continuously based on the mode of the zones being served.

      1) AbsMinOA* is the sum of Zone-Abs-OA-min for all zones in all Zone Groups that are in Occupied Mode but shall be no larger than the absolute minimum outdoor airflow AbsMinOA.

      2) DesMinOA* is the sum of Zone-Des-OA-min for all zones in all Zone Groups that are in Occupied Mode but shall be no larger than the design minimum outdoor airflow DesMinOA.

D. Minimum Outdoor Air Control with a Single Common Damper for Minimum Outdoor Air and Economizer Functions and Airflow Measurement

1. Outdoor Airflow Setpoint for California Title 24 Ventilation

a. See Section 3.8C.1 for calculation of current setpoints AbsMinOA* and DesMinOA*.

b. See zone CO2 control logic under terminal unit sequences.

c. The minimum outdoor air setpoint MinOAsp shall be reset based on the highest zone CO2 control-loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

2. Minimum Outdoor Air Control Loop

a. Minimum outdoor air control loop is enabled when the supply fan is proven on and the AHU is in Occupied Mode, and disabled and output set to zero otherwise.

b. For units with return fans:

The following logic limits the return damper position to ensure that minimum outdoor air is maintained at all times, while the actual return damper position is modulated by the SAT control loop.

1) The outdoor airflow rate shall be maintained at the minimum outdoor damper outdoor airflow setpoint MinOAsp by a direct-acting control loop whose output is mapped to the return air damper maximum position endpoint MaxRA-P.

The following logic directly controls the return damper position to ensure that exactly the minimum outdoor air – and no more – is provided when economizer lockout conditions are exceeded. When economizer lockout no longer applies, return damper control reverts to the SAT control loop.

2) While the unit is in Occupied Mode, if the economizer high limit conditions in Section 3.1P are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended, and the return air damper position shall be modulated directly to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P). The economizer damper shall remain open.

3) If the economizer high limit conditions in Section 3.1P are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

E. Return-Fan Control − Direct Building Pressure

1. See Section 1.2E.5 for pressure Zone Group assignments.

2. Return fan operates whenever the associated supply fan is proven on and shall be off otherwise.

3. Return fans shall be controlled to maintain return-fan discharge static pressure at setpoint (Section 3.8E.5).

4. Building static pressure shall be time averaged with a sliding 5-minute window and 15 second sampling rate (to dampen fluctuations). The averaged value shall be that displayed and used for control.

   a. Where multiple building pressure sensors are used, the highest of the averaged values for sensors within a pressure zone shall be used for control.

Due to the potential for interaction between the building pressurization and return-fan control loops, extra care must be taken in selecting the control loop gains. To prevent excessive control-loop interaction, the closed-loop response time of the building pressurization loop should not exceed 1/5 the closed-loop response time of the return-fan control loop. This can be accomplished by decreasing the gain of the building pressurization control loop.

5. A single P-only control loop for each pressure zone shall modulate to maintain the building pressure at a setpoint of 12 Pa (0.05 in. of water) with an output ranging from 0% to 100%. The loop shall be enabled when the supply and return fans for any unit within the pressure zone are proven ON and the minimum outdoor air damper is open. The exhaust dampers shall be closed with loop output set to zero otherwise. All exhaust damper and return fan static pressure setpoints for units in an associated pressure zone shall be sequenced based on building pressure control loop output signal, as shown in Figure 5.16.10.5.

A pressure zone is defined as an enclosed area with interconnected return air paths. All operating relief dampers and return fans that serve a pressure zone shall be controlled as if they were one system, using the same control loop, even if they are associated with different AHUs.
The appropriate boundaries for pressure zones, establishing which return fans run together, will need to be determined by the engineer based on building geometry.

   a. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.

   b. From 51% to 100%, the building pressure control loop shall reset the return-fan discharge static pressure setpoint from RFDSPmin at 50% loop output to RFDSPmax at 100% of loop output. See Section 1.3B.3 for RFDSPmin and RFDSPmax.

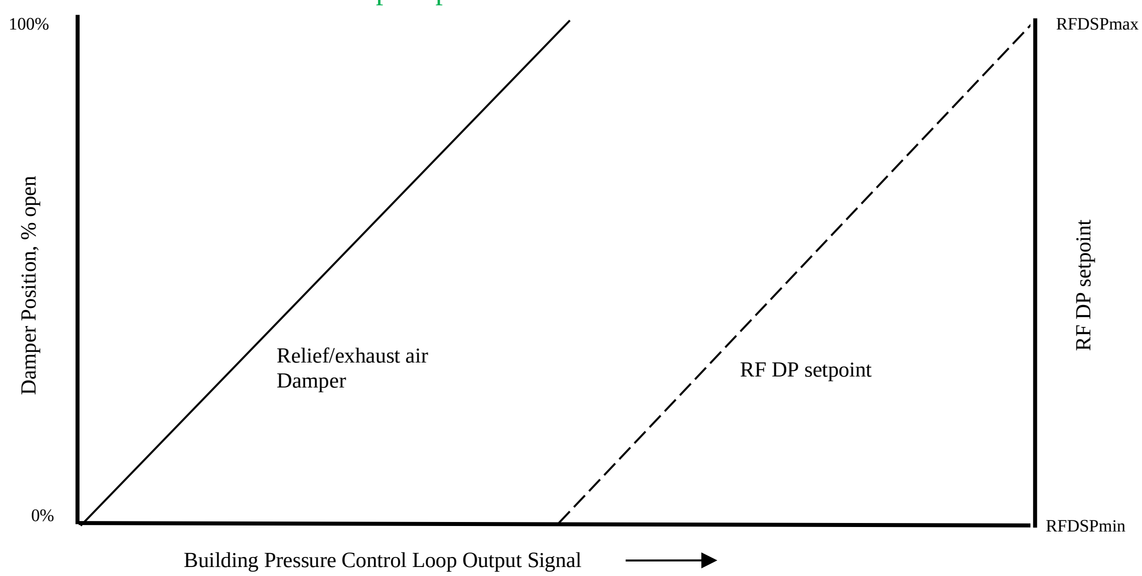


Figure 5.16.10.5 Exhaust damper position and return-fan DP reset

F. Alarms

1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval count when alarm is acknowledged.

2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

   a. Commanded on, status off: Level 2

   b. Commanded off, status on: Level 4

3. Generate a Level 4 maintenance alarm when pump has operated for more than 3000 hours. Reset interval counter when alarm is acknowledged.

4. Pump alarm is indicated by the status input being different from the output command for 15 seconds.

   a. Commanded on, status off: Level 2. Do not evaluate alarm until the device has been commanded on for 15 seconds.

   b. Commanded off, status on: Level 4. Do not evaluate the alarm until the device has been commanded off for 60 seconds.

5. Filter pressure drop exceeds the larger of the alarm limit or 12.5 Pa (0.05”) for 10 minutes when airflow (expressed as a percentage of design airflow or design speed if total airflow is not known) exceeds 20%: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

$$DP_x = DP_{100}(x)^{1.4}$$

where DP100 is the high-limit pressure drop at design airflow (determine limit from filter manufacturer) and DPx is the high limit at the current airflow rate x (expressed as a fraction). For instance, the setpoint at 50% of design airflow would be (0.5)1.4, or 38% of the design high-limit pressure drop. See Section 1.2E.4 for DP100.

The constant value threshold for the filter pressure drop alarm is a function of the transducer and A/D converter used to measure filter differential pressure. The value used shall be determined as the minimum accuracy of the transducer and A/D converter combination.

6. High building pressure (more than 25 Pa [0.10 in. of water]) for 5 minutes: Level 3.

7. Low building pressure (less than 0 Pa [0.0 in. of water], i.e., negative) for 5 minutes: Level 4.

Automatic fault detection and diagnostics (AFDD) is a sophisticated system for detecting and diagnosing air-handler faults.
To function correctly, AFDD requires specific sensors and data be available, as detailed in the sequences below. If this information is not available, AFDD tests that do not apply should be deleted.

G. Automatic Fault Detection and Diagnostics

The AFDD routines for AHUs continually assess AHU performance by comparing the values of BAS inputs and outputs to a subset of potential fault conditions. The subset of potential fault conditions that is assessed at any point depends on the operating state (OS) of the AHU, as determined by the position of the cooling and heating valves and the economizer damper. Time delays are applied to the evaluation and reporting of fault conditions to suppress false alarms. Fault conditions that pass these filters are reported to the building operator along with a series of possible causes.

These equations assume that the air handler is equipped with hydronic heating and cooling coils, as well as a fully integrated economizer. If any of these components are not present, the associated tests and variables should be omitted from the programming.

Note that these alarms rely on reasonably accurate measurement of mixed air temperature. An MAT sensor is required for many of these alarms to work, and an averaging sensor is strongly recommended for best accuracy.

1. AFDD conditions are evaluated continuously and separately for each operating AHU.

2. For units with return fans:

   a. The OS of each AHU shall be defined by the commanded positions of the heating coil control valve, cooling coil control valve and the return air damper in accordance with Table 2.

Table 2 VAV AHU Operating States

Operating State	Heating Valve Position	Cooling Valve Position	Return Air Damper Position
#1: Heating	> 0	= 0	= MaxRA-P
#2: Free cooling, modulating OA	= 0	= 0	MaxRA-P > x > 0%
#3: Mechanical + economizer cooling	= 0	> 0	= 0%
#4: Mechanical cooling, minimum OA	= 0	> 0	= MaxRA-P
#5: Unknown or dehumidification	No other OS applies		

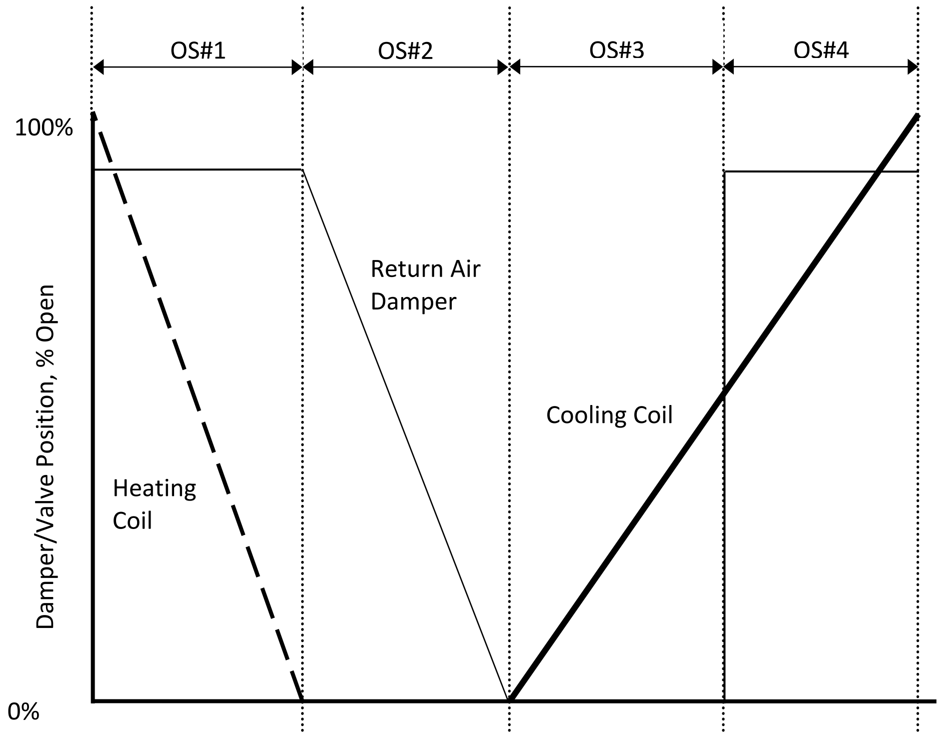


Figure 2 VAV AHU operating states.

3. The following points must be available to the AFDD routines for each AHU:

For the AFDD routines to be effective, an averaging sensor is recommended for SAT. An averaging sensor is essential for MAT, as the environment of the mixing box will be subject to nonuniform and fluctuating air temperatures. It is recommended that the OAT sensor be located at the AHU so that it accurately represents the temperature of the incoming air.

a. SAT = supply air temperature

b. MAT = mixed air temperature

c. RAT = return air temperature

d. OAT = outdoor air temperature

e. DSP = duct static pressure

f. SATSP = supply air temperature setpoint

g. DSPSP = duct static pressure setpoint

h. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%

i. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%

j. FS = fan speed command; 0% ≤ FS ≤ 100%

k. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)

l. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)

m. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)

n. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)

4. The following values must be continuously calculated by the AFDD routines for each AHU:

   a. Five-minute rolling averages with 1-minute sampling time of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently.

      1) SATavg = rolling average of supply air temperature

      2) MATavg = rolling average of mixed air temperature

      3) RATavg = rolling average of return air temperature

      4) OATavg = rolling average of outdoor air temperature

      5) DSPavg = rolling average of duct static pressure

      6) CCETavg = rolling average of cooling-coil entering temperature

      7) CCLTavg = rolling average of cooling-coil leaving temperature

      8) HCETavg = rolling average of heating-coil entering temperature

      9) HCLTavg = rolling average of heating-coil leaving temperature

   b. %OA = actual outdoor air fraction as a percentage = (MAT – RAT)/(OAT – RAT), or per airflow measurement station if available.

   c. %OAmin = active minimum OA setpoint (MinOAsp) divided by actual total airflow (from sum of VAV box flows or by airflow measurement station) as a percentage.

   d. OS = number of changes in operating state during the previous 60 minutes (moving window)

5. The internal variables shown in Table 5.16.14.5 shall be defined for each AHU. All parameters are adjustable by the operator, with initial values as shown.

Default values are derived from NISTIR 7365 and have been validated in field trials. They are expected to be appropriate for most circumstances, but individual installations may benefit from tuning to improve sensitivity and reduce false alarms.
The default values have been intentionally biased toward minimizing false alarms—if necessary, at the expense of missing real alarms. This avoids excessive false alarms that will erode user confidence and responsiveness. However, if the goal is to achieve the best possible

energy performance and system operation, these values should be adjusted based on field measurement and operational experience.
Values for physical factors, such as fan heat, duct heat gain, and sensor error, can be measured in the field or derived from trend logs. Likewise, the occupancy delay and switch delays can be refined by observing in trend data the time required to achieve quasi steady-state operation.
Other factors can be tuned by observing false positives and false negatives (i.e., unreported faults). If transient conditions or noise cause false errors, increase the alarm delay. Likewise, failure to report real faults can be addressed by adjusting the heating coil, cooling coil, temperature, or flow thresholds.

Table 5 VAV AHU AFDD Internal Variables

Variable Name	Description	Default Value
ΔTSF	Temperature rise across supply fan	1°C (2°F)
ΔTMIN	Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)	6°C (10° F)
ƐSAT	Temperature error threshold for SAT sensor	1°C (2°F)
ƐRAT	Temperature error threshold for RAT sensor	1°C (2°F)
ƐMAT	Temperature error threshold for MAT sensor	3°C (5°F)
ƐOAT	Temperature error threshold for OAT sensor	1°C (2°F) if local sensor @ unit. 3°C (5°F) if global sensor.
ƐF	Airflow error threshold	30%
ƐVFDSPD	VFD speed error threshold	5%
ƐDSP	Duct static pressure error threshold	25 Pa (0.1”)
ƐCCET	Cooling coil entering temperature sensor error. Equal to ƐMAT or dedicated sensor error	Varies, see Description
ƐCCLT	Cooling coil leaving temperature sensor error. Equal to ƐSAT or dedicated sensor error	
ƐHCET	Heating coil entering temperature sensor error; equal to ƐMAT or dedicated sensor error	
ƐHCLT	Heating coil leaving temperature sensor error. Equal to ƐSAT or dedicated sensor error	
ΔOSMAX	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend Fault Condition evaluation after a change in Mode	30
AlarmDelay	Time in minutes to that a Fault Condition must persist before triggering an alarm	30

Variable Name	Description	Default Value
TestModeDelay	Time in minutes that Test Mode is enabled	120

The purpose of ΔTmin is to ensure that the mixing box/economizer damper tests are meaningful. These tests are based on the relationship between supply, return, and outdoor air. If RAT ~ MAT, these tests will not be accurate and will produce false alarms.
The purpose of TestModeDelay is to ensure that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in Section 12.

6. Table 6 shows potential fault conditions that can be evaluated by the AFDD routines. If the equation statement is true, then the specified fault condition exists. The fault conditions to be evaluated at any given time will depend on the OS of the AHU.

The equations in Table 6 assume that the SAT sensor is located downstream of the supply fan and the RAT sensor is located downstream of the return fan. If actual sensor locations differ from these assumptions, it may be necessary to add or delete fan heat correction factors.
To detect the required economizer faults in California Title 24 section 120.2(i)7, use FC#2, #3, and #5 through #13 at a minimum. Other Title 24 AFDD requirements, including acceptance tests, are not met through these fault conditions.

Table 6 VAV AHU Fault Conditions

FC#1	Equation	DSPAVG < DSPSP - ƐDSP and VFDSPD ≥ 99% - ƐVFDSPD	Applies to OS #1 – #5
	Description	Duct static pressure is too low with fan at full speed	
	Possible Diagnosis	Problem with VFD Mechanical problem with fan Fan undersized SAT Setpoint too high (too much zone demand)	
FC#2 (omit if no MAT sensor)	Equation	MATAVG + ƐMAT < min[(RATAVG - ƐRAT), (OATAVG - ƐOAT)]	Applies to OS #1 – #5
	Description	MAT too low; should be between OAT and RAT	
	Possible Diagnosis	RAT sensor error MAT sensor error OAT sensor error	
FC#3 (omit if no MAT sensor)	Equation	MATAVG - ƐMAT > max[(RATAVG + ƐRAT), (OATAVG + ƐOAT)]	Applies to OS #1 – #5
	Description	MAT too high; should be between OAT and RAT	
	Possible Diagnosis	RAT sensor error MAT sensor error OAT sensor error	

FC#4	Equation	$\Delta OS > \Delta OSMAX$	Applies to OS #1 – #5
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#5 (omit if no MAT sensor)	Equation	$SATAVG + \varepsilon SAT \leq MATAVG - \varepsilon MAT + \Delta TSF$	Applies to OS #1
	Description	SAT too low; should be higher than MAT	
	Possible Diagnosis	SAT sensor error MAT sensor error Cooling coil valve leaking or stuck open Heating coil valve stuck closed or actuator failure Fouled or undersized heating coil HW temperature too low or HW unavailable	
FC#6	Equation	$\mid RATAVG - OATAVG \mid \geq \Delta TMIN$ and $\mid \%OA - \%OAMIN \mid > \varepsilon F$	Applies to OS #1, #4
	Description	OA fraction is too low or too high; should equal %OAMIN	
	Possible Diagnosis	RAT sensor error MAT sensor error OAT sensor error Leaking or stuck economizer damper or actuator	
FC#7 (omit if no heating coil)	Equation	$SATAVG < SATSP - \varepsilon SAT$ and $HC \geq 99\%$	Applies to OS #1
	Description	SAT too low in full heating	
	Possible Diagnosis	SAT sensor error Cooling coil valve leaking or stuck open Heating coil valve stuck closed or actuator failure Fouled or undersized heating coil HW temperature too low or HW unavailable Leaking or stuck economizer damper or actuator	
FC#8 (omit if no MAT sensor)	Equation	$\mid SATAVG - \Delta TSF - MATAVG \mid > \sqrt{\varepsilon_{SAT}^2 + \varepsilon_{MAT}^2}$	Applies to OS #2
	Description	SAT and MAT should be approximately equal	
	Possible Diagnosis	SAT sensor error MAT sensor error Cooling coil valve leaking or stuck open Heating coil valve leaking or stuck open	

FC#9	Equation	OATAVG - ƐOAT > SATSP - ΔTSF + ƐSAT	Applies to OS #2
	Description	OAT is too high for free cooling without additional mechanical cooling	
	Possible Diagnosis	SAT sensor error OAT sensor error Cooling coil valve leaking or stuck open	
FC#10 (omit if no MAT sensor)	Equation	$\mid MATAVG - OATAVG \mid > \sqrt{\varepsilon_{MAT}^2 + \varepsilon_{OAT}^2}$	Applies to OS #3
	Description	OAT and MAT should be approximately equal	
	Possible Diagnosis	MAT sensor error OAT sensor error Leaking or stuck economizer damper or actuator	
FC#11	Equation	OATAVG + ƐOAT < SATSP - ΔTSF - ƐSAT	Applies to OS #3
	Description	OAT is too low for mechanical cooling	
	Possible Diagnosis	SAT sensor error OAT sensor error Heating coil valve leaking or stuck open Leaking or stuck economizer damper or actuator	
FC#12 (omit if no MAT sensor)	Equation	SATAVG - ƐSAT - ΔTSF ≥ MATAVG + ƐMAT	Applies to OS #2 – #4
	Description	SAT too high; should be less than MAT	
	Possible Diagnosis	SAT sensor error MAT sensor error Cooling coil valve stuck closed or actuator failure Fouled or undersized cooling coil CHW temperature too high or CHW unavailable Heating coil valve leaking or stuck open	
FC#13	Equation	SATAVG > SATSP + ƐSAT and CC ≥ 99%	Applies to OS #3, #4
	Description	SAT too high in full cooling	
	Possible Diagnosis	SAT sensor error Cooling coil valve stuck closed or actuator failure Fouled or undersized cooling coil CHW temperature too high or CHW unavailable Heating coil valve leaking or stuck open	

FC#14	Equation	$CCETAVG - CCLTAVG \geq \sqrt{\varepsilon_{CCET}^2 + \varepsilon_{CCLT}^2 + \Delta TSF^*}$ *Fan heat factor included or not depending on location of sensors used for CCET and CCLT	Applies to OS #1, #2
	Description	Temperature drop across inactive cooling coil	
	Possible Diagnosis	CCET sensor error CCLT sensor error Cooling coil valve stuck open or leaking	
FC#15	Equation	$HCLTAVG - HCETAVG \geq \sqrt{\varepsilon_{HCET}^2 + \varepsilon_{HCLT}^2 + \Delta TSF^*}$ *Fan heat factor included or not depending on location of sensors used for HCET and HCLT	Applies to OS #2 – #4
	Description	Temperature rise across inactive heating coil	
	Possible Diagnosis	HCET sensor error HCLT sensor error Heating coil valve stuck open or leaking.	

7. A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the OS of the AHU:

   a. In OS#1 (heating), the following fault conditions shall be evaluated:

      1) FC#1: DSP too low with fan at full speed

      2) FC#2: MAT too low; should be between RAT and OAT

      3) FC#3: MAT too high; should be between RAT and OAT

      4) FC#4: Too many changes in OS

      5) FC#5: SAT too low; should be higher than MAT

      6) FC#6: OA fraction too low or too high; should equal %OAmin

      7) FC#7: SAT too low in full heating

      8) FC#14: Temperature drop across inactive cooling coil

   b. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:

      1) FC#1: DSP too low with fan at full speed

      2) FC#2: MAT too low; should be between RAT and OAT

      3) FC#3: MAT too high; should be between RAT and OAT

      4) FC#4: Too many changes in OS

5) FC#8: SAT and MAT should be approximately equal

6) FC#9: OAT too high for free cooling without mechanical cooling

7) FC#12: SAT too high; should be less than MAT

8) FC#14: Temperature drop across inactive cooling coil

9) FC#15: Temperature rise across inactive heating coil

c. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:

1) FC#1: DSP too low with fan at full speed

2) FC#2: MAT too low; should be between RAT and OAT

3) FC#3: MAT too high; should be between RAT and OAT

4) FC#4: Too many changes in OS

5) FC#10: OAT and MAT should be approximately equal

6) FC#11: OAT too low for mechanical cooling

7) FC#12: SAT too high; should be less than MAT

8) FC#13: SAT too high in full cooling

9) FC#15: Temperature rise across inactive heating coil

d. In OS#4 (mechanical Cooling, minimum OA), the following fault conditions shall be evaluated:

1) FC#1: DSP too low with fan at full speed

2) FC#2: MAT too low; should be between RAT and OAT

3) FC#3: MAT too high; should be between RAT and OAT

4) FC#4: Too many changes in OS

5) FC#6: OA fraction too low or too high; should equal %OAmin

6) FC#12: SAT too high; should be less than MAT

7) FC#13: SAT too high in full cooling

8) FC#15: Temperature rise across inactive heating coil

e. In OS#5 (other), the following fault conditions shall be evaluated:

1) FC#1: DSP too low with fan at full speed

2) FC#2: MAT too low; should be between RAT and OAT

3) FC#3: MAT too high; should be between RAT and OAT

4) FC#4: Too many changes in OS

8. For each air handler, the operator shall be able to suppress the alarm for any fault condition.

9. Evaluation of fault conditions shall be suspended under the following conditions:

   a. When AHU is not operating

   b. For a period of ModeDelay minutes following a change in mode (e.g., from Warmup Mode to Occupied Mode) of any Zone Group served by the AHU

10. Fault conditions that are not applicable to the current OS shall not be evaluated.

11. A fault condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

12. Test mode shall temporarily set ModeDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system, and ensure normal fault detection occurs after testing is complete.

13. When a fault condition is reported to the operator, it shall be a Level 3 alarm and shall include the description of the fault and the list of possible diagnoses from the table in Section 6.

H. Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to

   a. force HW valve full open if there is a hot-water coil,

   b. force HW valve full closed if there is a hot-water coil,

   c. force CHW valve full open, and

   d. force CHW valve full closed.

Per Section 3.1L, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 3.5E.
For example, the CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

I. Plant Requests

1. Chilled-Water Reset Requests

   a. If the supply air temperature exceeds the supply air temperature setpoint by 3°C (5°F) for 2 minutes, send 3 requests.

b. Else if the supply air temperature exceeds the supply air temperature setpoint by 2°C (3°F) for 2 minutes, send 2 requests.

c. Else if the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 85%.

d. Else if the CHW valve position is less than 95%, send 0 requests.

2. Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:

   a. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.

   b. Else if the CHW valve position is less than 95%, send 0 requests.

3. If There Is a Hot-Water Coil, Hot-Water Reset Requests

   a. If the supply air temperature is 17°C (30°F) less than setpoint for 5 minutes, send 3 requests.

   b. Else if the supply air temperature is 8°C (15°F) less than setpoint for 5 minutes, send 2 requests.

   c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.

   d. Else if the HW valve position is less than 95%, send 0 requests.

4. If There Is a Hot-Water Coil, Heating Hot Water Plant Requests. Send the heating hot-water plant that serves the AHU a heating hot-water plant request as follows:

   a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.

   b. Else if the HW valve position is less than 95%, send 0 requests.

3.9 PACKAGED AC UNIT WITH DDC (RM 253 AND RM 1024)

A. See “Generic Thermal Zones” (Section 3.4) for setpoints, loops, control modes, alarms, etc.

B. Supply fan control

   1. The unit fan shall run only when zone is in Cooling State or Heating State and off in Deadband State.

C. Cooling control

   1. Cooling is enabled when the zone is in Cooling State.

2. The zone Cooling Loop output shall be mapped to stage on cooling when the loop output is at 100 and staged off when the loop output is at 0. Cooling shall have a 5 minute minimum on time and a 5 minute minimum off-time

D. Alarms

1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.

2. Fan alarm is indicated by the status input being different from the output command for 15 seconds.

   a. Commanded on, status off: Level 2. Do not evaluate alarm until the device has been commanded on for 15 seconds.

   b. Commanded off, status on: Level 4. Do not evaluate the alarm until the device has been commanded off for 60 seconds.

3. Generate a Level 3 alarm if:

   a. Cooling output is on and supply air fan is proven on and supply air temperature is above 65°F for more than 3 minutes indicating cooling system failure.

3.10 GENERAL CONSTANT SPEED EXHAUST FAN

A. Exhaust Fan Control

1. Exhaust Fan Start/Stop

   a. Scheduled fans

      1) Exhaust fan shall operate when any of the associated system supply fans is proven on and any associated Zone Group is in the Occupied Mode. See Section 1.2D for Zone Group assignments.

   b. Fans controlled by space temperature

      1) Exhaust fan shall run when zone temperature rises above the active cooling setpoint until zone temperature falls more than 1°C (2°F) below the active cooling setpoint for 2 minutes.

The room temperature control method should only be used in non-occupied spaces where ventilation is not required (e.g., equipment rooms).

B. Alarms

1. Maintenance interval alarm when fan has operated for more than 3,000 hours: Level 4. Reset interval counter when alarm is acknowledged.

2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

   a. Commanded on, status off: Level 2

b. Commanded off, status off: Level 4

3.11 MISCELLANEOUS ALARMS

A. Points in Hand (Operator Override) via Workstation command (including name of operator who made the command) or via supervised HOA switch at output: Level 4

B. Fire alarm (via contact from Division 26 fire alarm system): Level 1

C. Equipment alarm (for equipment with alarm contacts such as VFDs, AC units): Level 2

D. Failure or disconnection of a sensor as indicated by signal widely out of range: Level 2.

E. Panel or LAN failure: Level 2

F. Loss of communication with any device via Gateway (e.g. VFD) for more than 30 seconds: Level 2 (alarm shall indicate which specific device is not responding).

END OF SECTION 259000