ADDENDUM #1

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

L-1240 Student Services and Equipment Plant BAS Upgrade

Los Medanos College
2700 E Leland Rd, Pittsburg, CA 94565

Date: July 29, 2024

NOTICE TO ALL CONTRACTORS

You are hereby notified of the following changes, clarifications and/or modifications to the original Contract Documents, Project Manual, Drawings, Specifications and/or previous Addenda. This Addendum shall supersede the original Contract Documents and previous Addenda wherein it contradicts the same, and shall take precedence over anything to the contrary therein. All other conditions remain unchanged.

This Addendum forms a part of the Contract Documents and modifies the original Contract Documents dated ***July 11, 2024.*** Acknowledge receipt of this Addendum in space provided on the Bid Proposal Form. Failure to acknowledge may subject Bidder to disqualification.

A. DELETIONS, ADDITIONS, CHANGES, REVISIONS

Item:

1. **REPLACE**: **L-1240 – LMC SS and Utility Plant BAS Upgrade – Drawings BAS.01, BAS.02, and M0.01.**
   DELETE existing L-1240 – LMC SS and Utility Plant BAS Upgrade – Drawings BAS.01, BAS.02, and M0.01, in their entirety, and **REPLACE WITH** new L-1240 – LMC SS and Utility Plant BAS Upgrade – Drawings BAS.01, BAS.02, and M0.01– ADDENDUM #1, dated 7/26/24 (attached), in their entirety.
   Note: All changes per addendum #1 have been clouded with note #2. Changes are related to adding scope for AC-3 (Fishbowl area of College Complex).

2. **ADD**: **L-1240 – LMC SS and Utility Plant BAS Upgrade – Drawing M0.06.**
   ADD NEW L-1240 – LMC SS and Utility Plant BAS Upgrade – Drawing M0.06 – ADDENDUM #1, dated 7/26/24 (attached).
   Note: New Drawings Sheet M0.06 shows the floorplan for the fishbowl area of the College Complex and the scope related to AC-3.

ADDENDUM #1

3. **REPLACE**: **Specification Section 250000 Building Automation Systems.**
   DELETE existing Section 250000 Building Automation Systems, in its entirety, and **REPLACE WITH** new Section 250000 Building Automation Systems– Addendum #1, dated 7/29/24 (attached), in its entirety.
   Note: All changes noted in red. Adding AC-3 in the Fishbowl area to the scope of work.

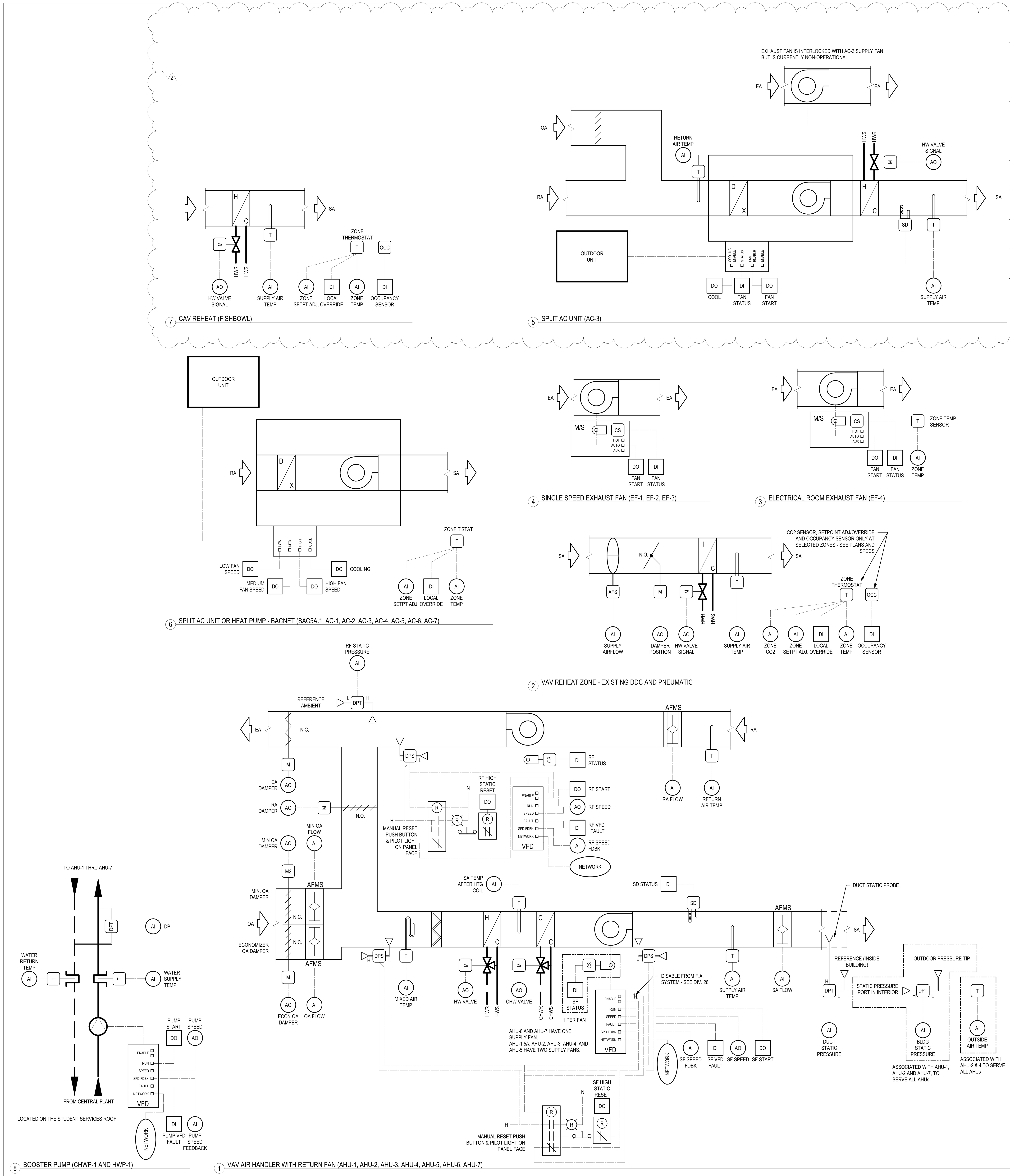
4. **REPLACE**: **Specification Section 259000 Building Automation Sequence of Operations.**
   DELETE existing Section 250000 Building Automation Sequence of Operations, in its entirety, and **REPLACE WITH** new Section 250000 Building Automation Sequence of Operations – Addendum #1, dated 7/29/24 (attached), in its entirety.
   Note: All changes noted in red. Adding AC-3 in the Fishbowl area to the scope of work.

B. If you have any questions regarding this Addendum, please contact:

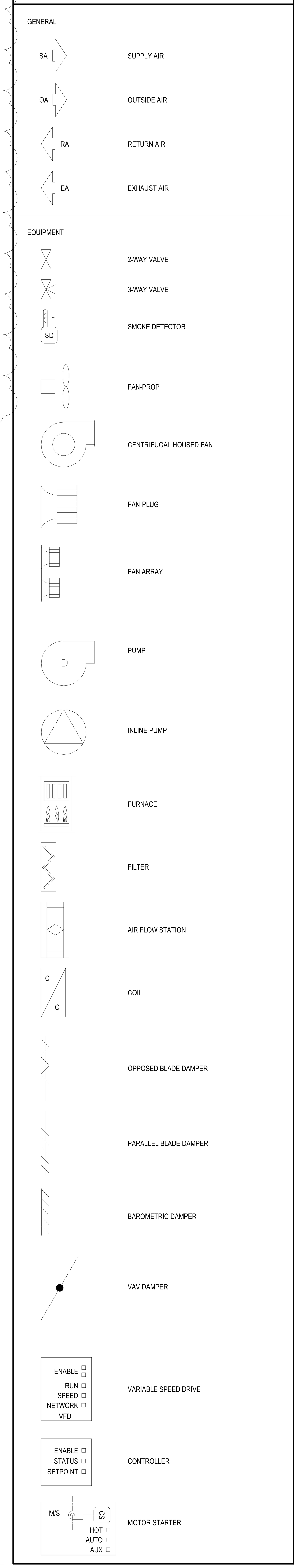
Mr. Ben Cayabyab, Contracts Manager
Contra Costa Community College District
500 Court St., Martinez, CA 94553
Email: **bcayabyab@4cd.edu**
Facsimile: **925-370-7512;**

All other terms and conditions of BID are to remain the same.

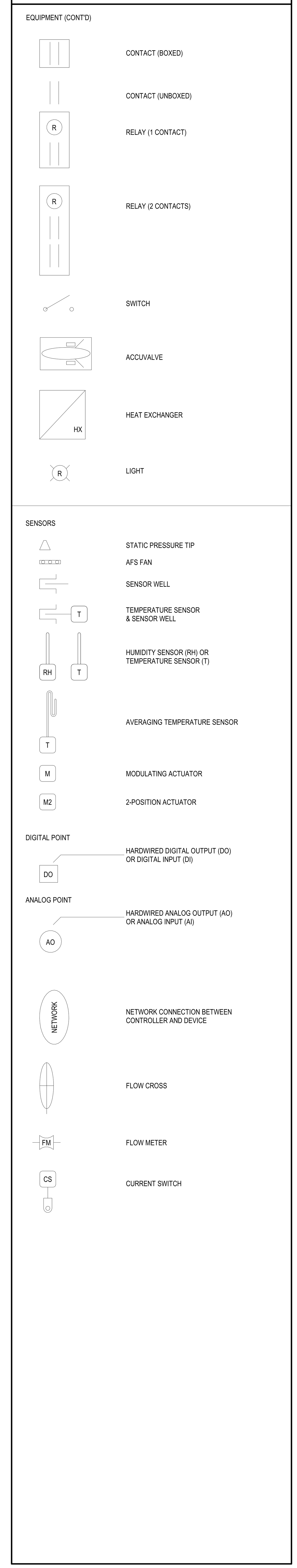
ATTACHMENTS:
L-1240 Student Services and Utility Plant BAS Upgrade – Drawing BAS.01 – Addendum #1
L-1240 Student Services and Utility Plant BAS Upgrade – Drawing BAS.02 – Addendum #1
L-1240 Student Services and Utility Plant BAS Upgrade – Drawing M0.01 – Addendum #1
L-1240 Student Services and Utility Plant BAS Upgrade – Drawing M0.06 – Addendum #1
Specification Section 250000 Building Automation Systems– Addendum #1
Specification Section 259000 Building Automation Sequence of Operations– Addendum #1
L-1240 Student Services and Equipment Plant BAS Upgrade – Pre-Bid Meeting Minutes



CONTROLS



CONTROLS



L-1240 STUDENT SERVICES AND UTILITY PLANT BAS UPGRADE

taylor | engineers

1080 Marina Village Parkway
Suite 501
Alameda, CA 94501-1142

ISSUES / REVISIONS

No.	Description	Date
1	ISSUE FOR BID	07.05.2024
2	ADDENDUM 1	07.26.2024

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

Drawn by LVR & HC

Scale NOT TO SCALE

HVAC CONTROLS DRAWINGS

BAS.01

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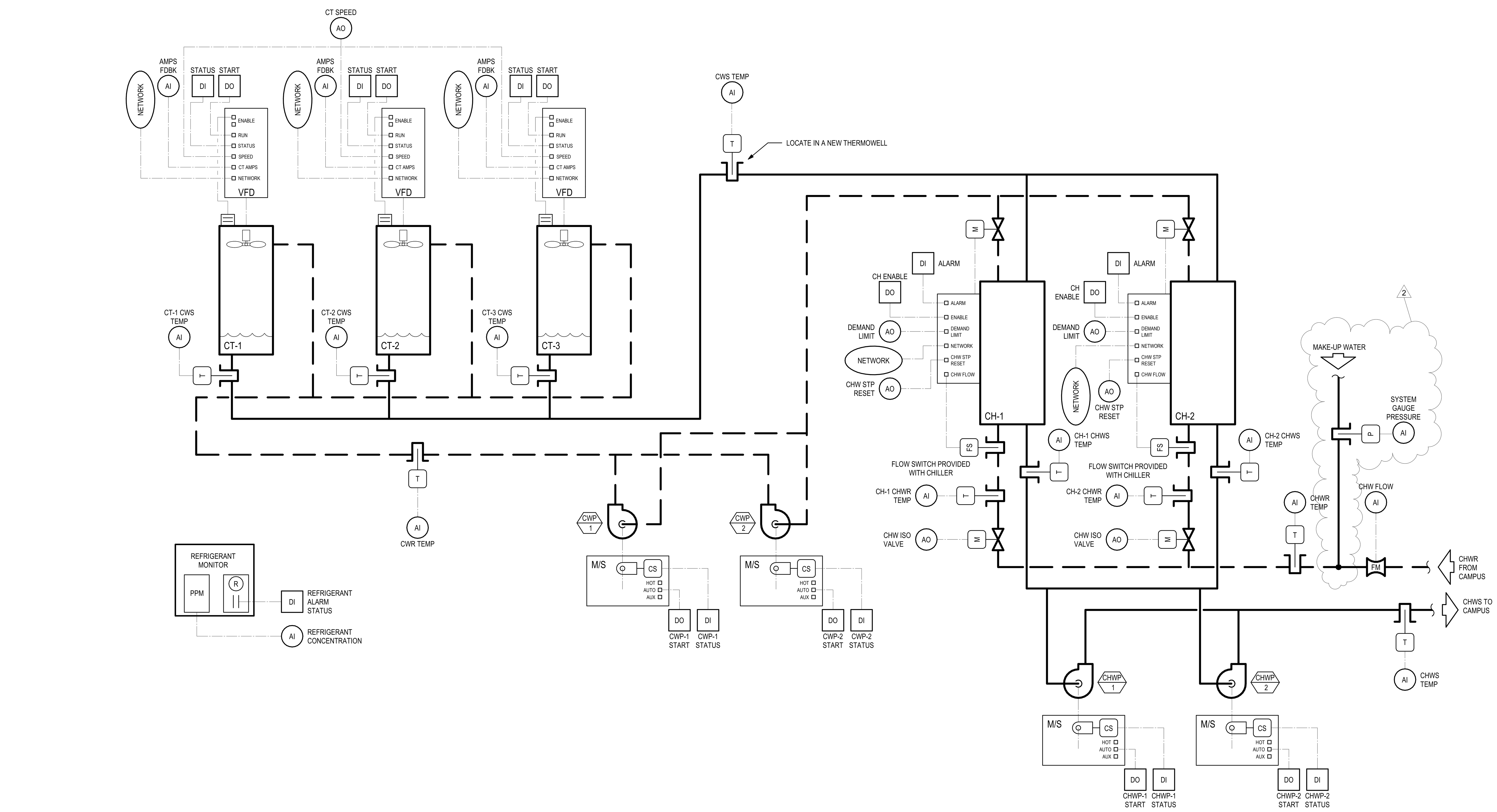
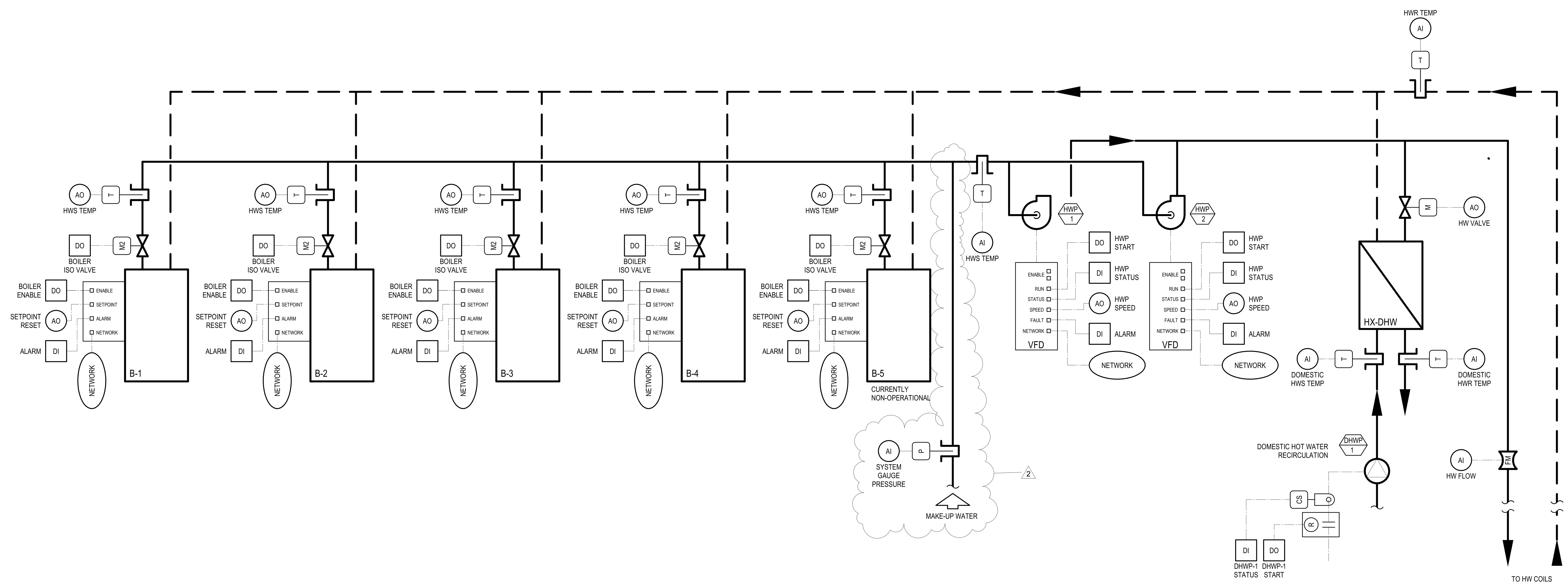


2 CHW PLANT



1 HW SYSTEM

L-1240 STUDENT SERVICES AND UTILITY PLANT BAS UPGRADE

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CONTRA COSTA COMMUNITY COLLEGE DISTRICT

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HVAC CONTROLS DRAWINGS

BAS.02

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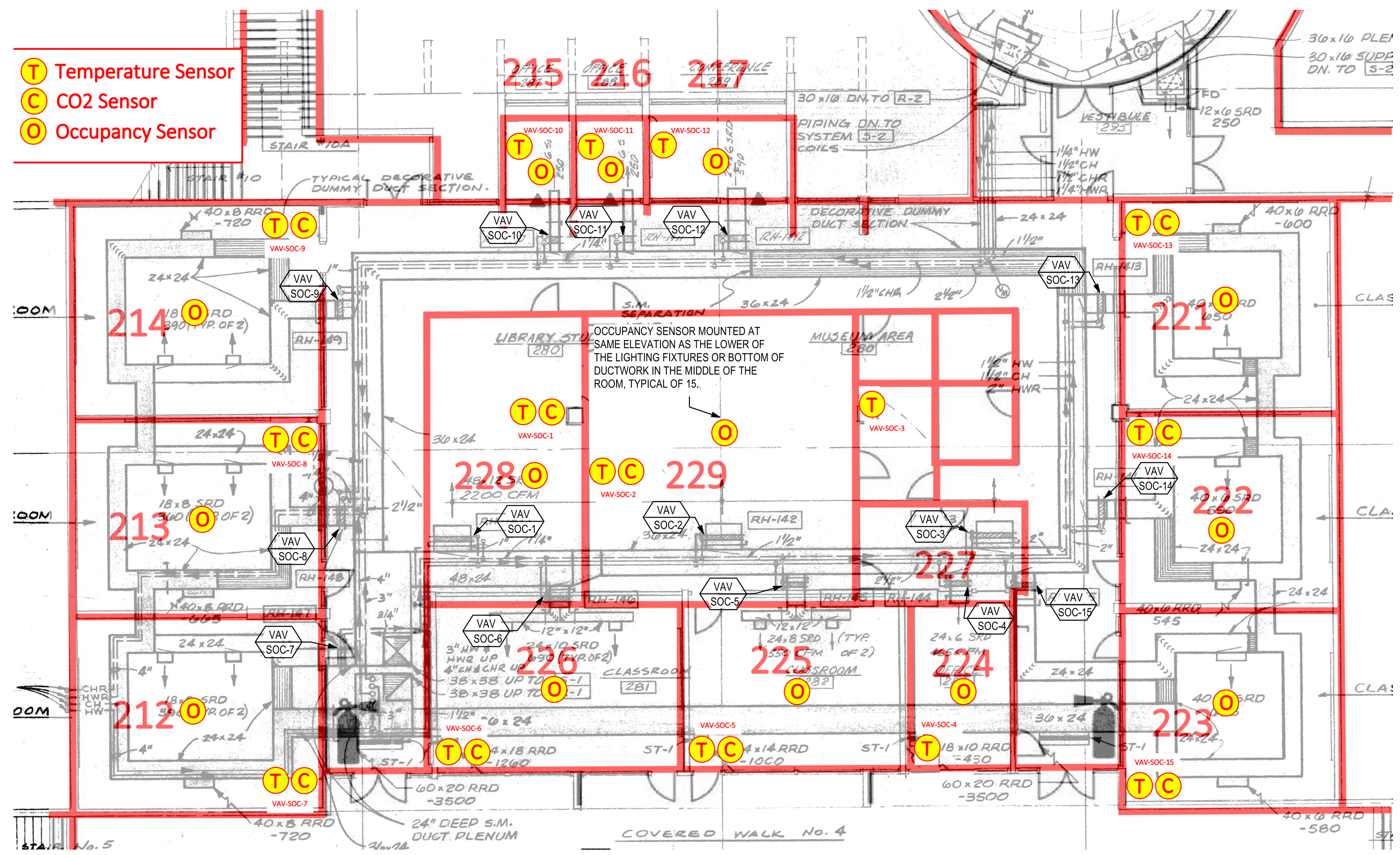

1 SECTOR 4 FLOOR PLAN

VAV BOXES

MARK	SPACES SERVED	INLET SIZE	DESIGN CFM			MIN OA		GPM	OCCUPIED-STANDBY	CO2 CONTROL	THERMOSTAT TYPE	REMARKS
			COOL	MIN	HEAT	AREA	OCCUPANCY					
VAV-SOC-1	RM 228	48x12	2200	85	1100	85	215	4.3	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-2	RM 229	48x12	2200	145	1100	145	370	4.3	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-3	RM 227, 211A, 211B, 211C, 211D	48x12	2200	80	1100	80	40	4.3	N	N	3C	EXISTING PNEUMATIC CONTROL
VAV-SOC-4	RM 224	24x6	465	35	230	35	15	8	Y	N	3C	EXISTING PNEUMATIC CONTROL
VAV-SOC-5	RM 225	24x12	1100	70	550	70	170	1.6	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-6	RM 226	24x12	1380	80	690	80	200	2.6	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-7	RM 212	24x9	780	85	390	85	215	1.2	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-8	RM 213	24x9	720	90	360	90	220	1.1	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-9	RM 214	24x9	780	95	390	95	240	1.2	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-10	RM 215	12x6	250	15	125	10	15	0.7	Y	N	3C	EXISTING PNEUMATIC CONTROL
VAV-SOC-11	RM 216	12x6	250	15	125	10	15	0.7	Y	N	3C	EXISTING PNEUMATIC CONTROL
VAV-SOC-12	RM 217	24x6	590	25	295	25	10	1.3	Y	N	3C	EXISTING PNEUMATIC CONTROL
VAV-SOC-13	RM 221	24x6	650	80	325	80	200	1.7	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-14	RM 222	24x6	590	75	295	75	190	1.3	Y	Y	3CC	EXISTING PNEUMATIC CONTROL
VAV-SOC-15	RM 223	24x9	780	95	390	95	240	1.5	Y	Y	3CC	EXISTING PNEUMATIC CONTROL

L-1240 STUDENT SERVICES AND UTILITY PLANT BAS UPGRADE

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ISSUES / REVISIONS

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1	ISSUE FOR BID	07.05.2024
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CONTRA COSTA COMMUNITY COLLEGE DISTRICT

Drawn by LVR & HC

Scale NOT TO SCALE

SOCIAL SCIENCES FLOOR PLAN

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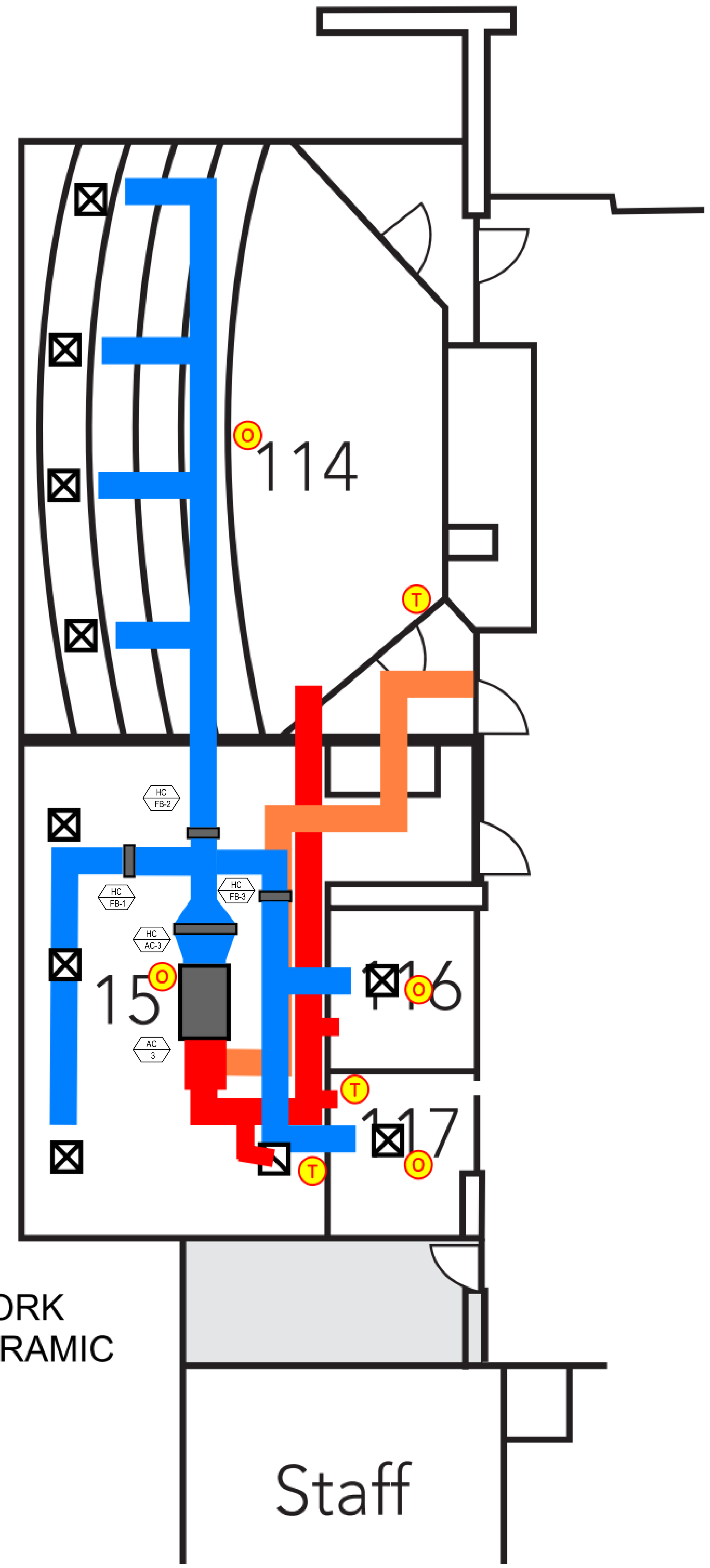
HEATING COILS

TAG	SERVING	CFM	EDB / EWB	LDB / LWB	EWT	LWT	ESTIMATED GPM	ROWS / FPI	CAP (KBH)	THERMOSTAT TYPE	REMARKS
HC AC-3	FISHBOWL	-	- / -	- / -	-	-	1.5	2 / -	-	-	EXISTING PNEUMATIC CONTROL
HC FB-1	ROOM 115	-	- / -	- / -	-	-	2	1 / -	-	3C	EXISTING PNEUMATIC CONTROL
HC FB-2	ROOM 114	-	- / -	- / -	-	-	2	2 / -	-	3C	EXISTING PNEUMATIC CONTROL
HC FB-3	ROOM 116 & 117	-	- / -	- / -	-	-	0.5	1 / -	-	3C	EXISTING PNEUMATIC CONTROL

T Temperature Sensor

O Occupancy Sensor



NOT TO SCALE - DUCTWORK AND EQUIPMENT IS DIAGRAMIC TO CONVEY SCOPE

1 FISHBOWL FLOOR PLAN

L-1240 STUDENT SERVICES AND UTILITY PLANT BAS UPGRADE

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ISSUES / REVISIONS

No.	Description	Date
2	ADDENDUM 1	07.26.2024

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

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FISHBOWL FLOOR PLAN

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SECTION 250000

BUILDING AUTOMATION SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. The project scope includes the following areas in various wings of the College Complex building at Los Medanos College, as well as the associated chilled and hot water plants:

1. The Student Services wing is served by six air handing units, AHU-2 through AHU-7, and those AHUs serve 72 zones covering two connected floors that total approximately 32,000 ft^2. The air distribution system dates to 2012 with Andover Continuum digital direct controls (DDC) throughout.

2. Sector 4 is conditioned by 15 zones covering approximately 7,000 ft^2 making up the Social Sciences department on the second floor north of the College Complex. The air distribution primarily dates to the early 1970s with a retrofit to convert the pneumatically-controlled constant volume reheat zones into variable air volume with the addition of slide-in retrofit terminals. The pneumatic VAV zones are to be converted to DDC as part of this project. The associated AHU is not in the scope of this project.

3. Sector 5A is served by AHU-1 Student Services with 9 zones covering approximately 4,500 ft^2 of classrooms and offices on the second floor east of the College Complex. The air distribution was retrofitted in 2015 with new VAV terminals and Andover Continuum DDC controls.

~~3.~~4. AC-3 serves classrooms 114 and 115 and offices 116 and 117 in the first floor "Fishbowl" area. AC-3 is an air-conditioning unit with hot water heating coil that serves three reheat zones. Minimum outside air is relieved by an interlocked exhaust fan.

~~4.~~5. The Central Plant is a separate building located south of the College Complex. The heating plant is made up of four boilers (two additional boilers are non-operational and out of scope), and two variable speed pumps. The heating hot water plant was updated in 2012 and has DDC controls. The chilled water plant is made up of two water cooled centrifugal chillers, two constant speed chilled water pumps, three cooling towers, and two constant speed condenser water pumps. The chilled water plant has pneumatic control valves.

B. This project consists of:

1. Upgrading the existing controls to new Automated Logic Corp. (ALC) Building Automation System (BAS).

2. Updating all control sequences to latest building standard sequences as described in Section 259000 Building Automation Sequences of Operation.

3. Updating and adding new graphics.

4. Adding new monitoring points.

5. Adding integration to lighting controls. Integrate the existing Wattstopper lighting controls system in the Student Services wing into the BAS. Add BACnet IP connection to lighting controls server in electrical closet between Student Services rooms 306 and 307. Provide all necessary programming and configuration in Wattstopper and BAS to map occupancy sensors from lighting controls to HVAC thermal zones for use with occupied-standby logic and to apply dimming to lighting controls based on demand shed signals from the BAS. Note that occupancy sensing in other areas of the project is through new dedicated occupancy sensors.

6. Providing spare ALC controllers:

   a. Five Optiflex Advanced VAV Controllers OF342-E2

   b. Five Room sensors ZS2P-ALC

C. Work Excluded

1. Cost of repairing existing equipment that is specified to be reused, if required.

2. Asbestos abatement. If asbestos is discovered during the course of the work, Contractor shall notify Owner who will retain abatement contractor.

3. Fire Alarm Systems (FAS). The existing FAS in the building is separate from the existing BAS and shall remain independent.

4. Temporary cooling equipment for spaces served by 24/7 auxiliary cooling systems during scheduled down-time in accordance with Paragraph 1.8E.

1.2 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 except as specifically excluded in their proposal.

1.3 PRICING

A. Base Bid

1. All work shown on drawings and specified herein.

B. Alternates

1. Network integration for the Emergency Generator. For alternate: Provide new Basler controller with Modbus networking capability for WINCO DR120I4 generator and integrate into BAS for monitoring. Winco contact: service@wincogen.com. Existing Basler controller model number 51ANNNSNH001. For base scope, connect hard wired status monitoring point to (E) generator controller.

2. Refrigerant monitor. Replace existing refrigerant monitor with new. Add new hardwired monitoring points and network integration as specified herein. See Paragraphs 2.9N and 2.12D.6.

3. Energy monitoring. Add pulse monitoring of one PG&E electrical meter and two PG&E gas meters. See Paragraph 2.12D.13.

4. Cooling tower make-up water flow meter. Provide and install flow meter for monitoring cooling tower make-up water flow. See Paragraphs 2.9L.7 and 2.12D.13.

C. 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. Replacement of hot water reheat coil with new 2-row coil

2. Add/deduct controls for each VAV reheat box using TS-3A sensor

3. Add/deduct each TS-3C sensor in lieu of TS-3A sensor

4. Add/deduct each TS-3CC (CO2) sensor in lieu of TS-3A sensor

5. Add/deduct each ceiling mounted dual tech occupancy with wiring to controller for occupied standby control.

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.

Term	Definition
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.
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.
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. Vishal Gupta vishal.gupta@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 80 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 1.15B.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.

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 and Graphics) and shall be submitted no less than 30 days before software is to be installed in field devices.

5. Submittal Package 3 (Pre-Functional Test Forms) shall be submitted no less than 30 days prior to conducting tests.

6. Submittal Package 4 (Pre-Functional Test Report) shall be submitted no less than 14 after conducting tests.

7. Submittal Package 5 (Post-Construction Trend Points List) shall be submitted 14 days prior to the start of the trend collection period.

8. Submittal Package 6 (Functional Test Report) shall be submitted no more than 7 days after conducting tests.

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

10. 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. 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 and Graphics)

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. 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.).

4. 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.

5. 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.

6. 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 2.11C.3.

7. 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.

8. 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.

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

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

   b. Format: See Paragraph 2.11C.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 systems 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 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 pneumatic actuators where indicated (see Control Points list) and replace with electric.

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.

3. 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 existing local control panels to locate new equipment where they meet the requirements for the new application. Note that control panels in the Central Plant Building are to be NEMA 4 per Paragraph 2.8B.2.

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 modulating ball valves with electric actuators at air handling units and DDC reheat zones. Replace existing globe valves and actuators at pneumatically controlled reheat zones. See VAV schedule.

2. Replace existing butterfly isolation valves at chiller plant.

3. Reuse existing isolation valves at hot water plant.

I. Temperature Sensors

1. Reuse or replace existing temperature sensors as indicated in Control Points lists.

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. 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
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 virtual 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) To communicate with the central CSS (and internet via VPN), the building Supervisory LAN shall connect via managed switch, provided by the College IT Group, to the College IT LAN located in building MDF/IDF(s) or other location as directed by the College IT Group. Coordinate final switch locations with College IT Group.

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 network provided by the College IT Group.

b. Supervisory LAN: Ethernet-based, 100 or 1000 Mbps BACnet/IP network interconnecting the server and OWS(s) to BCs and certain gateways as specified herein. LAN shall be IEEE 802.3 Ethernet with switches and routers that support 100 Mbps minimum throughput. 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.

1) College IT Group shall furnish and install all network switches through which BAS devices communicate. Contractor shall coordinate switch port quantities and locations with College IT Group. Managed switches are located in rooms 240 Data in Sector 5A, 3302 Data and 4401 Elec in Student Services, and the central plant building.

2) BAS contractor shall furnish a temporary server and switch(es) as necessary during system startup and commissioning to maintain the construction schedule.

a) Where there are multiple network switches, BAS contractor shall provide and install ethernet between temporary switches, as required, to establish a temporary network for construction.

~~3) No temporary provisions for remote access (e.g. Cradlepoint router) are allowed.~~

~~4)~~3) College IT Group shall be responsible for provisioning IP addresses for BAS IP enabled devices, as well as all IP enabled devices that integrate into the BAS inclusive of lighting controls and power monitoring.

~~5)~~4) College IT Group shall configure a VLAN to isolate the BAS network and devices integrated into the BAS from other portions of the College's IT LAN. Should BAS and integrated systems be placed on multiple VLANs, College IT Group shall be responsible for configuring routing policies through VLANs to allow integration specified herein.

~~6)~~5) Division 25 Contractor to provide and install patch panel(s) in two or four post racks provided by and in location specified by the College IT Group. For bid purposes, assume these will be located in MDF/IDF rooms. CommScope Systimax or equal.

~~7)~~6) Supervisory LAN ethernet cables from BAS IP enabled devices shall be terminated on patch panels by Division 25 Contractor. Final connections between patch panel, patch cables and managed switch by College IT Group.

~~8)~~7) IP enabled BAS devices shall connect directly to Owner furnished switches. Integrating IP devices through a BAS controller is not acceptable.

c. Primary LAN: High-speed, peer-to-peer communicating LAN used to connect AACs, ASCs, and certain gateways and sensors where specified herein. Acceptable technologies include and are limited to:

1) Ethernet (IEEE802.3) per the Supervisory LAN

d. Secondary LAN: Network used only to connect certain gateways and sensors where specified herein. It shall not 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:

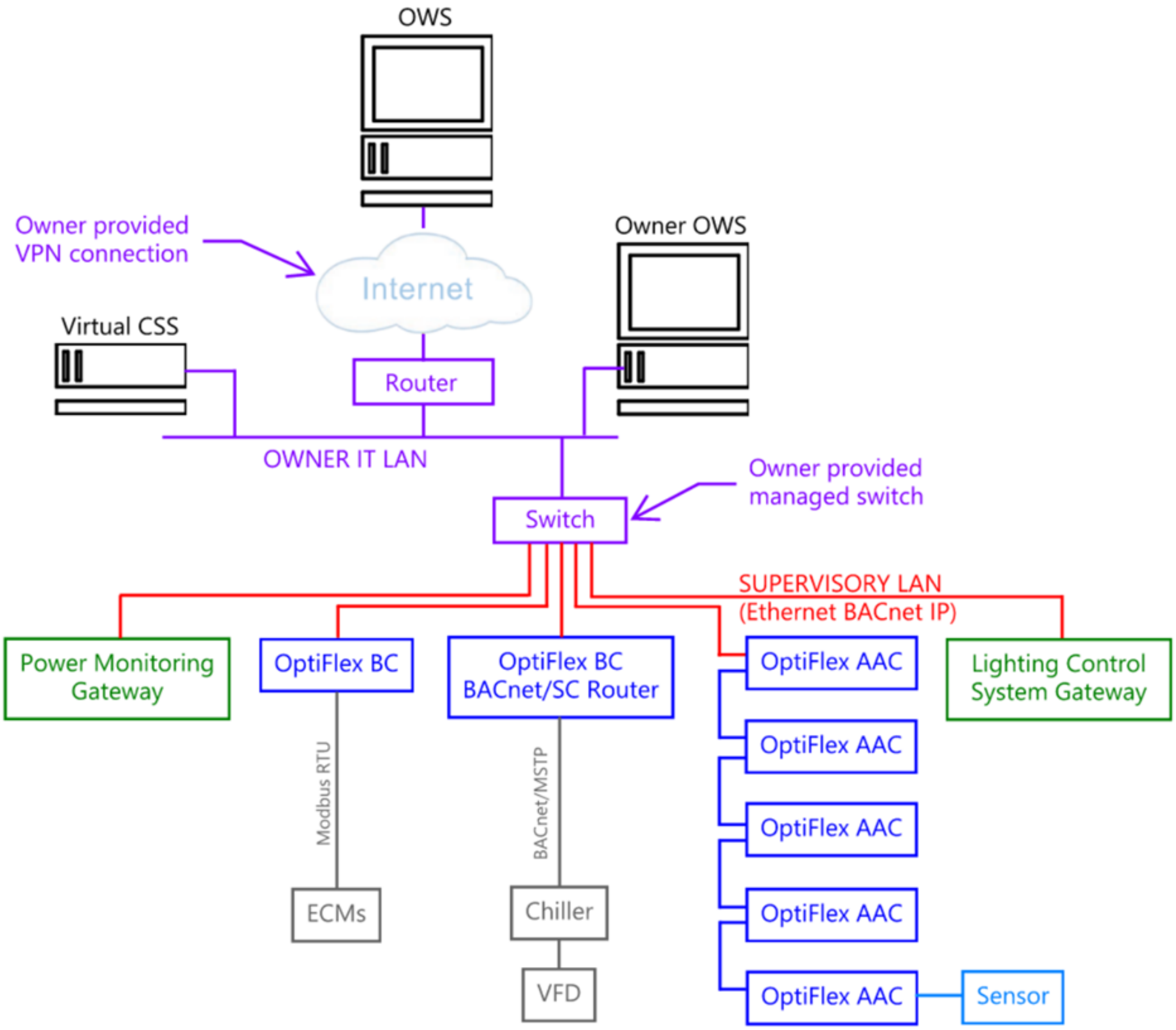
1) BACnet over Master Slave/ Token Passing (MS/TP)

2) Modbus RTU over RS-485

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

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

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



4. Operator Interfaces and Servers

   a. The Control Systems Server (CSS) is existing. See Paragraph 1.12B.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.

   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
Mixed Air drybulb temperature	±1ºF
Outside Air drybulb temperature	±0.5ºF
Chilled and Condenser Water Temperature	±0.2ºF
Hot Water Temperature	±0.5ºF

Measured Variable	Reported Accuracy
Chilled/Hot Water Delta-T (supply to return) at building mains from central plant only	±0.15ºF
Relative Humidity − general	±5% RH
Relative Humidity − outdoor air	±3% RH
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 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.

1.13 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

1.14 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.

1.15 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.

D. If controllers are not plenum rated and are mounted in an air plenum, e.g. ceiling return plenum, include a plenum kit or mount in a control panel.

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

Equipment/System	Interface		
	Type	Location	Connect to this Network:
Variable Speed Drives	BACnet/MSTP	Each VFD	Secondary
Chillers (Existing)	BACnet/IP or BACnet/MSTP per existing (verify)	Each Chiller in the chiller room	Supervisory or Secondary per existing
Boilers (Existing)	(E) Modbus RS-485	Each Boiler in the boiler room	Secondary per existing
Lighting Controls	BACnet/IP or BACnet/MSTP per existing (verify)	Electrical Room between room 307 and 306 & 4402	per existing
Refrigerant monitor (Alternate)	Modbus RS-485 or BACnet/MSTP	Chiller room	Secondary
Emergency Generator (Alternate)	Modbus RS-485	Chiller room	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 6A 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/PANELS

A. 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.

B. Construction

1. Indoor:

a. Mechanical or electrical rooms etc.: NEMA 1

b. Air plenums: NEMA 12

2. Outdoor and in the Central Plant Building: NEMA 4

C. 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.

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

E. Provide surge suppression device for power supply to all BAS controllers.

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 2.12 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. Or equal

2. Butterfly Valves

a. Body: Extended neck epoxy coated cast or ductile iron with full lug pattern, ANSI Class bolt pattern to match specified flanges.

b. Seat: EPDM replaceable, non-collapsible, phenolic backed.

c. Disc: Polished aluminum bronze or stainless steel, pinned or mechanically locked to shaft. Sanded castings are not acceptable.

d. Bearings: Bronze or stainless steel.

e. Shaft: 416 stainless steel supported at three locations with PTFE bushings for positive shaft alignment.

f. Close off rating: Bubble-tight shutoff greater or equal to 125% of pump shut-off head.

3. 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

4. Minimum valve assembly pressure ratings

a. Chilled water: 125 psi at 60ºF

b. 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

2) Chiller head pressure control: butterfly

3) Two-position isolation: butterfly or non-characterized ball type

b. Valve Characteristic

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

2) 3-way valves controlling cooling coils and condenser water heat exchangers: linear.

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

4) 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

2. Chilled water at coils: 5 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.5, 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. Electric Actuators for Large Butterfly Valves

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

b. The valve actuator shall consist of a capacitor-type reversible electric motor, gear train, limit switches and terminal block, all contained in a die cast aluminum enclosure.

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

d. Output shaft shall be electroless nickel plated to prevent corrosion.

e. Actuator shall have a motor rated for minimum 75% duty cycle. Duty cycle shall be defined as running time divided by installed time at maximum torque.

f. Actuator shall be suitable for operation in ambient temperature ranging from -22°F to +150°F.

g. A pre-wired cable shall bring wiring outside enclosure to avoid necessity of opening cover.

h. Gears shall be hardened alloy steel, permanently lubricated. A self-locking gear assembly or a brake shall be supplied.

i. Actuator shall be equipped with a hand wheel for manual override to permit operation of the valve in the event of electrical power failure or system malfunction. Hand wheel must be permanently attached to the actuator. When in manual operation electrical power to the actuator will be permanently interrupted.

j. The hand wheel will not rotate while the actuator is electrically driven.

k. Actuator shall have heater and thermostat to minimize condensation within the actuator housing.

l. Provide limit (end) position switches where indicated on schematics.

m. Actuators shall provide clear visual indication of valve position.

5. 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**
Outside air damper	CLOSED	CLOSED
Return air damper	OPEN	OPEN
Exhaust/relief air damper	CLOSED	CLOSED
Domestic hot water generator	CLOSED	CLOSED
AHU heating coil valves	OPEN	LAST
AHU cooling coil valves	CLOSED	LAST
Equipment isolation valves	OPEN	LAST
Hot water reheat coil valves	CLOSED	LAST
VAV box dampers	OPEN	LAST

6. 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.

7. 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. Sensor probe shall be 304 stainless steel with length selected to be near the center of the duct width but need not be longer than 12 inches.

1) Where specified for VAV boxes with HW coils, select probe length based on HW coil width as follows:

Typical Box Inlet Size		HW Coil Width	Probe length
Standard HW Coil	Oversized HW Coil		
<12”	<10”	<16”	6” or 8”
12” to 14”	10” to 12”	16-20”	8”
>14”	>12”	>20”	12”

3. Water Temperature Sensors

a. TS-2A: Well mounted immersion sensor, ¼” stainless steel probe, double encapsulated sensor, with enclosure suitable for location.

b. TS-2B: Same as TS-2A except provide extra precision (XP) temperature sensors to meet accuracy specified Paragraph 1.11B.2.

c. All piping immersion sensors shall be in one-piece machined brass or stainless steel wells that allow removal from operating system, with lagging extension equal to insulation thickness where installed in insulated piping. Wells shall be rated for maximum system operating pressure, temperature and fluid velocity. The well shall penetrate the pipe by the lesser of approximately half the pipe diameter or eight inches. The use of direct immersion or strap-on type sensors is not acceptable.

4. Room Sensors

a. Thermostat tags refer to the following:

Type:	Tag	
ALC model	ZS2 Standard	ZS2 Pro
Display	Blank	LCD
Temperature only	TS-3A	TS-3C
With humidity	TS-3AH	TS-3CH
With CO_2	TS-3AC	TS-3CC
With CO_2 and humidity	TS-3AHC	TS-3CHC

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.

b. See equipment schedules for thermostat type.

5. 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. Occupancy Sensor (OS-1)

1. Dual technology with passive infrared and ultrasound sensing. Detection verification of both technologies must occur in order to activate lighting systems. Upon verification, detection by either shall hold lighting on

2. Ceiling mounted

a. Flat, unobtrusive appearance and 360^o coverage.

b. Coverage: 1300 ft^2

3. 24 VDC/VAC

4. UL listed

5. Manufacturers

a. Wattstopper

b. Or equal

H. Pressure Transmitters (PT)

1. PT-1: Water, General Purpose

a. Fast-response stainless steel sensor

b. Two-wire transmitter, 4-20 mA output with zero and span adjustments

c. Accuracy

1) Overall Accuracy (at constant temp) ±0.5% full scale, includes non-linearity, repeatability, and hysteresis

d. Long Term Stability 0.5% FS per year

e. Pressure Limits

1) Rated pressure: see points list

2) Proof pressure = 3x rated pressure

3) Burst pressure = 5x rated pressure

f. Manufacturers

1) Setra 209

2) Kele & Associates P51 Series

3) Or equal

I. 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. DPT-3A: Include LCD display of reading.

h. 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

J. 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

K. 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

L. Flow Meter (FM)

1. FM-1: (not used)

2. FM-2: Magnetic Insertion Type Flow Meters

   a. Magnetic Faraday point velocity measuring device.

   b. Insertion type complete with hot-tap isolation valves to enable sensor removal without water supply system shutdown.

   c. 4-20 mA transmitter proportional to flow or velocity.

   d. Accuracy: ± 1% of reading from 0.25 to 20 fps

   e. Flow range: 0.25 to 20 fps

   f. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer’s primary standards which must be accurate to within 0.1% and traceable to the U.S. National Institute of Standards and Technology (NIST).

   g. Manufacturers:

      1) Onicon F-3500

      2) Onicon FSM-3

      3) FloCat YD20-A

      4) Marsh McBirney MultiMag 284

      5) SeaMetrics 100/200 Series

6) Or equal

3. FM-3A: Not used

4. FM-3B: Not used

5. FM-4: Not used

6. FM-5: Not Used

7. FM-6: Domestic and makeup water meters (Alternate)

a. 2 inches and smaller: Multi-jet water meter

1) Multi-jet velocity type meter

2) Magnetic drive – no gearing exposed to water

3) 125 psi cast bronze body with integral strainer

4) Meet all requirements of AWWA C-708 Multi-Jet Meter

5) Accuracy: ±1.5% of reading

6) Hall affect low voltage pulse output, with configurable volume per pulse set to 1 gallon per pulse or smallest value the controller will accept

7) Odometer-type gallons totalizer dial face with cover

8) Designed for vertical or horizontal piping

9) For potable water: NSF-61 certified and in compliance with California Proposition 65

10) Manufacturers:

a) SeaMetrics MJE or MJHE (MJNE for potable water)

b) Elster Amco M700

c) Master Meter

d) Equal

M. 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.

N. Refrigerant Monitor (RM-1). Alternate.

1. Non-dispersive or photo-acoustic infrared multi-point stationary refrigerant gas leak monitor system designed to continuously measure refrigerants used in chiller equipment. The alarm system shall comply with Mechanical Code and ASHRAE Standard 15 requirements including:

   a. The refrigerant detector shall perform automatic self-testing of sensors. Where a failure is detected, a trouble signal shall be activated.

   b. The refrigerant detector as installed, including any sampling tubes, shall activate responses within a time not to exceed 30 seconds after exposure to refrigerant concentration exceeding the Alarm (Evacuate) setpoint value specified herein.

2. The refrigerant monitor shall be capable of monitoring refrigerant in concentrations of 0 PPM to a minimum of 1000 PPM. The Monitor shall have a low range resolution of 1 PPM and an accuracy of ±10 ppm in the range of 1 PPM through 100 PPM. Readings above 100 PPM must have an accuracy of ±10% of reading.

3. The refrigerant monitor shall have a minimum of one sample port or sensor for each chiller in the chiller room. See floor plans.

4. The monitor shall be factory tested and calibrated for the specified refrigerant or refrigerants. Factory certification of the calibrations shall be provided with the O&M manuals.

5. The display shall continuously display the refrigerant concentration level and alarm status.

6. The monitor shall be equipped with the following outputs.

   a. One binary output shall indicate a monitor malfunction alarm.

   b. A minimum of three alarm levels with separate binary outputs, each programmable to adjustable user-defined refrigerant concentration setpoints and user-defined reset (manual or auto).

   c. RS485 Modbus RS-485 with 16 or 32 bit registers, or BACnet MSTP interface, with read/write capability of all control points and setpoints.

7. The monitor shall have a NEMA-1 enclosure. The enclosure shall have a rust and corrosion resistant finish.

8. Include:

   a. Unit mounted strobe and alarm horn

   b. Remote strobe(s) and horn(s) for each chiller room entrance

c. Break-glass fan switch(es) for the primary chiller room entrance

d. Break-glass emergency off switch(es) for the primary chiller room entrance

e. Fan on and off status pilot lights for the primary chiller room entrance

9. Alarm horns shall be capable of providing a sound pressure level of not less than 15 dB above the operating ambient noise sound pressure level of the space in which they are installed, 85 dBA minimum.

10. Manufacturer

a. Bacharach

b. MSA Chillgard

c. OI Analytical/General Analysis Corporation

d. Or equal

2.10 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).

2.11 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 supplied herein.

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 2.11C.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.

2.12 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. New Device
   a. Where listed, a new device (sensor, actuator, etc.) is required as indicated.
5. New Point
   a. Where listed, a new control point and communication wiring are required as indicated. Where indicated otherwise, the point is part of the existing DDC system; existing point conduit and wiring may be reused in accordance with Paragraph 1.9C.

~~4.~~6. 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.~~7. 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	–

2. Chillers

Description	**Type**	**Device**	**Trend Logging**		**Calibra-tion**
			Comm-issioning	**Contin-uous**	
On/off status	DI	Through network	COV	COV	–

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Alarm	DI or AI	Through network. (May have multiple integer values depending on alarm type – see chiller BACnet panel submittal.)	COV	COV	–
Call for condenser water pump	DI	Through network	COV	COV	–
Condenser water flow status	DI	Through network	COV	COV	–
Call for chilled water pump	DI	Through network	COV	COV	–
Chilled water flow status	DI	Through network	COV	COV	–
Chiller in local mode	DI	Through network	COV	COV	–
Chiller in surge	DI	Through network	COV	COV	–
Total number of surge events	AI	Through network	+1	+1	–
Chilled water supply temperature	AI	Through network	1 min.	10 min.	F
Chilled water return temperature	AI	Through network	1 min.	10 min.	F
Condenser water supply temperature	AI	Through network	1 min.	10 min.	F
Condenser water return temperature	AI	Through network	1 min.	10 min.	F
Condenser temperature	AI	Through network	–	10 min.	F
Evaporator temperature	AI	Through network	–	10 min.	F
Condenser (head) pressure	AI	Through network	–	10 min.	F
Evaporator pressure	AI	Through network	–	10 min.	F
Anti-recycle time remaining	AI	Through network	–	10 min.	–
Variable speed drive speed	AI	Through network	1 min.	10 min.	–
Inlet guide vane signal	AI	Through network	1 min.	10 min.	–
Operating hours	AI	Through network	–	–	–
Oil pressure	AI	Through network	–	–	F
Oil sump temperature	AI	Through network	–	–	F
Power, kW	AI	Through network	1 min.	10 min.	F
Percent of full load current (%FLA)	AI	Through network	–	–	F
Chilled water differential pressure	AI	Through network	1 min.	10 min.	F
Condenser water differential pressure	AI	Through network	1 min.	10 min.	F

3. Boilers (not all points available with all manufacturers)

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Status/fault code 1-47	AI	Through network	±1	±1	–
Unit Status code 0-5	AI	Through network	±1	±1	–
HW supply temperature	AI	Through network	1 min.	10 min.	F
HW return temperature	AI	Through network	10 min.	10 min.	F
Exhaust temperature	AI	Through network	10 min.	10 min.	F
FFWD temperature	AI	Through network	10 min.	10 min.	F
Firing rate %	AI	Through network	1 min.	10 min.	F
O2 level	AI	Through network	10 min.	10 min.	F
CO level	AI	Through network	10 min.	10 min.	F
Flame strength %	AI	Through network	10 min.	10 min.	F
Active HWST setpoint	AI	Through network	1 min.	10 min.	F
HWST Setpoint command	AO	Through network	±1°F	±1°F	–

4. Refrigerant Monitor (Alternate)

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Alarm Setpoint – caution	AO	Through network	±100 PPM	±100 PPM	–
Alarm Setpoint – warning	AO	Through network	±100 PPM	±100 PPM	–
Alarm Setpoint – alarm	AO	Through network	±100 PPM	±100 PPM	–
Temperature Tolerance	AO	Through network	±1°F	±1°F	–
Alarm condition – caution	DI	Through network	COV	COV	–
Alarm condition – warning	DI	Through network	COV	COV	–
Alarm condition – alarm	DI	Through network	COV	COV	–
Unit failure/trouble alarm	DI	Through network	COV	COV	–
Communications alarm	DI	Through network	COV	COV	–
Refrigerant concentration	AI	Through network	±50 PPM	±50 PPM	F

5. Lighting Controls

a. Global

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Demand Shed 1	DO	Through network	COV	COV	–
Demand Shed 2	DO	Through network	COV	COV	–
Demand Shed 3	DO	Through network	COV	COV	–

b. For each lighting zone

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Occupancy Sensor State	DI	Through network	COV	COV	–

6. Emergency Generator (Alternate)

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Status normal power	DI	Through network	COV	COV	–
Status generator power	DI	Through network	COV	COV	–
Generator running	DI	Through network	COV	COV	–
Generator not in auto	DI	Through network	COV	COV	–
Shut-down summary alarm	DI	Through network	COV	COV	–
Fuel tank alarm – low level	DI	Through network	COV	COV	–
Fuel tank alarm – high level	DI	Through network	COV	COV	–
Fuel tank alarm – rupture	DI	Through network	COV	COV	–
Water temperature alarm	DI	Through network	COV	COV	–
Low DC battery voltage	DI	Through network	COV	COV	–
Battery charger malfunction	DI	Through network	COV	COV	–
Ground fault	DI	Through network	COV	COV	–
Low coolant level	DI	Through network	COV	COV	–
Pre-alarm Low fuel	DI	Through network	COV	COV	–
Pre-alarm high water temperature	DI	Through network	COV	COV	–
Pre-alarm low oil pressure	DI	Through network	COV	COV	–
Over-speed alarm	DI	Through network	COV	COV	–
Over-crank alarm	DI	Through network	COV	COV	–
High water temperature alarm	DI	Through network	COV	COV	–
Low oil pressure alarm	DI	Through network	COV	COV	–
Emergency stop alarm	DI	Through network	COV	COV	–
Pre-overload alarm	DI	Through network	COV	COV	–
Overload alarm	DI	Through network	COV	COV	–
AC current Phase 1	AI	Through network	±10%	±10%	–
AC current Phase 2	AI	Through network	±10%	±10%	–
AC current Phase 3	AI	Through network	±10%	±10%	–
AC voltage neutral	AI	Through network	±10%	±10%	–
AC voltage Phase 1	AI	Through network	±10%	±10%	–
AC voltage Phase 2	AI	Through network	±10%	±10%	–
AC voltage Phase 3	AI	Through network	±10%	±10%	–

D. Hardwired Points

1. VAV Box with reheat (existing DDC zones)

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
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	OS-1 (where applicable - see Drawings)	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	–	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 zones in Sector 4)

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	OS-1 (where applicable - see Drawings)	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. CAV reheat zone (Fishbowl)

Description	Type	Device	New Device	New Point	Trend Logging		Calib ra-tion
					Comm-issioning	Contin-uous	
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 (FB-3 only)	1 min	15 min	F
HW valve signal	AO	(N) 2-way valve and electric actuator to replace pneumatic	X	X	1 min	15 min	
Zone Occupancy Status	DI	OS-1 (where applicable - see Drawings)	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

~~3.~~4. VAV Air Handler with Return Fan

Description	Type	Device	New Device	New Point	Trend Logging		Calib ra-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	X	COV	COV	–
Supply Fan High Static Alarm Reset	DO	Dry contact to 120V or 24V control circuit	X	X	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	
Min Outside Air Damper	AO	(E) actuator			1 min	15 min	
Economizer 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 on 3-way valve			1 min	15 min	
Hot Water Valve	AO	(E) actuator on 3-way valve			1 min	15 min	
Supply Fan Status (one per fan – see drawings)	DI	Connect to (E) current switch			COV	COV	
Supply Fan VFD Fault	DI	Connect to VFD fault			COV	COV	
Return Fan Status (one per fan – see drawings)	DI	Connect to (E) current switch			COV	COV	
Return Fan VFD Fault	DI	Connect to VFD fault			COV	COV	
Duct Smoke Detector	DI	(E) sensor			COV	COV	

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Supply Air Temperature	AI	(E) sensor			1 min	15 min	
Supply air temperature leaving the heating coil	AI	(E) sensor			1 min	15 min	
Mixed Air Temperature	AI	(E) sensor			1 min	15 min	
Outside Air Temperature	AI	(E) sensor, applies only to AHU-2 and AHU-4			1 min	15 min	
Return Air Temperature	AI	(E) sensor			1 min	15 min	
Supply Airflow	AI	(E) sensor			1 min	15 min	
Min Outside 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	
Building Static Pressure	AI	(E) sensor, applies only to AHU-1, AHU-2 and AHU-7			1 min	15 min	
Return Fan Static Pressure	AI	DPT-3, 0 to 1 inches	X	X	1 min	15 min	F
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.~~5. Booster Pumps. Applies to CHWP-1 and HWP-1

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Pump Start/Stop	DO	Connect to VFD run			COV	COV	
Pump Speed	AO	Connect to VFD speed			1 min	15 min	
Pump VFD Fault	DI	Connect to VFD fault			COV	COV	
Pump VFD feedback	AI				1 min	15 min	
Return Water Temp	AI	(E) sensor			1 min	15 min	
Supply Water Temp	AI	(E) sensor			1 min	15 min	
Water differential Pressure	AI	(E) sensor			1 min	15 min	

~~5.~~6. Chiller/tower plant

Description	Type	Device	New Device	New point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
CH-1 on/off	DO	Connect to chiller enable contact on chiller panel			COV	COV	–

Description	Type	Device	New Device	New point	Trend Logging		Calib ra- tion
					Comm- issioning	Contin- uous	
CH-2 on/off	DO	Connect to chiller enable contact on chiller panel			COV	COV	–
Start CHWP-1	DO	(E) Dry contact to 120V starter control circuit			COV	COV	–
Start CHWP-2	DO	(E) Dry contact to 120V starter control circuit			COV	COV	–
Start CWP-1	DO	Dry contact to 120V starter control circuit		X	COV	COV	–
Start CWP-2	DO	Dry contact to 120V starter control circuit		X	COV	COV	–
Start CT-1	DO	Connect to VFD Run			COV	COV	–
Start CT-2	DO	Connect to VFD Run			COV	COV	–
Start CT-3	DO	Connect to VFD Run			COV	COV	–
CH-1 CW isolation valve	–	Modulating butterfly valve, line size. Controlled by chiller control panel directly – not BAS controlled. Replace valve body and actuator.	X		–	–	–
CH-2 CW isolation valve	–	Modulating butterfly valve, line size. Controlled by chiller control panel directly – not BAS controlled. Replace valve body and actuator.	X		–	–	–
CT-1, 2, and 3 speed	AO	Connect to VFD Speed on CT-1, 2, and 3			1 min	5 min	–
CH-1 CHW isolation valve	AO	Modulating butterfly valve, line size. Replace valve body and actuator.	X	X	1 min	5 min	–
CH-2 CHW isolation valve	AO	Modulating butterfly valve, line size. Replace valve body and actuator.	X	X	1 min	5 min	–
Chilled water setpoint reset	AO	Connect to chiller panel	X	X	1 min	5 min	–
Demand limit setpoint	AO	Connect to chiller panel		X	±5%	±5%	–
CT-1 Status	DI	(E) Connect to VFD status					
CT-2 Status	DI	(E) Connect to VFD status					
CT-3 Status	DI	(E) Connect to VFD status					
Refrigerant alarm status (Alternate)	DI	Relay contact to (N) RM-1	X	X	COV	COV	

Description	Type	Device	New Device	New point	Trend Logging		Calibration
					Commissioning	Continuous	
CHWP-1 Status	DI	(E) starter					
CHWP-2 Status	DI	(E) starter					
CWP-1 Status	DI	(E) starter					
CWP-2 Status	DI	(E) starter					
CH-1 Alarm	DI	(E) chiller panel					
CH-2 Alarm	DI	(E) chiller panel					
Refrigerant concentration (Alternate)	AI	Output from refrigerant monitor	X	X	±50 PPM	±50 PPM	F
CWS temperature from towers CT-1	AI	TS-2A	X		5 min	15 min	HH
CWS temperature from towers CT-2	AI	TS-2A	X		5 min	15 min	HH
CWS temperature from towers CT-3	AI	TS-2A	X		5 min	15 min	HH
CWR temperature - common	AI	TS-2A	X		5 min	15 min	HH
CWS temperature - common	AI	TS-2A in new thermowell	X		5 min	15 min	HH
CHWR temperature - common	AI	TS-2B	X		5 min	15 min	HH
CHWS temperature - common	AI	TS-2B	X		5 min	15 min	HH
CH-1 CHWR temperature	AI	TS-2A	X		5 min	15 min	DB
CH-1 CHWS temperature	AI	TS-2A	X		5 min	15 min	DB
CH-2 CHWR temperature	AI	TS-2A	X		5 min	15 min	DB
CH-2 CHWS temperature	AI	TS-2A	X		5 min	15 min	DB
CHW supply flow	AI	FM-2	X	X	5 min	15 min	F
CHW system gauge pressure	AI	PT-1, 0 to 60 psi in new tap	X	X	15 min	1 hr	F
CT-1 amps	AI	(E) CT			5 min	15 min	
CT-2 amps	AI	(E) CT			5 min	15 min	
CT-3 amps	AI	(E) CT			5 min	15 min	

~~6.~~7. Hot Water System

Description	Type	Device	New Device	New point	Trend Logging		Calibration
					Commissioning	Continuous	
Boiler B-1 enable	DO	Connect to boiler enable contact			COV	COV	–

Description	Type	Device	New Device	New point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Boiler B-2 enable	DO	Connect to boiler enable contact			COV	COV	–
Boiler B-3 enable	DO	Connect to boiler enable contact			COV	COV	–
Boiler B-4 enable	DO	Connect to boiler enable contact			COV	COV	–
Boiler B-5 enable	DO	Connect to boiler enable contact			COV	COV	–
Start HWP-1	DO	Connect to contact in starter			COV	COV	–
Start HWP-2	DO	Connect to contact in starter			COV	COV	–
B-1 HHW Iso-Valve	DO	(E) Modulating valve			COV	COV	
B-2 HHW Iso-Valve	DO	(E) Modulating valve			COV	COV	
B-3 HHW Iso-Valve	DO	(E) Modulating valve			COV	COV	
B-4 HHW Iso-Valve	DO	(E) Modulating valve			COV	COV	
B-5 HHW Iso-Valve	DO	(E) Modulating valve			COV	COV	
HWP-1 Speed	AO	Connect to VFD Speed			1 min	15 min	
HWP-2 Speed	AO	Connect to VFD Speed			1 min	15 min	
B-1 setpoint reset	AO	Connect to boiler reset input		X	1 min	5 min	–
B-2 setpoint reset	AO	Connect to boiler reset input		X	1 min	5 min	–
B-3 setpoint reset	AO	Connect to boiler reset input		X	1 min	5 min	–
B-4 setpoint reset	AO	Connect to boiler reset input		X	1 min	5 min	–
B-4 setpoint reset	AO	Connect to boiler reset input		X	1 min	5 min	–
Boiler B-1 Alarm	DI	Connect to contact in boiler panel			COV	COV	–
Boiler B-2 Alarm	DI	Connect to contact in boiler panel			COV	COV	–
Boiler B-3 Alarm	DI	Connect to contact in boiler panel			COV	COV	–
Boiler B-4 Alarm	DI	Connect to contact in boiler panel			COV	COV	–
Boiler B-5 Alarm	DI	Connect to contact in boiler panel			COV	COV	–
HWP-1 status	DI	(E) sensor			COV	COV	See 3.11F
HWP-2 status	DI	(E) sensor			COV	COV	See 3.11F
HWP-1 Fail Alarm	DI	(E) sensor					
HWP-2 Fail Alarm	DI	(E) sensor					

Description	Type	Device	New Device	New point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
B-1 HWS temperature	AI	(E) sensor			1 min.	±2°F	F
B-2 HWS temperature	AI	(E) sensor			1 min.	±2°F	F
B-3 HWS temperature	AI	(E) sensor			1 min.	±2°F	F
B-4 HWS temperature	AI	(E) sensor			1 min.	±2°F	F
B-5 HWS temperature	AI	(E) sensor			1 min.	±2°F	F
Common HWS temperature	AI	(E) sensor			1 min.	±2°F	HH
HWR temperature	AI	(E) sensor			1 min.	±2°F	HH
HW system gauge pressure	AI	PT-1, 0 to 60 psi in new tap	X	X	15 min	1 hr	F
HW flow	AI	(E) sensor			1 min.	10 min	F

8. Multiple Zone Air-conditioning Unit (AC-3 Fishbowl)

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
Fan Start (EF interlocked with SF)	DO				COV	COV	–
Cooling	DO				COV	COV	–
Hot Water Valve	AO	(N) actuator and 2-way valve to replace pneumatic	X		1 min	15 min	–
Fan Status	DI	Connect to (E) current switch			COV	COV	–
Supply Air Temperature	AI	(N) sensor	X		1 min	15 min	F
Return Air Temperature	AI	(N) sensor	X		1 min	15 min	F

~~7.~~9. Single Zone Air-conditioning Unit

a. Applies to AC-SS-4 and AC-SS-6. Split systems are controlled by (E) ALC OptiPoint BACnet Plus thermostat with (E) Mitsubishi PAC-US444CN-1 thermostat adapter interfaces. Connect controllers to new network.

Tag	Location	Make	Note
AC-SS-4	Student Services 4403 Data	Mitsubishi	

AC-SS-6	Student Services 4401 Network	Mitsubishi	Redundant with AC-SS-7

Description	**Type**	**Device**	**New Device**	**New Point**	**Trend Logging**		**Calibra-tion**
					Comm-issioning	**Contin-uous**	
Low fan speed	DO	Contact on thermostat adapter			COV	COV	–
Medium fan speed	DO	Contact on thermostat adapter			COV	COV	–
High fan speed	DO	Contact on thermostat adapter			COV	COV	–
Cooling	DO	Contact on thermostat adapter			COV	COV	–
Local Override	DI	ALC OptiPoint			COV	COV	–
Zone Temperature Setpoint Adjustment	AI	ALC OptiPoint			15 min	60 min	–
Zone Temperature	AI	ALC OptiPoint			1 min	15 min	F

b. Applies to AC-SS-1 thru AC-SS-3, AC-SS-5, and AC-SS-7. Provide (N) ALC OptiPoint BACnet Plus thermostat with thermostat adapter interfaces. Connect controllers to new network.

Tag	Location	Make	Note
AC-SAC5A.1	Sector 5A 241 Data	LG	
AC-SS-1	Student Services 3306 Elev	Daikin	
AC-SS-2	Student Services Level 3 Data	Daikin	
AC-SS-3	Student Services 3302 Data	Daikin	
AC-SS-5	Student Services 4402 Elec	Daikin	
AC-SS-7	Student Services 4401 Network	Carrier	Redundant with AC-SS-6

Description	**Type**	**Device**	**New Device**	**New Point**	**Trend Logging**		**Calibra-tion**
					Comm-issioning	**Contin-uous**	
Low fan speed	DO	Contact on thermostat adapter	X	X	COV	COV	–
Medium fan speed	DO	Contact on thermostat adapter	X	X	COV	COV	–

Description	Type	Device	New Device	New Point	Trend Logging		Calibra-tion
					Comm-issioning	Contin-uous	
High fan speed	DO	Contact on thermostat adapter	X	X	COV	COV	–
Cooling	DO	Contact on thermostat adapter	X	X	COV	COV	–
Local Override	DI	ALC OptiPoint	X	X	COV	COV	–
Zone Temperature Setpoint Adjustment	AI	ALC OptiPoint	X	X	15 min	60 min	–
Zone Temperature	AI	ALC OptiPoint	X	X	1 min	15 min	F

~~8.~~10. Single Speed Exhaust Fans. Applies to EF-1 through EF-3

Description	Type	Device	New Device	New Point	Trend Logging		Cali bra-tion
					Comm-issioning	Contin -uous	
Fan Start/Stop	DO	(E) Dry contact to 120V starter control circuit			COV	COV	–
Fan Status	DI	(E) CS-1			COV	COV	See 3.11F

~~9.~~11. Single Speed Exhaust Fans. Applies to EF-4

Description	Type	Device	New Device	New Point	Trend Logging		Cali bra-tion
					Comm-issioning	Contin -uous	
Fan Start/Stop	DO	(E) Dry contact to 120V starter control circuit			COV	COV	–
Fan Status	DI	(E) CS-1			COV	COV	See 3.11F
Zone Temperature	AI	TS-3A			1 min	15 min	F

~~10.~~12. Domestic Water Heat Exchanger

Description	Type	Device	New Device	New Point	Trend Logging		Cali bra-tion
					Comm-issioning	Contin -uous	
HW Valve	AO	(E) valve actuator					
DHW Supply Temp	AI	(E) sensor					
DHW Return Temp	AI	(E) sensor					
DHW Pump Start/Stop	DO	(E) Dry contact to 120V starter control circuit		X	COV	COV	
DHW Pump Status	DI	CS-1	X	X	COV	COV	

~~11.~~13. Miscellaneous

Description	**Type**	**Device**	**New Device**	**New point**	**Trend Logging**		**Calibra-tion**
					Comm-issioning	**Contin-uous**	
Parking Lot C Lights	DO	(E) relay			COV	COV	–
Police Lights	DO	(E) relay			COV	COV	–
Main Control Air	AI	(E) sensor			1 min	15 min	
Air Valve	DO	(E) contact			COV	COV	
Sewage Lift Station Alarm	DI	(E) contact		X	COV	COV	
Emergency Generator Status (See Alternates)	DI	(E) contact		X	COV	COV	
Natural gas flow – main campus (Alternate)	pulse	(E) PG&E meter		X	1 min.	10 min	F
Natural gas flow – College Complex Boilers (Alternate)	pulse	(E) PG&E meter		X	1 min.	10 min	F
Power – Main Campus (Alternate)	pulse	(E) PG&E meter		X	1 min.	10 min	F
Cooling tower makeup water (Alternate)	AI	FM-6	X	X	15 min	15 min	F

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. 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	X	X	X

Application Category	**Examples**	**Acceptable Controller**		
		ASC	**AAC**	**BC**
	status of sump pumps or associated float switches, temperatures in monitored electrical rooms.			
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.

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. 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 2.12C.

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

5. Initiate trends of points as indication in Paragraph 2.12C.

C. External Communications

1. Provided through College IT VPN.

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 or located outdoors: 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.

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. Unless transformers are provided with equipment, 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 controllers 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 installed in raceway

1) Class 2 wiring shall be installed in UL Listed approved raceway 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 where not in reach of access panels

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

3) Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment (for example steam pipes or flues).

4) 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.

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

6) 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.

7) 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.

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

c. Class 2 wiring not installed in raceway

1) Class 2 wiring need not be installed in raceway where located in concealed and readily 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) On top of rectangular ductwork located so as not to be visible by occupants

f) 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, except where located on top of rectangular ductwork per Paragraph 3.10A.2.c.1)e).

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

3. 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).

4. 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.

5. 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.

6. Use coded conductors throughout with different colored conductors.

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

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

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

10. 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.

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. Terminate all control or interlock wiring.

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

14. 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

    a. Hot water pumps

15. 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

16. 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. IP networks

a. Ethernet Cable

1) RJ45 connectors shall comply with EIA-568 T568B wiring standards.

b. AACs and ASCs

1) Daisy chain wiring is acceptable for controllers with Ethernet pass-through capability.

2) No more than 40 controllers per connection to managed switch.

3) No more than 60 feet of ethernet cabling between two devices in the daisy chain.

c. BCs

1) Connect directly to LAN (no daisy chaining with other controllers).

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

5. Each cable terminating at a panel shall have two coils worth of extra cable for future pulling of cable.

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

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

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

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

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

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

12. 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.

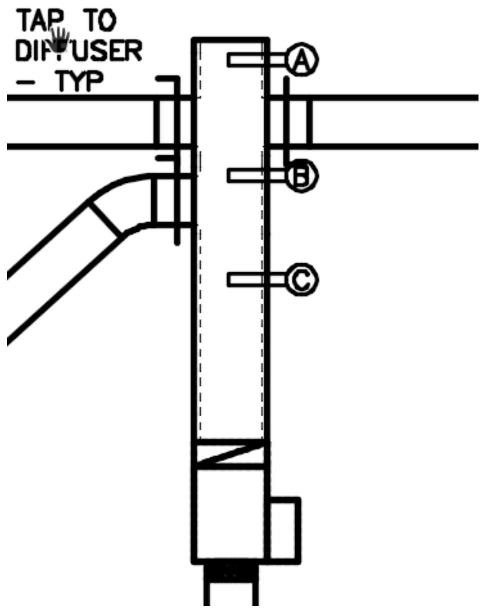
2. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.

3. Temperature sensors at coils:

a. No part of the sensor or its support elements or conduit shall be in contact with the coil, coil framing or coil support elements.

b. Discharge temperature sensors on VAV boxes

1) Sensor probe shall be mounted as far from the coil as possible but upstream of the last diffuser tap and at least 3 feet downstream of the coil. For example:



a) Location A is not allowed because it is beyond the last diffuser tap.

b) Location B is allowed since it is as far as possible without being beyond the last diffuser tap provided it is at least 3 feet from the coil.

c) Location C is not allowed even if it is 3 feet downstream of the coil since location B is "possible" and preferred.

2) For single point sensors, the probe shall be located as near as possible to the center of the duct both vertically and horizontally. See Paragraph 2.9F.2.a.1) for probe length.

4. All pipe-mounted temperature sensors shall be installed in wells. For small piping, well shall be installed in an elbow into pipe length. Install the sensor in the well with a thermal-conducting grease or mastic. Use a closed-cell insulation patch that is integrated into the pipe insulation system to isolate the top of the well from ambient conditions but allow easy access to the sensor. Install a test plug adjacent to all wells for testing and calibration.

5. Unless otherwise noted on Drawings or Points List, temperature sensors/thermostats, humidity sensors/humidistats, 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.

6. 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. Filter Differential Pressure

   a. Install static-pressure tips upstream and downstream of filters with tips oriented in direction of flow. If there is a Magnehelic gauge installed by the AHU manufacturer, it may be removed and discarded with its pressure tips used for the DPT provided the DPT has an LCD so it can double as a visual gauge.

   b. Mount transmitter on outside of filter housing or filter plenum in an accessible position with LCD display clearly visible. This sensor is used in lieu of an analog gauge and thus must be readily viewable.

3. 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.

4. 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.

5. 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.

6. Piping differential pressure transducers shall have one of the following:

   a. Five valve manifold, brass, two valves to allow removal of sensor without disrupting the hydronic system, an equalizing valve to allow the sensor to be zeroed and to prevent sensor from experiencing full static (as opposed to differential), and two valves used as air vents that also can be used as test plugs for calibration.

   b. For sensors using two separate sensors, install test plugs on each connection for calibration and also used as vents.

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. Fluid Flow Meters: Install per manufacturer’s recommendations for unobstructed straight length of pipe both upstream and downstream of sensor. Commission per the manufacturer’s startup and commissioning recommendations. Complete all manufacturer’s startup documentation and include this in prefunctional commissioning report.

H. Occupancy Sensors

1. Install per manufacturer’s recommendations.

2. Ceiling mounted:

   a. Locate as close to center of room as practicable with a mounting height of 8 to 12 feet, and at least 4 to 6 feet away from supply air vents. Ensure mounting height is sufficiently low so that view of room is unobstructed by ducts and lighting fixtures.

   b. Mount in junction box. Where installed in spaces with exposed concrete structure, mount junction box with rigid raceway to achieve desired mounting height.

3. Test per manufacturer's recommendations to ensure occupancy and vacancy are effectively detected.

I. Refrigerant Monitor (Alternate)

1. Meet all requirements of Chapter 11 of the CMC.

2. Monitor Installation and Configuration

a. Install in accordance with the manufacturer’s instructions.

b. Piping (for pumped sample draw type): Materials and installation shall be as per pneumatic control piping.

c. Locate sample ports in likely locations for refrigerant leaks from chillers, one port per chiller. Locate port in accordance with chiller manufacturer installation instructions. Where these instructions do not recommend a location, locate port 18 inches off the floor adjacent to the chiller on the side closest to the exhaust intake and furthest from the makeup air supply.

d. Alarm Configuration

1) For each refrigerant in room, set the three refrigerant monitor alarm setpoints as follows:

	Caution (Leak)	Warning (Spill)	Alarm (Evacuate)
Action	Display	Display Horn Strobe	Display Horn Strobe Exhaust Fan
Reset	Auto	Manual	Manual
Refrigerant	Setpoint (ppm)		
123	25	35	50

2) Manual reset shall be only possible from panel face within chiller room.

3. Alarm Controls

a. Inside the chiller room, provide:

1) Visual and audible alarms. Alarms may be integral to the refrigerant monitor.

b. Outside each chiller room entrance, provide:

1) Visual and audible alarms

c. Outside the primary chiller room entrance, provide:

1) Visual and audible alarms

2) Manual fan-on break-glass

3) Manual emergency-chiller-off break-glass switch

4) Fan on (green) and off (red) status lights wired to current switch to indicate fan status

d. Hardwire refrigerant alarm contact and break-glass switch to start exhaust fan (on high speed if motor is multi-speed). The BAS shall not be used for this purpose.

e. Also wire manual wind-up timer on-off switch inside primary entry to start fan (for comfort ventilation) on low speed if motor is multi-speed. Provide label at switch indicating "Ventilation Fan".

f. Hardwire a contact that indicates emergency- chiller-off break-glass manual alarm to the BAS. Program BAS to stop all refrigeration equipment in room when contact indicates alarm.

g. Generate trouble alarm when monitor detects a malfunction. Trouble alarm shall not initiate horn and strobe.

J. Actuators

1. Type: All actuators shall be electric.

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

3. Dampers

a. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage, or follow manufacturer's instructions to achieve same effect.

b. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

c. Provide all mounting hardware and linkages for actuator installation.

4. 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 CWS CWR HWS HWR CHWS CHWR OA SA RA EA GAS FLUID	Command Status Light Power Voltage Current ValvePos DamperPos Temperature Humidity Pressure Flow Energy Speed Signal	On/off On/off Footcandles Watts Volts Amps %open %open °F %RH Psig, “H_2O Cfm, gpm Btu %, Hz %
	HVAC	Airhandling Exhaust Heatplant Coolplant Misc				
	PLMB	Domwater Air Natgas N2 O2 Irrigation Waste Misc				
	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 1.15).

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. Include real-time site utility data such as campus electrical demand and natural gas demand shown roughly on the map where the utilities connect to the site.

    c. Electricity demand limiting

        1) Demand limit. Include entries for sliding window interval and a table of Off-Peak, On-Peak or Partial-Peak demand time periods, both Summer and non-Summer, with three adjustable demand level limits for each and adjustable deadband.

        2) Electricity demand calculation. For each month, show actual peak kW and kWh for each time-of-day rate period. Show side-by-side as month-this-year and month-last-year, and month-to-date and year-to-date data.

    d. Natural gas demand page. For each month, show actual peak therms/hr and therms for each rate period. Show side-by-side as month-this-year and month-last-year, and month-to-date and year-to-date data. Include adjustable conversion of gas volumetric flow rate to therms.

    e. 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.

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

g. Each air handler and fan-coil: Provide link to associated HW and CHW plants where applicable.

h. 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.

i. 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.

j. Electrical power monitoring system: Show a schematic of the electrical system based on one-line diagrams with meter current kW reading and month-to-date kWh shown in actual locations. Show side-by-side kWh and peak demand as month-this-year and month-last-year, and month-to-date and year-to-date data. Power flow shall change on the diagram (by changing line color or width) to show which power line is active.

k. Water meters: Show side-by-side gallons and peak demand gpm as month-this-year and month-last-year, and month-to-date and year-to-date data.

l. Central plant equipment including chilled water system, cooling tower system, hot water system, steam system, generators, etc.: The flow path shall change on the diagram (by changing piping line color or width) to show which piping has active flow into each boiler, chiller, tower, etc. as valve positions change.

m. 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); occupancy status; 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); Heating Static Pressure Reset current requests, cumulative %-request-hours, and request Importance Multiplier (dual duct); Heating SAT Reset current requests, cumulative %-request-hours, and request Importance Multiplier (dual duct).

4) AC and Heat Pumps: operating mode; zone temperature; active heating setpoint; active cooling setpoint; supply air temperature; fan status; fan speed (where applicable); Cooling stages; Heating stages.

5) Electrical meters and switches: Volts, current, kW, switch positions.

n. 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.

o. 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.

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

q. All other BAS controlled/monitored equipment.

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

s. 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. Water Systems Balancing

1. Prepare water systems for balancing in following manner

a. Verify the following conditions

1) Strainers have been cleaned

2) Piping systems are completely full of water, all air properly vented

3) All coil and heat exchanger shut-off, balance, and control valves are fully open

2. Pumps

a. Test and report for each pump at test conditions indicated in Paragraphs below.

1) Tag

2) Manufacturer and model of pump and motor

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

4) Pump shut-off head from curves, measured shut-off head, and resulting impeller diameter from pump curve

5) At test condition specified

a) Volts and amps

b) Calculated brake horsepower

c) Entering and leaving gage pressure and difference in feet

d) Flow rate deduced from pump curve

e) Flow rate measured by BAS flowmeter

f) For pump with variable speed drive

1. Speed (Hz)

2. Kilowatts

b. Include pump curve from installed pump in final report.

3. Boilers

a. Confirm that isolation valve at each boiler is shut when commanded so by BAS, or adjust if necessary, through visual inspection and monitoring of measured flow and pump shut-off pressure. Record date and time, measured HW flow through BAS, and differential pressure across pump at pump speed corresponding to pump test above.

F. Air System Balancing

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

2. 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. Set hot water supply temperature setpoint to 180°F.

d. Use BAS terminal "commissioning" software where available and record all calibration and test data through the BAS.

e. Zero transmitter prior to each test.

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

g. 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

h. 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

      f) Number of coil rows

3. 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.

4. 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.

5. 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. 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 3.14F.4.

3) For systems with both a design minimum outdoor air rate and an "absolute" minimum outdoor air rate, repeat the tests above for the lower rate achieved by slowing down the supply air fan.

c. 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

d. 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 3.14F.5.b.3).

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

G. 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. Submit Submittal Package 3 (Pre-Functional Test Forms) and receive approval.
10. Perform BAS Pre-functional Tests (start up, calibration and tuning) and submit completed forms as Submittal Package 4 (Pre-Functional Test Report) for approval.
11. Receive BAS Pre-functional Test Report approval and approval to schedule Functional Tests.
12. Field test application programs prior to functional testing.
13. Submit Package 5 (Post-Construction Trend Points List) in format specified for review and approval.
14. Receive approval of successful Trend Log configuration, or reconfigure as required.
15. Prepare and initiate commissioning Trend Logs.
16. Perform and record functional tests and submit Submittal Package 6 (Functional Test Report) for approval.
17. Assist in TAB tests and determining setpoints for Testing, Adjusting and Balancing.
18. Submit Package 7 (Training Materials) and receive approval.
19. Receive BAS Functional Test Report approval and approval to schedule Demonstration Tests.
20. Perform Demonstration Tests to Commissioning Provider and College's Representatives and submit Demonstration Test Report.
21. Receive acceptance of Demonstration Tests.
22. Train College personnel on BAS operation and maintenance.
23. Substantial Completion

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

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

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

27. Provide administration level password access to the College.

28. Final Acceptance

29. Begin Warranty Period.

30. Prepare and initiate continuous Trend Logs per Paragraph 2.12A.4.

31. Update all software as specified.

32. 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
Condenser Water Temperature	±2ºF
Chilled Water Temperature	±1ºF
Hot Water Temperature	±3ºF
Duct Temperature	±2ºF
Water Differential Pressure	±1.5 psi
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 by Testing, Adjusting, and Balancing Contractor. Some balancing procedures require the BAS to be operational and require Contractor time and assistance.

2. Calibration Software

a. Software shall be provided 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 performed for Testing, Adjusting, and Balancing to determine fan and pump 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 3 working days.

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 2.11 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 2.11 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 2.11C.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 2.11 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. Provide training sessions for personnel indicated in Paragraph 3.16G.

2. Training materials, including slides, shall be submitted prior to any training in Submittal Package 7.

3. Training shall be conducted after all commissioning is complete and systems are fully operational.

4. Off-site Primary System Training

   a. Training on basic BAS functions as listed in Paragraph 3.16C.4 shall be given off-site by the primary manufacturer's training staff, either at the factory or at a permanent training facility. Training by Contractor staff is not acceptable.

   b. The appropriate level of training shall be provided for each of the persons listed in Paragraph 3.16G.

   c. The length of each training period will depend on the complexity of the system and the audience, described below. Minimum training shall be 24 hours per trainee, but period shall be longer if required to complete the training tasks described below.

   d. Expenses for transportation to and from the training facility, hotel, and meals shall be provided by the Owner and excluded from the BAS bid. Cost for books, manuals and any other type of training equipment or material shall be included in the BAS bid.

5. On-Site Training

   a. Include 40 hours total of on-site training to assist personnel in becoming familiar with site-specific issues, systems, control sequences, etc.

   b. Owner shall be permitted to videotape training sessions.

   c. Training may be in non-contiguous days at the request of the Owner.

6. During the warranty period, provide unlimited telephone support for all trained operators.

D. Operators are divided into three categories and shall receive training including but not limited to the tasks listed.

1. Day-to-day Operators shall be trained to

   a. Proficiently operate the system

   b. Understand control system architecture and configuration

   c. Understand BAS system components

   d. Understand system operation and control sequences

   e. Operate the workstation and peripherals

   f. Log on and off the system

g. Access graphics, point reports, and logs

h. Adjust and change system set points, time schedules, and holiday schedules

i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals

j. Understand and acknowledge alarms

k. Understand system drawings, and Operation and Maintenance manual

l. Understand the Project layout and location of control components

m. Print point and predefined reports

2. Advanced Operators shall be trained to do all items for Day-to-Day operators plus

a. Make and change graphics on the workstation

b. Create, delete, and modify alarms, including annunciation and routing

c. Create, delete, and modify point trend logs, and graph or print these both on an ad-hoc basis and at user-definable time intervals

d. Create, delete, and modify reports

e. Add, remove, and modify system's physical points

f. Create, modify, and delete programming

g. Add control panels

h. Add Operator Workstations

i. Create, delete, and modify system displays — both graphical and otherwise

j. Perform BAS system field checkout procedures

k. Perform BAS controller unit operation and maintenance procedures

l. Perform workstation and peripheral operation and maintenance procedures

m. Perform BAS system diagnostic procedures

n. Configure hardware including PC boards, switches, communication, and I/O points

o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware

p. Adjust, calibrate, and replace system components

q. Maintain software and prepare backups

3. System Managers/Administrators shall be trained to do all items for Day-to-Day operators plus

    a. Maintain software and prepare backups

    b. Create and print custom reports, including tenant billing summaries

    c. Interface with project-specific, third-party operator software

    d. Add new users and understand password security procedures

E. Training materials shall include step-by-step instructions (including illustrations, screen captures, etc.) for how to perform all task identified in Paragraph 3.16C.4 such that a new Operator, who has not attended the training in person and has minimal familiarity with this BAS system, can easily follow the instructions and successfully perform all of the identified tasks. One copy of training material shall be provided per student. An electronic copy of the materials shall be stored on the OWS.

F. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

G. The type and number of personnel and location for training shall include

1. Day-to-day Operator: 2

2. Advanced Operator: 1

3. System Managers/Administrators: 1

END OF SECTION 250000

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

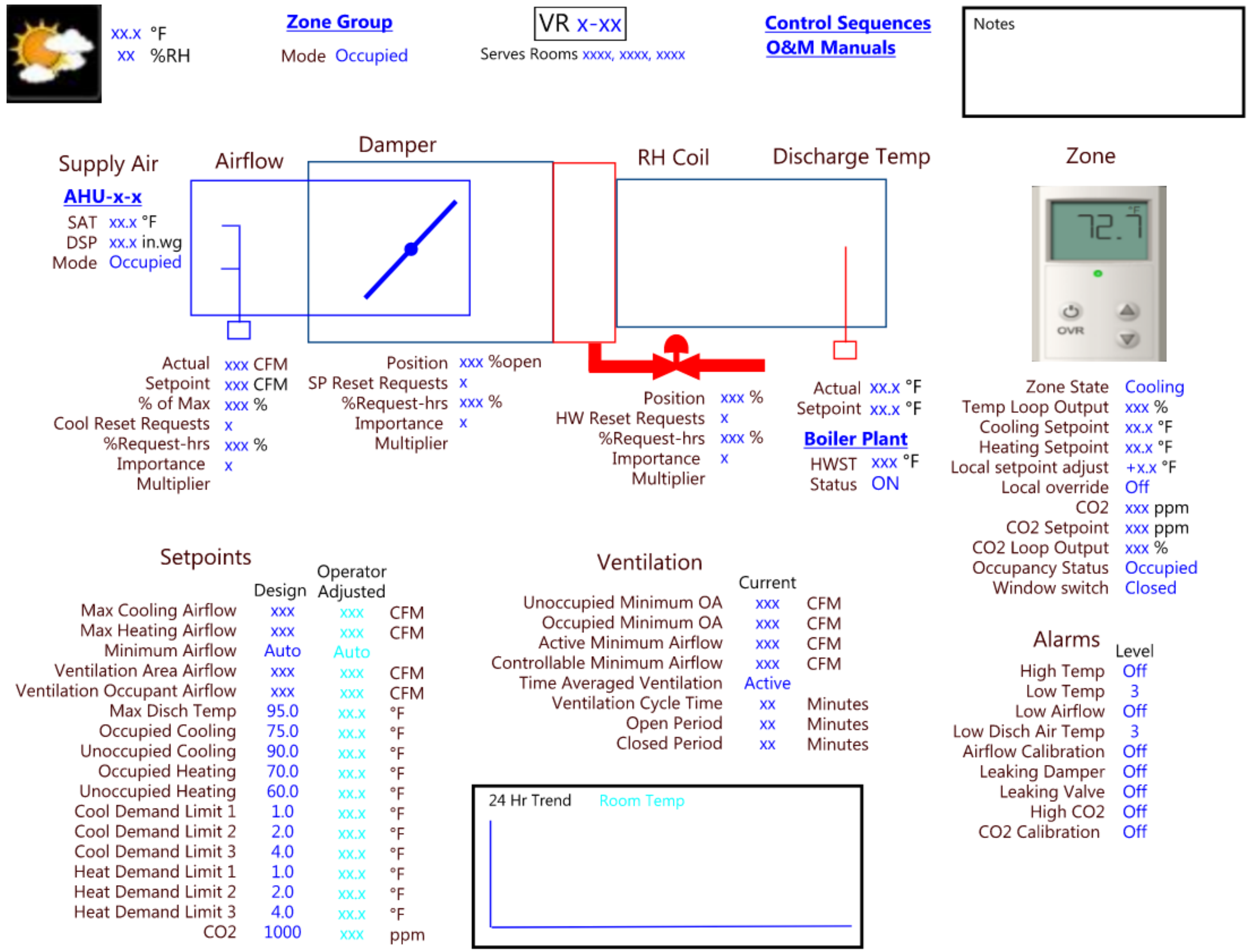
Total Airflow

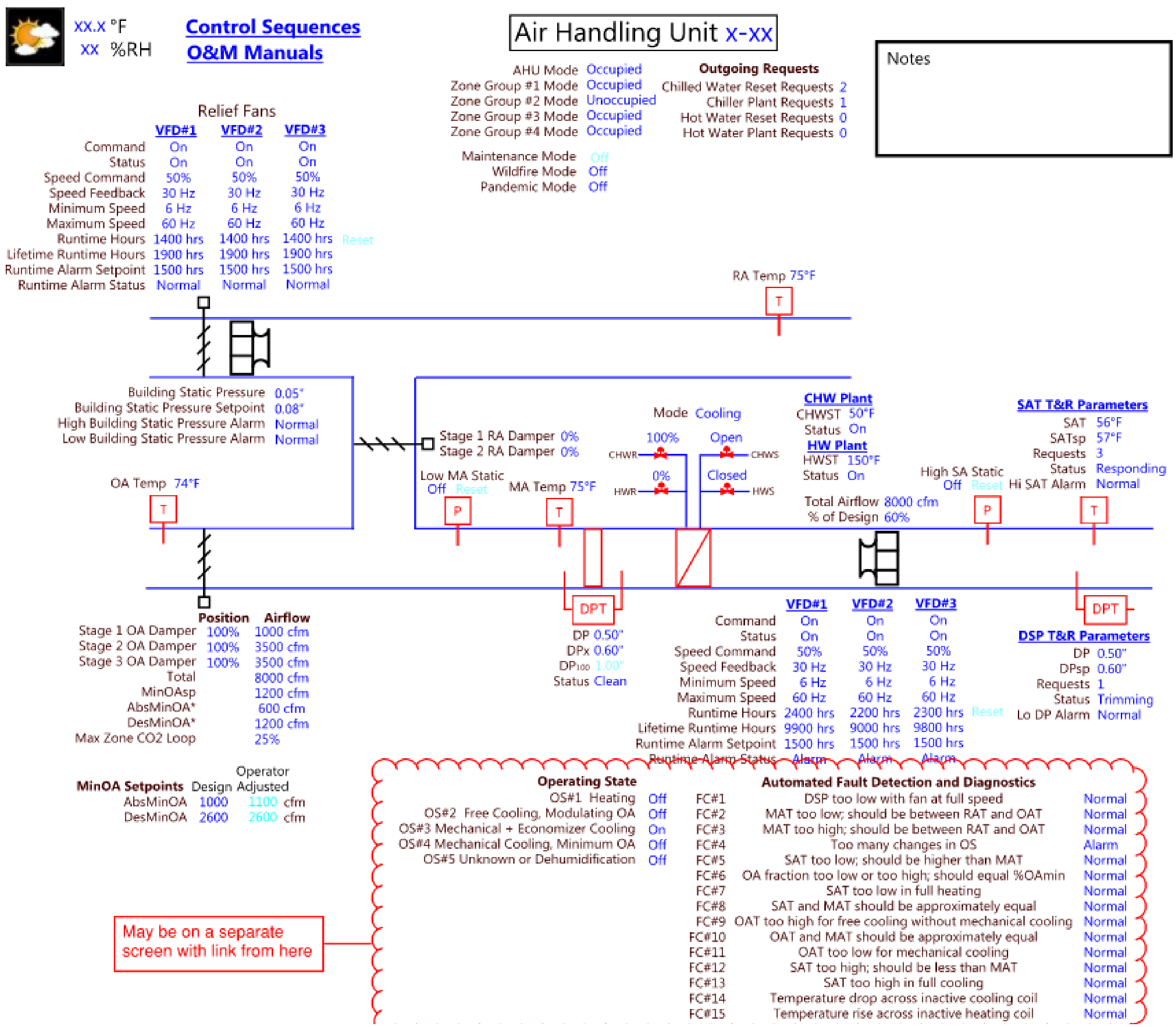
Airflow Setpoints xxx cfm
Actual Airflow xxx cfm
Occupant OA xxx cfm
Area OA xxx cfm
Total OA xxx cfm

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			


xx.x °F
xx %RH
Zone Group
Mode Occupied
VR x-xx
Serves Rooms xxxx, xxxx, xxxx
Control Sequences
O&M Manuals
Notes
Supply Air
AHU-x-x
SAT xx.x °F
DSP xx.x in.wg
Mode Occupied
Airflow
Damper
RH Coil
Discharge Temp
Zone
72.7
OVR
Actual xxx CFM
Setpoint xxx CFM
% of Max xxx %
Cool Reset Requests x
%Request-hrs xxx %
Importance x
Multiplier
Position xxx %open
SP Reset Requests x
%Request-hrs xxx %
Importance x
Multiplier
Position xxx %
HW Reset Requests x
%Request-hrs xxx %
Importance x
Multiplier
Actual xx.x °F
Setpoint xx.x °F
Boiler Plant
HWST xxx °F
Status ON
Zone State Cooling
Temp Loop Output xxx %
Cooling Setpoint xx.x °F
Heating Setpoint xx.x °F
Local setpoint adjust +x.x °F
Local override Off
CO2 xxx ppm
CO2 Setpoint xxx ppm
CO2 Loop Output xxx %
Occupancy Status Occupied
Window switch Closed
Setpoints
Design
Operator Adjusted
Max Cooling Airflow xxx xxx CFM
Max Heating Airflow xxx xxx CFM
Minimum Airflow Auto Auto
Ventilation Area Airflow xxx xxx CFM
Ventilation Occupant Airflow xxx xxx CFM
Max Disch Temp 95.0 xx.x °F
Occupied Cooling 75.0 xx.x °F
Unoccupied Cooling 90.0 xx.x °F
Occupied Heating 70.0 xx.x °F
Unoccupied Heating 60.0 xx.x °F
Cool Demand Limit 1 1.0 xx.x °F
Cool Demand Limit 2 2.0 xx.x °F
Cool Demand Limit 3 4.0 xx.x °F
Heat Demand Limit 1 1.0 xx.x °F
Heat Demand Limit 2 2.0 xx.x °F
Heat Demand Limit 3 4.0 xx.x °F
CO2 1000 xxx ppm
Ventilation
Current
Unoccupied Minimum OA xxx CFM
Occupied Minimum OA xxx CFM
Active Minimum Airflow xxx CFM
Controllable Minimum Airflow xxx CFM
Time Averaged Ventilation Active
Ventilation Cycle Time xx Minutes
Open Period xx Minutes
Closed Period xx Minutes
24 Hr Trend Room Temp
Alarms
Level
High Temp Off
Low Temp 3
Low Airflow Off
Low Disch Air Temp 3
Airflow Calibration Off
Leaking Damper Off
Leaking Valve Off
High CO2 Off
CO2 Calibration Off


xx.x °F
xx %RH
Control Sequences
O&M Manuals
Air Handling Unit x-xx
Notes
AHU Mode Occupied
Zone Group #1 Mode Occupied
Zone Group #2 Mode Unoccupied
Zone Group #3 Mode Occupied
Zone Group #4 Mode Occupied
Maintenance Mode Off
Wildfire Mode Off
Pandemic Mode Off
Outgoing Requests
Chilled Water Reset Requests 2
Chiller Plant Requests 1
Hot Water Reset Requests 0
Hot Water Plant Requests 0
Relief Fans
VFD#1 VFD#2 VFD#3
Command On On On
Status On On On
Speed Command 50% 50% 50%
Speed Feedback 30 Hz 30 Hz 30 Hz
Minimum Speed 6 Hz 6 Hz 6 Hz
Maximum Speed 60 Hz 60 Hz 60 Hz
Runtime Hours 1400 hrs 1400 hrs 1400 hrs Reset
Lifetime Runtime Hours 1900 hrs 1900 hrs 1900 hrs
Runtime Alarm Setpoint 1500 hrs 1500 hrs 1500 hrs
Runtime Alarm Status Normal Normal Normal
RA Temp 75°F
T
Building Static Pressure 0.05"
Building Static Pressure Setpoint 0.08"
High Building Static Pressure Alarm Normal
Low Building Static Pressure Alarm Normal
OA Temp 74°F
T
Stage 1 RA Damper 0%
Stage 2 RA Damper 0%
Low MA Static
Off Reset
P
MA Temp 75°F
T
Mode Cooling
100% Open
CHWR CHWS
0% Closed
HWR HWS
CHW Plant
CHWST 50°F
Status On
HW Plant
HWST 150°F
Status On
Total Airflow 8000 cfm
% of Design 60%
High SA Static
Off Reset
P
SAT T&R Parameters
SAT 56°F
SATsp 57°F
Requests 3
Status Responding
Hi SAT Alarm Normal
T
DPT
DP 0.50"
DPx 0.60"
DP100 1.00"
Status Clean
DPT
Position Airflow
Stage 1 OA Damper 100% 1000 cfm
Stage 2 OA Damper 100% 3500 cfm
Stage 3 OA Damper 100% 3500 cfm
Total 8000 cfm
MinOAsp 1200 cfm
AbsMinOA* 600 cfm
DesMinOA* 1200 cfm
Max Zone CO2 Loop 25%
VFD#1 VFD#2 VFD#3
Command On On On
Status On On On
Speed Command 50% 50% 50%
Speed Feedback 30 Hz 30 Hz 30 Hz
Minimum Speed 6 Hz 6 Hz 6 Hz
Maximum Speed 60 Hz 60 Hz 60 Hz
Runtime Hours 2400 hrs 2200 hrs 2300 hrs Reset
Lifetime Runtime Hours 9900 hrs 9000 hrs 9800 hrs
Runtime Alarm Setpoint 1500 hrs 1500 hrs 1500 hrs
Runtime Alarm Status Alarm Alarm Alarm
DSP T&R Parameters
DP 0.50"
DPsp 0.60"
Requests 1
Status Trimming
Lo DP Alarm Normal
Operator
MinOA Setpoints Design Adjusted
AbsMinOA 1000 1100 cfm
DesMinOA 2600 2600 cfm
Operating State
OS#1 Heating Off
OS#2 Free Cooling, Modulating OA Off
OS#3 Mechanical + Economizer Cooling On
OS#4 Mechanical Cooling, Minimum OA Off
OS#5 Unknown or Dehumidification Off
Automated Fault Detection and Diagnostics
FC#1 DSP too low with fan at full speed Normal
FC#2 MAT too low; should be between RAT and OAT Normal
FC#3 MAT too high; should be between RAT and OAT Normal
FC#4 Too many changes in OS Alarm
FC#5 SAT too low; should be higher than MAT Normal
FC#6 OA fraction too low or too high; should equal %OAmin Normal
FC#7 SAT too low in full heating Normal
FC#8 SAT and MAT should be approximately equal Normal
FC#9 OAT too high for free cooling without mechanical cooling Normal
FC#10 OAT and MAT should be approximately equal Normal
FC#11 OAT too low for mechanical cooling Normal
FC#12 SAT too high; should be less than MAT Normal
FC#13 SAT too high in full cooling Normal
FC#14 Temperature drop across inactive cooling coil Normal
FC#15 Temperature rise across inactive heating coil Normal
May be on a separate screen with link from here

SECTION 259000

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	80ºF
Classroom	70ºF	73ºF	60ºF	80ºF
Server	–	80ºF	–	80ºF
IDF/MDF	–	78ºF	–	78ºF
Electrical	–	85ºF	–	85ºF

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
Fishbowl	AC-3	VAV-FB-1 thru VAV-FB-3		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Sector 4 Social Sciences	n/a	VAV-SOC-1 thru VAV-SOC-15		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Sector 5A	AHU-1	VAV-5A-1 thru VAV-5A-9	EF-1	WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-2	VAV-SSC-3-2-X and VAV-SSC-4-2-X		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-3	VAV-SSC-3-3-X and VAV-SSC-4-3-X	EF-2 and EF-3	WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-4	VAV-SSC-3-4-X and VAV-SSC-4-4-X		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-5	VAV-SSC-3-5-X and VAV-SSC-4-5-X		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-6	VAV-SSC-3-6-X and VAV-SSC-4-6-X		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
Student Services	AHU-7	VAV-SSC-3-7-X and VAV-SSC-4-7-X		WD: 6 am to 8pm WE: 8 am to 10pm HOL: off
IDF rooms	n/a			ALL: 12 am to 12 am

E. Building Chilled Water Pump

1. DP-MAX: 19 psi

F. Building Hot Water Pump

1. DP-MAX: 16 psi

G. 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. Duct Design Maximum Static Pressure, Max_DSP

1) AHU-1: 1.35 inches

2) AHU-2: 1.35 inches

3) AHU-3: 1.25 inches

4) AHU-4: 1.35 inches

5) AHU-5: 1.25 inches

6) AHU-6: 1.25 inches

7) AHU-7: 1.25 inches

3. Ventilation Setpoints

a. AbsMinOA: the design outdoor air rate when all zones with CO2 sensors or occupancy sensors are unpopulated.

1) AHU-1: 575 cfm

2) AHU-2: 970 cfm

3) AHU-3: 950 cfm

4) AHU-4: 860 cfm

5) AHU-5: 915 cfm

6) AHU-6: 470 cfm

7) AHU-7: 650 cfm

b. DesMinOA: the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable.

1) AHU-1: 585 cfm

2) AHU-2: 970 cfm

3) AHU-3: 1125 cfm

4) AHU-4: 910 cfm

5) AHU-5: 920 cfm

6) AHU-6: 465 cfm

7) AHU-7: 655 cfm

4. 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

5. DP100, filter high limit differential pressure at design airflow = 1 in.w.c. or value from manufacturer's submittal whichever is lower

6. Pressure Zone Group Assignments

Pressure Zone Group Name	AHU Tag	RF Tag	Building Pressure Sensor Location(s)
Sector 5A	AHU-1	EF-1	(E) Sector 5A
Student Services	AHU-2 AHU-3 AHU-4 AHU-5 AHU-6 AHU-7	EF-2 EF-3 EF-4	(E) with AHU-2 (E) with AHU-7

A. Water Cooled Chilled Water Plant

1. Temperature Setpoints

a. CHWSTminX, the lowest chilled water supply temperature setpoint for Chiller X = 44°F

b. CHWSTmax, the maximum chilled water supply temperature setpoint used in plant reset logic = 60°F

c. CWRTdesX, the condenser water return (chiller condenser leaving) temperature at chiller selection conditions for Chiller X = 84°F each

d. CWSTdesX, the condenser water supply (chiller condenser entering) temperature at chiller selection conditions for Chiller X= 75°F each

e. CH-LOT, the outdoor air lockout temperature below which the chiller plant is prevented from operating = 63°F

2. Chiller Lift Setpoints

a. LIFTminX, the minimum allowable lift at minimum load for Chiller X, as determined from the manufacturer's recommendations, where lift is the difference between condenser water return temperature and chilled water supply temperature.

1) CH-1: 11°F

2) CH-2: 11°F

b. LIFTmaxX, design lift at design load for Chiller X = CWRTdesX minus CHWSTminX = 42°F

3. Capacity

a. QchX, design capacity of Chiller X, in tons = 350 tons each

4. Headered Pump Design Quantities

a. N-PCHWP, the number of primary chilled water pumps that operate at design conditions = 2

B. Hot Water Plant

1. Temperature Setpoints

a. HWSTmax, the highest hot water supply temperature setpoint = 180°F

HW-LOT, the outdoor air lockout temperature above which the boiler plant is prevented from operating = 75°F

2. Boiler Flow Setpoints

a. HW-MinFlowX, the design minimum Boiler water flowrate as recommended by the manufacturer for Boiler X, in gpm = 25 gpm each

b. HW-DesFlowX, the design boiler hot water flowrate for Boiler X, in gpm = 186 gpm each

3. Minimum Boiler Firing Rate

a. B-FiringMinX, the lowest %-firing rate of Boiler X before cycling = 10%

4. Capacity

a. QbX, design output capacity of Boiler X, in KBtu/h = 1860 KBH each

b. PHWFdesign, design primary loop flow, in gpm (each loop) = 1200 gpm

5. Headered Pump Design Quantities

   a. N-PHWP, the number of primary hot water pumps that operate at design conditions = 2

1.3 INFORMATION PROVIDED BY (OR IN CONJUNCTION WITH) THE TESTING, ADJUSTING, AND BALANCING CONTRACTOR

A. Coordinate with Testing, Adjusting and Balancing Contractor for setpoint determination.

B. Multiple-Zone Air-Handler Information

1. 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

2. Return-Fan Discharge Static Pressure Setpoints. (For return-fan direct building pressure control, see Section 3.11E~~3.9E~~.)

   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.

C. Water Cooled Chilled Water Plant

1. Minimum Speeds

   a. Where minimum speeds are not required for flow control per other balancer provided setpoints above, minimum speed setpoints for all VFD-driven pumps and tower fans shall be determined in accordance with Section 250000 Building Automation System for the following as applicable:

      1) Cooling Tower Fans

D. Hot Water Plant

1. Minimum Speeds

   a. Where minimum speeds are not required for flow control per other balancer provided setpoints above, minimum speed setpoints for all VFD-driven pumps and tower fans shall be determined for hot water pumps in accordance with Section 250000 Building Automation System.

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 A 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 3.1R) 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. Equipment Staging and Rotation

1. Parallel equipment shall be lead/lag or lead/standby rotated to maintain even wear.

2. Two runtime points shall be defined for each equipment:

a. Lifetime Runtime: The cumulative runtime of the equipment since equipment start-up. This point shall not be readily resettable by operators.

Lifetime Runtime should be stored to a software point on the control system server so the recorded value is not lost due to controller reset, loss of power, programming file update, etc.

b. Staging Runtime: An operator resettable runtime point that stores cumulative runtime since the last operator reset.

Staging Runtime provides a resettable runtime counter, which allows for reset of the staging runtime hours used for lead/lag or lead/standby rotation between maintenance intervals or equipment replacement while maintaining a separate log of the Lifetime Runtime. If runtime were not resettable, and logic relied only on Lifetime Runtime for determining staging lead/lag position, newly added equipment could run for years as the lead equipment before swapping rotation positions with older equipment per the logic below.

3. Lead/lag equipment: Unless otherwise noted, identical parallel staged equipment (such as CHW pumps and cooling towers) shall be lead/lag alternated when more than one is off or more than one is on so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the lead stage equipment.

This strategy effectively makes it such that equipment are not "hot swapped", e.g., a pump would not be started and another stopped during operation just for runtime equalization.

For example, assume there are two equipment and only one is on, but the operating equipment has exceeded the run hours of the disabled equipment. The equipment will not rotate positions until either a stage up or down occurs. If the plant stages up, then both equipment will be on and lead/lag position will switch; when the plant next stages down, the former lead equipment with more run hours will then turn off.

Expanding further, for a plant with three equipment, if all three are off or all are on, the staging order will simply be based on run hours from lowest to highest. If two equipment are on, the one with more hours will be set to be stage 2 while the other is set to stage 1; this may be the reverse of the operating order when the equipment were started. If two of the equipment are off, the one with the more hours will be set to be stage 3 while the other is set to stage 2; this may be the reverse of the operating order when the equipment were stopped.

Example with three pumps:

1. *P-1 (1000 hours), 2 (950 hours), and 3 (900 hours) are all off. Staging logic makes lead/lag order: 3, 2, 1.*
2. *P-3 starts. Logic does not change its order since it is on by itself.*
3. *P-3 runs for 51 hours. Since it is on and others off, the lead/lag order does not change. It can run this way indefinitely and the order does not change.*
4. *There is then a stage-up command. P-2 (the next in lead/lag order) is started. So, both P-2 and P-3 are on. P-3 now has more run hours than P-2. So, the Lead/lag order changes to: 2, 3, 1.*
5. *These two pumps run another 51 hours. Run times are P-1 (1000 hours), P-2 (1001), and P-3 (1002). No changes are made to lead/lag order because P-1 is off alone.*
6. *There is a stage down command. P-2 is now lead so it stays on. P-3 is shut off. The order for the two off pumps is now adjusted because P-1 has fewest run hours. Lead/lag order is now: 2, 1, 3.*
7. *P-2 runs for 100 more hours. It now has the longest runtime, but order does not change since it is on alone. Order is still 2, 1, 3.*
8. *There is a stage down or plant-off command. P-2 shuts off. Run times are P-1 (1000 hours), P-2 (1101), and P-3 (1002). Since all are off, order is switched to: 1, 3, 2.*

4. Lead/standby equipment:

   a. Unless equipment runs continuously, parallel equipment that are 100% redundant shall be lead/standby alternated when more than one of the equipment is off so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the earlier stage equipment.

For example, assuming there are three equipment, if all three are off, the staging order will be based on run hours from lowest to highest.

   b. If equipment runs continuously, lead/standby positions shall switch at an adjustable day of the week and time (e.g., every Tuesday at 10:00 am) based on Staging Runtime; standby equipment shall first be started and proven on before former lead equipment is changed to standby and shut off.

1) Variable speed fans and pumps shall have a deceleration rate of 1 Hz/second or slower set in BAS logic when disabled to prevent nuisance trips of operating equipment (e.g., chillers).

5. Exceptions to Lead/lag and Lead/standby rotation

a. Operators with appropriate access level shall be able to manually command staging order via software points, but not overriding the In-Alarm or Hand-Operation logic in the following subsections.

1) Staging order changes initiated via operator override shall be instituted as part of normal staging events.

2) Staging order shall remain overridden until released by operators.

b. Faulted Equipment:

1) A faulted equipment is any equipment commanded to run that is either not running when it should or unable to perform its required duty. If an operating equipment has any fault condition described subsequently, a Level 2 alarm shall be generated and a response shall be triggered as defined below.

a) Fans and Pumps

1. Status point not matching its on/off point for 3 seconds after a time delay of 15 seconds while the equipment is commanded on.

b) Chillers

1. Safety shutdown alarm condition either through network or hardwired alarm contact

2. Chiller is manually shut off as indicated by the status of the Local/Auto switch from chiller gateway, or

3. Chiller status remains off 5 minutes after command to start (note: this condition only applies when a chiller first starts, i.e., once status is proven, then status is no longer used as a fault condition because status will come and go if chiller cycles on low load), or

4. For 10 minutes, chilled water return temperature has been at least 3°C (5°F) above the CHWST setpoint, and delta-T across the chiller, as determined based on the difference between chilled water return temperature and chilled water supply temperature measured at the chiller (i.e., not common CHWST), has been less than 2°C (3°F).

c) Boilers

1. Safety shutdown alarm condition either through network or hardwired alarm contact, or

2. If boiler leaving water temperature remains 8.3°C (15°F) below setpoint for 15 minutes and delta-T across the boiler, as determined based on the difference between hot water supply temperature and hot water return temperature measured at the boiler (i.e., not common HWST), has been less than 6°C (10°F).

d) Cooling Towers

1. Tower fan has failed as defined above, or

2) Upon identification of a fault condition or when equipment is in Maintenance Mode:

a) For fans, pumps, and cooling towers:

1. The next commanded off equipment in the staging order, Equipment "B", shall be commanded on while alarming Equipment "A" remains commanded on.

2. If Equipment "B" fails to prove status (i.e., it also goes into alarm), it shall remain commanded on and the preceding step shall be repeated until the quantity of equipment called for by the current stage has proven on, or there are no more available equipment.

3. Set alarming equipment to the last positions in the lead/lag or lead/standby staging order sequenced reverse chronologically (i.e., the equipment that alarmed most recently is sent to last position).

4. Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up on the staging order if another equipment goes into alarm.

5. Equipment in alarm shall run if so called for by the lead/lag or lead/standby staging order and present stage.

b) For chillers and boilers:

1. The next commanded off equipment in the staging order, Equipment "B", shall be commanded on while alarming Equipment "A" is commanded off and set to the last position in the lead/lag staging order.

2. If Equipment B fails to prove status (i.e., it also goes into alarm), repeat the preceding step until the quantity of equipment called for by the lead/lag logic have proven on or until all equipment has been tried.

3. If all equipment has been tried and the quantity of non-alarming equipment is less than called for then the most recently alarmed equipment will remain commanded on.

4. Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up in the staging order if another equipment goes into alarm.

5. Equipment in alarm shall run if so called for by the lead/lag staging order and present stage.

The sequence for chillers and boilers differs from that used for pumps and cooling towers in that the alarming equipment does not remain commanded on until the next equipment proves status. The pump and tower logic mitigates the risk of lost loads and/or chain reaction trips of chillers and boilers by still taking advantage of any capacity the alarming equipment may provide until the lag equipment proves. This approach does not however typically work for chillers and boilers because bringing on the lag equipment while still commanding the alarming equipment to run may prevent a successful startup of the lag equipment. For example, in a parallel variable primary chilled water plant under low load conditions, starting a lag chiller while keeping the alarming chiller enabled may cause both chillers to trip on either low chilled water flow or low condenser water flow unless the minimum chilled water flow setpoint is changed to maintain minimum chilled water flow and condenser water pumps are staged to maintain minimum condenser flow through both chillers.

Example: For a set of (4) lead/lag equipment, the current staging order is Equipment A, B, C, then D. The current stage requires two equipment, so A and B are running. Then A goes into alarm. A is then commanded off at the same time as C is commanded on. If C then goes into alarm it is commanded off at the same time that D is commanded on. If D then goes into alarm it remains commanded on since all equipment has been tried. If B (the last equipment not in alarm) also goes into alarm then it remains commanded on (as the last alarming equipment with no non-alarming equipment available). At this point all equipment are in alarm and only B and D will remain commanded on until an equipment comes out of alarm. The staging order is B, D, A, C. Note that staging up/down is disabled in this condition per Sections 3.13C.9~~3.11C.9~~ and 3.14C.6~~3.12C.6~~.

c. Hand Operation. If a piece of equipment is on-in-hand (e.g., via an HOA switch or local control of VFD), the equipment shall be set to the lead device, and a Level 4 alarm shall be generated. The equipment will remain as lead until. Hand operation is determined by the following:

Any condition in which equipment appears to continue to run after being commanded off is considered a case of hand operation; in practice, this condition may arise due to other circumstances (e.g., a bad current transducer).

1) Fans and Pumps

a) Status point not matching its on/off point for 15 seconds after a time delay of 60 seconds when the equipment is commanded off.

Logic for hand operation of chillers, boilers, and cooling towers is not provided because sequences cannot stably respond to overrides by operators in all possible scenarios. For example, if a chiller is turned on in hand in a variable primary system with only one other chiller currently running, the control system would need to react by opening the isolation valves of the chiller placed in hand and either (1) immediately shutting down the former lead chiller or (2) changing the minimum chilled water flow setpoint, opening isolation valves, and possibly staging on condenser water pumps and cooling towers. Chillers, boilers, and cooling towers should only be placed in hand by changing the staging sequence manually via the control system interface; they cannot be safely or stably operated in hand at the chiller/boiler/tower controllers.

Q. 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 1.2G.4. Setpoints listed below are for current California Energy Standards.

2. Title 24

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

R. 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 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 3.1R.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)

S. 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

T. Occupancy Sensor Status

1. Occupancy status of all spaces shall be via the Lighting Control BACnet interface, unless otherwise noted.

2. Where a zone serves more than one room, “unoccupied” (or “unpopulated” per Guideline 36 terminology) means all rooms are unoccupied and “occupied” (populated) means any room is occupied.

3. In case of the network connection with the Lighting Controls is lost:

a. For all other zones, occupancy status shall default to “occupied” if the Zone Group is in Occupied Mode and “unoccupied” for any other Zone Group Mode.

U. 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.

V. Outdoor Air Pollution Mode

1. Provide a 2-position software switch for Outdoor Air Pollution Mode:

a. Off. Locks Outdoor Air Pollution Mode off.

b. Outdoor Air Pollution Mode is enabled for a preset period of time, after which Outdoor Air Pollution Mode shall be disabled. The preset time shall be operator adjustable for up to 1 week.

2. When Outdoor Air Pollution Mode is enabled:

a. Generate a Level 1 alarm.

b. Disable all air economizers.

c. Generate a daily Level 3 alarm at a scheduled time indicating that Outdoor Air Pollution Mode is still active.

3.2 ELECTRICITY DEMAND LIMITING

*Automatic Demand Response is required by Title 24 for all non-healthcare systems with DDC to the zone.*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. Include Demand Shed commands to the lighting control system via BACnet interface for each Demand Level. The response to each Demand Shed command shall be programmed into the lighting control system.

3. 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.

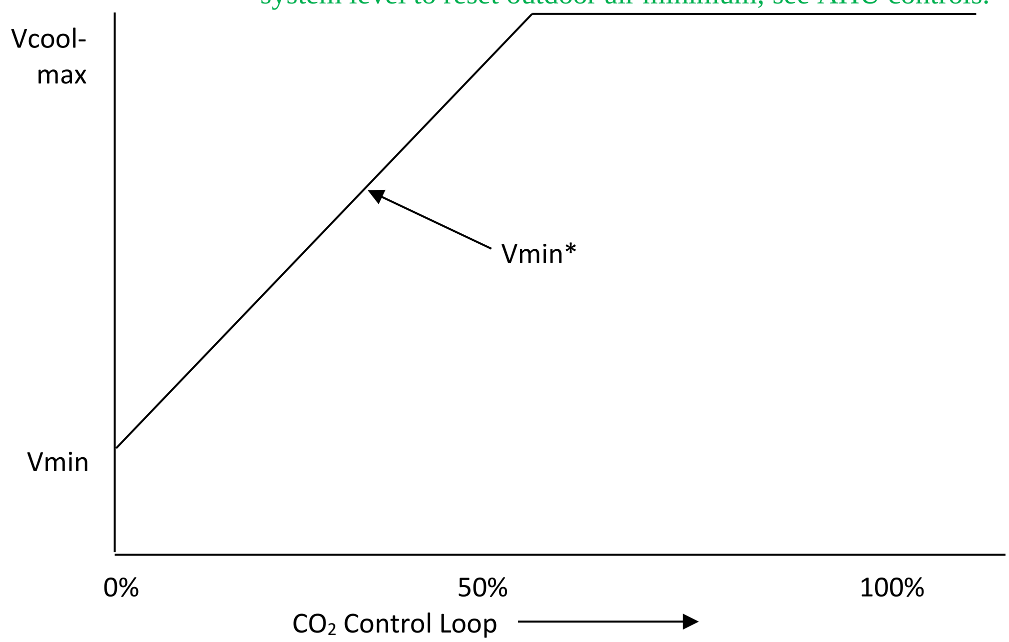


Figure 5.2.1.4-1 Vmin* reset with CO2 loop.

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 CO_2 sensors:

1. If the CO_2 concentration is less than 300 ppm, or the zone is in Unoccupied Mode for more than 2 hours and zone CO_2 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 CO_2 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, fan-powered 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. 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.

d. 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.

c. Suppress zone temperature alarms as follows:

1) After zone setpoint is changed per Section 3.1S.

2) While Zone Group is in Warmup Mode or Cooldown Mode.

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.

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

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.

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.

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.

F. Zone-Group Operating Modes. Each Zone Group shall have the modes shown in the following subsections.

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.

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.

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 3.4~~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 and described in the following subsections.

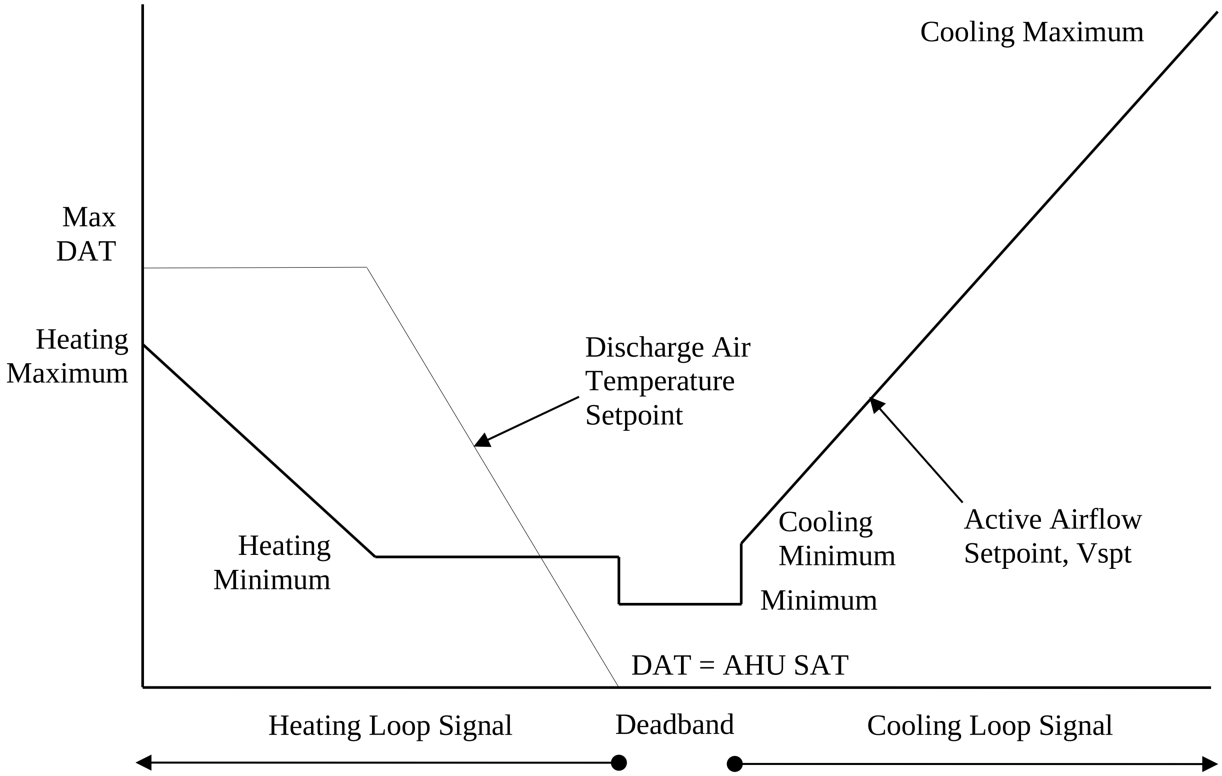


Figure 5.6.5 Control logic for VAV reheat zone.

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 50%, the heating-loop output shall reset the discharge temperature setpoint from the current AHU SAT setpoint to a maximum of MaxΔT above space temperature setpoint. The active airflow setpoint shall be the heating minimum endpoint.

    b. From 51% to 100%, if the DAT is greater than room temperature plus 3°C (5°F), the heating-loop output shall reset the active airflow setpoint from the heating minimum endpoint to the heating maximum endpoint.

    c. 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 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 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 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 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 5°F for 2 minutes and after suppression period due to setpoint change per Section 3.1S, send 3 requests.

b. Else if the zone temperature exceeds the zone's cooling setpoint by 3°F for 2 minutes and after suppression period due to setpoint change per Section 3.1S, 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. If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the DAT is 30°F less than setpoint for 5 minutes, send 3 requests.

b. Else if the DAT is 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 and Heating Hot-Water Plant, 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 CAV REHEAT ZONE

A. See "Generic Thermal Zones" (Section 3.4) for setpoints, loops, control modes, alarms, etc.

B. Maximum DAT rise above heating setpoint MaxΔT = 25°F.

C. Temperature control

1. When the Zone State is deadband, the heating coil is disabled unless the DAT is below the minimum setpoint (see Section 3.7C.3).

2. When the Zone State is heating, the Heating Loop shall maintain space temperature at the heating setpoint. The heating-loop output shall reset the discharge temperature setpoint from the current AC unit SAT setpoint to a maximum of MaxΔT above space temperature setpoint. 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).

3. In Occupied Mode, the heating coil shall be modulated to maintain a DAT no lower than 50°F.

D. Alarms

1. Low-Discharge Air Temperature

   a. If heating hot-water plant is proven on, and the DAT is 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 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.

2. Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 5°F, and the fan serving the zone is proven on, generate a Level 4 alarm.

E. System Requests

1. If There Is a Hot-Water Coil, Hot-Water Reset Requests

   a. If the DAT is 30°F less than setpoint for 5 minutes, send 3 requests.

b. Else if the DAT is 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.

2. If There Is a Hot-Water Coil and Heating Hot-Water Plant, 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.

3.8 MULTIPLE ZONE AC UNIT

A. Supply fan control

1. The supply fan shall run whenever the unit is in any mode other than Unoccupied Mode, except as noted below:

a. When all associated zones are sensed to be unpopulated and in deadband mode.

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. Cooling Supply Air Temperature Setpoint

a. Design setpoints:

1) Min_ClgSAT: 55

2) Max_ClgSAT: 70

b. During Occupied Mode and Setup Mode, setpoint shall be reset using T&R logic (see Section 3.1O) between Min_ClgSAT and Max_ClgSAT. The parameters shown in the table below are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	SPmax
SPmin	Min_ClgSAT

SPmax	Max_ClgSAT
Td	10 minutes
T	2 minutes
I	0
R	Zone cooling SAT requests
SPtrim	+0.2°F
SPres	–0.3°F
SPres-max	–1.0°F

c. During Cooldown Mode, setpoint shall be Min_ClgSAT.

d. During Warmup Mode and Setback Mode, setpoint shall be 90°F.

3. Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to stage on the cooling coil. Provide hysteresis and a 5 minute minimum on time and a 5 minute minimum off-time (adjustable).

4. Preheat Control

a. If the DX cooling has been off for at least 10 minutes, the hot water valve shall be modulated to maintain the supply air temperature at a minimum preheat setpoint of 50°F.

C. 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 the alarm until the equipment has been commanded on for 15 seconds.

b. Commanded off, status on: Level 4. Do not evaluate the alarm until the equipment has been commanded off for 60 seconds.

D. Plant Requests

1. Hot-Water Reset Requests

a. If the HW valve position is greater than 95% and the supply air temperature is 30°F less than SATsp for 5 minutes, send 3 requests.

b. Else if the HW valve position is greater than 95% and the supply air temperature is 15°F less than SATsp 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.

2. Heating Hot-Water Plant Requests

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~~3.9 SINGLE ZONE SPLIT AC UNIT WITH DDC

A. Supply fan control

1. The unit fan shall run only when zone is in Cooling State and off in Deadband State.

2. Fan speed shall be mapped to the zone Cooling Loop output, staging up to low speed at 33%, up to medium speed at 66%, and up to high speed at 100%; staging down to medium speed at 66%, and down to low speed at 33%.

B. 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 25% 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

C. Redundant units

1. AC-6 and AC-7 provide redundant lead/standby cooling to Student Services room 4401. When a unit is in standby mode, the cooling setpoint shall be offset to be 2ºF higher than that of the lead unit.

D. Alarms

1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.

~~3.8~~3.10 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

~~3.9~~3.11 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. Supply fan shall also run when system is in Setback Mode or Warmup Mode (i.e., all modes except unoccupied).

b. 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	0.5 in. of water
SPmin	0.1 in. of water
SPmax	Max_DSP (see Section 1.2G.2)
Td	10 minutes
T	2 minutes
I	2
R	Zone static pressure reset requests
SPtrim	–0.05 in. of water
SPres	+0.06 in. of water
SPres-max	+0.13 in. of water

Informative note: The number of ignored requests can be adjusted to balance responsiveness to demand (fewer ignores) vs energy efficiency (more ignores). The value that is set should be considered as a function of the total number of downstream zones or systems that can send requests. As a default, set the number of ignored requests to 10% of the total downstream zones or systems, rounded to the nearest integer.

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.).

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

   a. See Section 1.2G.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.

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	+0.2°F
SPres	–0.3°F
SPres-max	–1.0°F

Informative note: The number of ignored requests can be adjusted to balance responsiveness to demand (fewer ignores) vs energy efficiency (more ignores). The value that is set should be considered as a function of the total number of downstream zones or systems that can send requests. As a default, set the number of ignored requests to 10% of the total downstream zones or systems, rounded to the nearest integer.

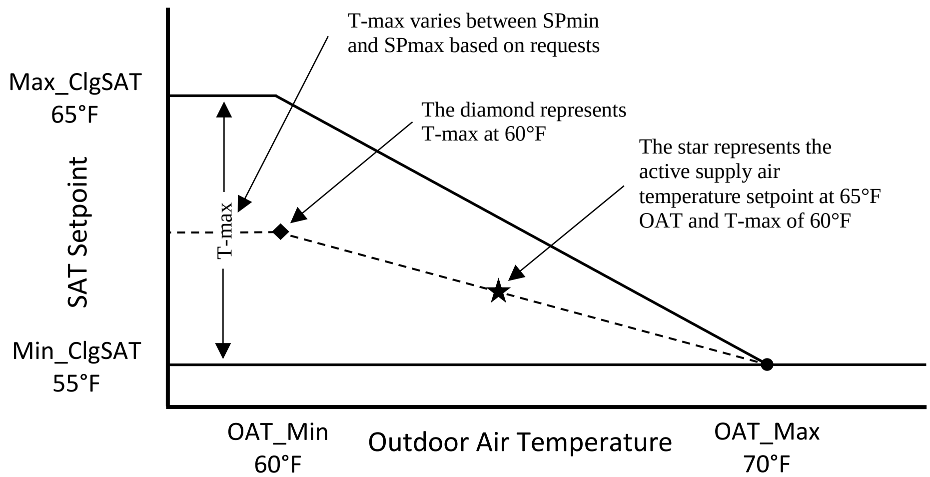


Figure 5.16.2.2 Example supply air temperature reset diagram.

c. During Cooldown Mode, setpoint shall be Min_ClgSAT.

d. During Warmup Mode and Setback Mode, setpoint shall be 35°C (95°F).

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 3.11D.3~~3.9D.3~~).

2) For units with a separate minimum outdoor air damper, economizer damper minimum position MinOA-P is 0%, and return air damper maximum position MaxRA-P is modulated to control minimum outdoor air volume (see Section 3.11D~~3.9D~~).

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) whenever minimum outdoor air control is active. See logic for Minimum Outdoor Air Control below.

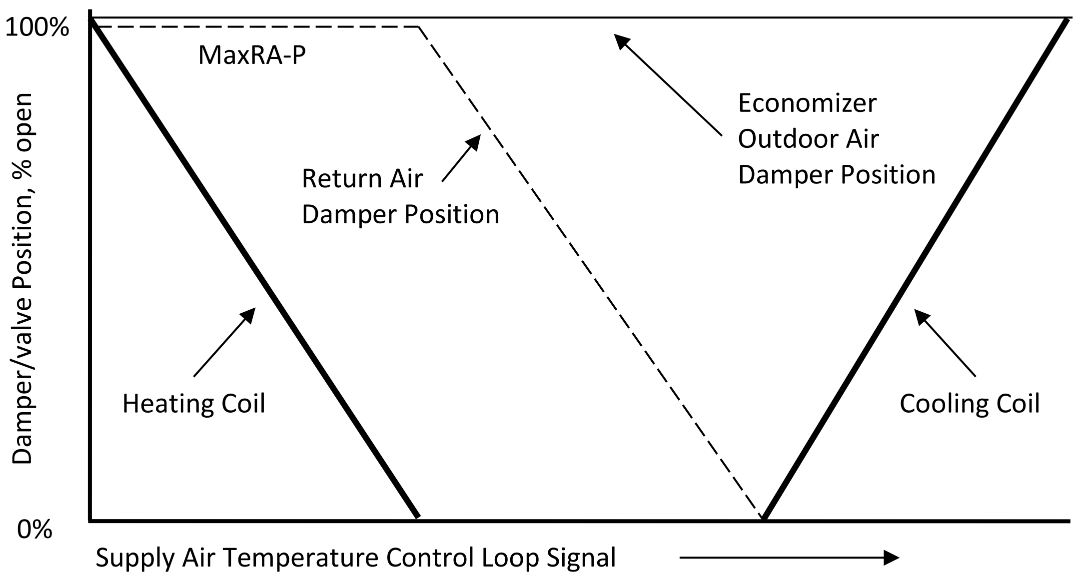


Figure 5.16.2.3 SAT loop mapping with return-fan control with direct building pressure controls.

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 1.2G.3.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 Separate Minimum Outdoor Air Damper and Airflow Measurement

1. Outdoor Airflow Setpoint for California Title 24 Ventilation

a. See Section 3.11C.13.9C.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. Open the minimum outdoor air damper when the supply fan is proven ON, the AHU is in Occupied Mode and MinOAsp is greater than zero. Minimum outdoor air damper shall be closed otherwise.

3. Outdoor Air and Return Air Dampers

a. For units with return fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.
The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

1) When the supply air fan is proven on and the system is in Occupied Mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

2) Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and any of the following conditions are true:

a) The economizer high limit conditions in Section 3.1Q are exceeded for 10 minutes.

b) When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P for 10 minutes.

c) Outdoor Air Pollution Mode is enabled per Section 3.1V.

3) When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 3.11B3.9B shall be suspended per the following sequence:

a) Fully open return air damper; and

b) Wait 15 seconds, then close the economizer outdoor air damper; and

c) Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 3.11B~~3.9B~~. Economizer outdoor air damper remains closed.

d) The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at setpoint MinOAsp.

4) Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or all of the following conditions are true:

a) The economizer high limit conditions in Section 3.1Q are exceeded for 10 minutes.

b) The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P for 10 minutes.

c) Outdoor Air Pollution Mode is disabled per Section 3.1V.

5) When minimum outdoor air control is disabled:

a) Economizer outdoor air damper shall be fully opened.

b) MaxRA-P shall be set to 100%.

c) Economizer and return air damper positions shall be controlled by the SAT control loop per Section 3.11B~~3.9B~~.

E. Return-Fan Control − Direct Building Pressure

1. See Section 1.2G.6 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 3.11E.5~~3.9E.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 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.2 for RFDSPmin and RFDSPmax.

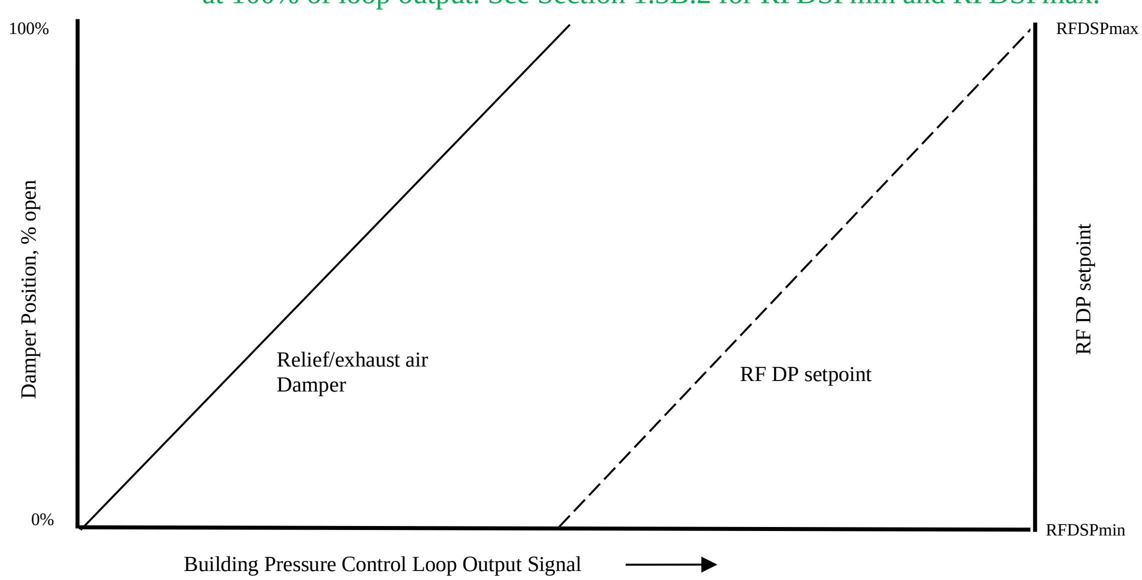


Figure 5.16.10.5 Exhaust damper position and return-fan DP reset

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. High building pressure (more than 0.10 in. of water) for 5 minutes: Level 3.

4. Low building pressure (less than 0.0 in. of water, i.e., negative) for 5 minutes: Level 4.

G. Automatic Fault Detection and Diagnostics

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		

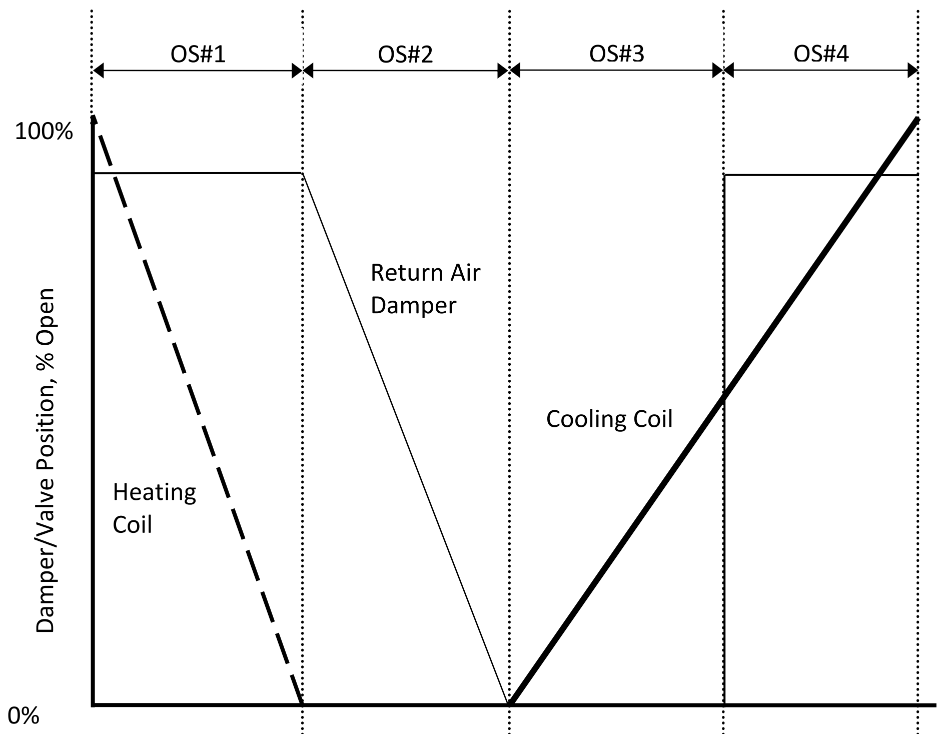


Figure 2 VAV AHU operating states.

3. The following points must be available to the AFDD routines for each AHU:

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.

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

Variable Name	Description	Default Value
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
TestModeDelay	Time in minutes that Test Mode is enabled	120

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.

Table 6 VAV AHU Fault Conditions

FC#1	Equation	$\text{DSPAVG} < \text{DSPSP} - \varepsilon\text{DSP}$ and $\text{VFDSPD} \geq 99\% - \varepsilon\text{VFDSPD}$	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	$\text{MATAVG} + \varepsilon\text{MAT} < \min[(\text{RATAVG} - \varepsilon\text{RAT}), (\text{OATAVG} - \varepsilon\text{OAT})]$	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	$\text{MATAVG} - \varepsilon\text{MAT} > \max[(\text{RATAVG} + \varepsilon\text{RAT}), (\text{OATAVG} + \varepsilon\text{OAT})]$	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	$\Delta\text{OS} > \Delta\text{OSMAX}$	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 Gas or electric heat unavailable DX cooling stuck on	
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 Gas or electric heat unavailable DX cooling stuck on 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	$\lvert MATAVG - OATAVG \rvert > \sqrt{\varepsilon_{MAT}^2 + \varepsilon_{OAT}^2}$	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 DX cooling unavailable Gas or electric heat stuck on 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 DX cooling unavailable Gas or electric heat stuck on 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 DX cooling stuck on	
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.

I. Plant Requests

1. Chilled-Water Reset Requests

   a. If the supply air temperature exceeds the supply air temperature setpoint by 5°F for 2 minutes, send 3 requests.

   b. Else if the supply air temperature exceeds the supply air temperature setpoint by 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 30°F less than setpoint for 5 minutes, send 3 requests.

b. Else if the supply air temperature is 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.

~~3.10~~3.12 GENERAL CONSTANT SPEED EXHAUST FAN

A. Exhaust Fan Control

1. Exhaust Fan Start/Stop

a. Scheduled fans (EF-1, EF-2 and EF-3)

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 (EF-4)

1) Exhaust fan shall run when zone temperature rises above the active cooling setpoint until zone temperature falls more than 2°F below the active cooling setpoint for 2 minutes.

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~~3.13 WATER COOLED CHILLED WATER PLANT

A. See Section 1.2A for Design Setpoints. See Section 1.3C for TAB setpoints.

B. Plant Enable/Disable

1. The chiller plant shall include an enabling schedule that allows operators to lock out the plant during off-hours, holidays, or any other scheduled event, e.g., to allow off-hour operation of HVAC systems except the chiller plant. The default schedule shall be 24/7 (adjustable).

2. Enable the plant in the lowest stage when the plant has been disabled for at least 15 minutes and:

   a. If at least one of the following is true, and:

      1) Number of Chiller Plant Requests > I (I = Ignores shall default to 0, adjustable)

      2) OAT>Plant Enable Temp. Set initially to 75°F (Adjustable setting to enable plant based on OAT, while there is no communication to many of the chilled water coils controlled by the Andover system. Set this as high as possible but to a lower value if chilled water coils in Andover are being starved and plant is not enabled. When majority of chilled water coils are controlled by ALC and communicated Chiller Plant Requests, this limit should be set higher to effectively disable it.)

   b. OAT>CH-LOT, and

   c. The chiller plant enable schedule is active.

3. Disable the plant when it has been enabled for at least 15 minutes and:

   a. Neither of the following is true, or:

      1) Number of Chiller Plant Requests ≤ I for 3 minutes, or

      2) OAT> Plant Enable Temp

   b. OAT<CH-LOT – 1°F, or

   c. The chiller plant enable schedule is inactive.

4. When the plant is enabled:

   a. Open the CHW isolation valve of the lead chiller.

b. (CW isolation valve is opened by chiller)

c. Stage on lead primary CHW pump, CW pump, and cooling towers per Sections 3.13E~~3.11E~~, 3.13F~~3.11F~~, and 3.13G~~3.11G~~ respectively.

d. Once the lead pumps are proven on, enable the lead chiller.

5. When the plant is disabled:

a. Shut off the enabled chiller(s).

Where chillers have a CHW request network point, consider increasing the delay to 10 minutes to ensure that flow is not cut off too soon. Where chillers do not have this point (e.g., older chillers without network interfaces), the default delay is appropriate.

b. For each enabled chiller, close the CHW isolation valve after 3 minutes or the chiller is not requesting CHW flow.

Where chillers have a CW request network point, consider increasing the delay to 10 minutes to ensure that flow is not cut off too soon. Where chillers do not have this point (e.g., older chillers without network interfaces), the default delay is appropriate.

c. For each enabled chiller, CW isolation valve is closed directly by chiller.

d. Disable the operating primary CHW pump(s), CW pump(s), and cooling tower(s) per Sections 3.13E~~3.11E~~, 3.13F~~3.11F~~, and 3.13G~~3.11G~~ respectively.

C. Chiller Staging

1. Chiller stages shall be defined as follows:

Chiller Stage	Enabled Chillers
0	None
1	CH-1 or CH-2
2	CH-1 and CH-2

2. Interchangeable chillers indicated with “or” in the table above shall be lead/lag controlled per Section 3.1P.3. If a chiller is in alarm per Section 3.1P.5.b, its CHW isolation valve shall be closed.

3. Chillers are staged in part based on required capacity, Qrequired, relative to design capacity of a given stage, which is the sum of the design capacity of each chiller active in each stage. This ratio is the operative part load ratio, OPLR.

4. Qrequired is calculated based on chilled water return temperature (CHWRT) entering the chillers, active chilled water supply temperature setpoint (CHWSTSP), and measured flow through the primary circuit flow meter (FLOWP), as shown in the equation below. Qrequired used in logic shall be a 5-minute rolling average of instantaneous values sampled at a minimum of every 30 seconds.

$$Q_{required} = \frac{FLOW_P(CHWRT - CHWST_{SP})}{24}\ [tons]$$

Required capacity, as opposed to actual load, is used to provide more stable staging since chilled water supply temperature setpoint changes less dynamically than actual chilled *water supply temperature. Note that using entering return temperature, as opposed to temperature upstream of waterside economizers or chilled water minimum flow bypasses as applicable, is critical for calculations to be executed properly.*

5. When a stage up or stage down transition is initiated, hold Qrequired fixed at its last value until the longer of the successful completion of the stage change (e.g., lag chiller proven on) and 15 minutes.

As staging occurs, flowrate and return temperature may fluctuate, so Qrequired may be unstable. As detailed subsequently, Qrequired impacts plant part load ratio, which drives condenser water return temperature setpoint and tower control. As such, if Qrequired is unstable, so too would be condenser water return temperature, and thus chiller lift.

6. OPLR shall be calculated as follows:

$$OPLR = \frac{Q_{required}[tons]}{Sum\ of\ QchX\ for\ Chillers\ in\ stage}$$

7. Minimum cycling part load ratio, OPLRMIN, shall be calculated as:

$$OPLR_{MIN,stage} = \frac{Sum\ of\ MinUnloadTonsX\ for\ Chillers\ in\ stage}{Sum\ of\ QchX\ for\ Chillers\ in\ stage}$$

8. Stage up events are initiated in part based on current stage OPLR exceeding a stage up part load ratio, SPLRUP; stage down events are initiated in part based on OPLR for the next lower stage falling below a stage down part load ratio, SPLRDN.

9. Staging events require that a chiller stage be available. A stage shall be deemed unavailable if the stage cannot be achieved because a chiller required to operate in the stage is faulted per Section 3.1P.5.b.1)b) or a chilled water or condenser water pump dedicated to that chiller is faulted per Section 3.1P.5.b.1)a); otherwise, the stage shall be deemed available.

   a. Set SPLRUP as follows:

      1) SPLRUP shall be calculated as the 5 minute rolling average of the following equation sampled at least every 30 seconds:

$$SPLR_{UP} = Min(Max(0.45, E * LIFT + F), 0.9)$$

$$LIFT = CWRT - CHWST_{SP}$$

$$E = \frac{0.9}{(LIFT_{MAX} - LIFT_{MIN})}$$

$$F = E * (0.4 * LIFT_{MAX} - 1.4 * LIFT_{MIN})$$

         a) LIFTmin and LIFTmax shall be calculated as the averages of LIFTminX and LIFTmaxX for all variable speed centrifugal chillers operating in the current stage respectively.

Centrifugal chiller efficiency varies significantly with lift. As lift increases for a given load, centrifugal compressors must run faster to avoid surge. Capacity trimming under such conditions is accomplished using inlet guide vanes or variable geometry diffusers, which reduces chiller efficiency. The above equation resets the centrifugal staging point up when lift

is high to minimize throttling of surge control devices and keep chillers operating near to their optimal efficiency. Engineers should consult with the chiller manufacturer to obtain part load efficiency data and adjust the optimal staging bounds for each application. See the ASHRAE Fundamentals of Design and Control of Central Chilled-Water Plants Self-Directed Learning Course for how E and F can be optimally determined. The E and F values above are the simplified coefficients from this SDL, Appendix A normalized for a plant with any number of chillers.
Upper and lower limits of 0.45 and 0.9 are placed on SPLR to ensure stable plant staging irrespective of the optimal staging point indicated by the lift reset curve. Using a two chiller plant with equally sized machines as the simplest example, bounding SPLR to a minimum of 0.45 ensures that the logic does not stage on the second machine if doing so would cause the chillers to be less than 22.5% loaded (0.45 OPLR divided by 2). Bounding SPLR to a maximum of 0.9 ensures that the logic does not delay staging once the operating chiller is more than 90% loaded (OPLR > 0.9) since doing so could risk losing the load.

b. Set SPLRDN as follows:

In the sections below, the stage down SPLR values appear identical to the stage up values. It is important to remember, per Section 3.13C.8~~3.11C.8~~, that these values are applied against the OPLR values of different plant stages, so they yield different tonnage thresholds.
Note also that the stage down conditions below do not yield a hysteresis band. I.e., if the positive displacement chiller rules were applied to a plant with only two screw chillers sized at 200 tons each, the plant stage up and stage down points would both be 160 tons. This is acceptable because the stages have minimum run times to prevent cycling. Furthermore, plant load for most applications generally trends in one direction for multiple hours before beginning to trend the opposite direction. As such, there is little risk of repeated stage cycling.

1) When a variable speed centrifugal chiller operates in the next lower stage, SPLRDN shall be calculated as the 5 minute rolling average of the following equation sampled at least every 30 seconds:

$$SPLR_{DN} = Min(Max(0.45, E * LIFT + F), 0.9)$$

$$LIFT = CWRT - CHWST_{SP}$$

$$E = \frac{0.9}{(LIFT_{MAX} - LIFT_{MIN})}$$

$$F = E * (0.4 * LIFT_{MAX} - 1.4 * LIFT_{MIN})$$

a) LIFTmin and LIFTmax shall be calculated as the averages of LIFTminX and LIFTmaxX for all variable speed centrifugal chillers operating in the next lower stage respectively.

10. Staging shall be executed per the conditions below subject to the following requirements.

a. Each stage shall have a minimum runtime of 15 minutes.

b. Timers shall reset to zero at the completion of every stage change.

c. Any unavailable stage (see Section 9) shall be skipped during staging events, but staging conditionals in the current stage shall be evaluated as per usual.

d. Chilled water supply and return temperatures used in staging logic shall be those located in common supply and return mains hardwired to plant controllers.

e. Stage up if any of the following is true:

1) Availability Condition: The equipment necessary to operate the current stage are unavailable. The availability condition is not subject to the minimum stage runtime requirement. Or

2) Efficiency Condition: Current stage OPLR > SPLRUP for 15 minutes and current stage OPLR is not decreasing at a rate greater than 2.5% per minute averaged over 5 minutes; or

3) Failsafe Condition:

a) CHW supply temperature is 2°F > setpoint for 15 minutes.

f. Stage down if both of the following are true:

1) Next available lower stage OPLR < SPLRDN for 15 minutes and next lower stage OPLR is not increasing at a rate greater than 2.5% per minute averaged over 5 minutes; and

2) The failsafe stage up condition is not true.

The first stage up condition stages the chillers at the optimum load point, SPLR, to maximize chiller efficiency. The second stage up condition acts as a failsafe bringing on the lag chiller if one or more coils is starved because chilled water differential pressure is below setpoint or chilled water supply temperature is above setpoint for an extended period. The former may occur if chilled water delta-T is degraded from design or one pump is down for maintenance and the pump(s) are unable to drive additional flow through the operating chiller; the latter may occur if the lead chiller has an active fault condition that is not generating a failure alarm. It is also possible that the OPLR calculation could go out of calibration due to a failed flow meter and/or return temperature sensor, thus necessitating fallback on the failsafe conditions. Note that the DP failsafe condition does not apply to series chiller plants since bringing on an additional chiller would only increase pressure drop in a series chiller plant.
At various points in all of the staging sequences, there is a requirement to wait for requests for CHW and CW flow to clear, or 3 minutes to elapse, before moving on to the next step in staging. Where chillers have CHW and CW request network points, consider increasing the delay to 10 minutes to ensure that flow is not cut off too soon. Where chillers do not have these points (e.g., older chillers without network interfaces), the default delay is appropriate.

11. Whenever there is a stage-up command:

a. Command operating chillers to reduce demand to 75% of their current load. Wait until actual demand <80% of current load up to a maximum of 5 minutes before proceeding.

The above section is recommended for applications where a sudden change in load may induce a chiller trip. This was commonly true of older chillers but has often proven unnecessary for modern machines with more robust capacity controls. Leave it if unsure.

b. Start the next CW pump. Wait 30 seconds.

c. Slowly open CHW isolation valve of the chiller being enabled. Determine valve timing in the field as that required to prevent nuisance trips.

Slowly opening the chilled water isolation valve prevents a sudden disruption in flow through the active chiller.

d. Start the next stage chiller after the CHW isolation valve is fully open (as determined by end switch status, or nominal valve timing if end switches are not provided).

e. Release the demand limit.

12. Whenever there is a stage-down command:

a. If staging down from any other stage, shut off the last stage chiller.

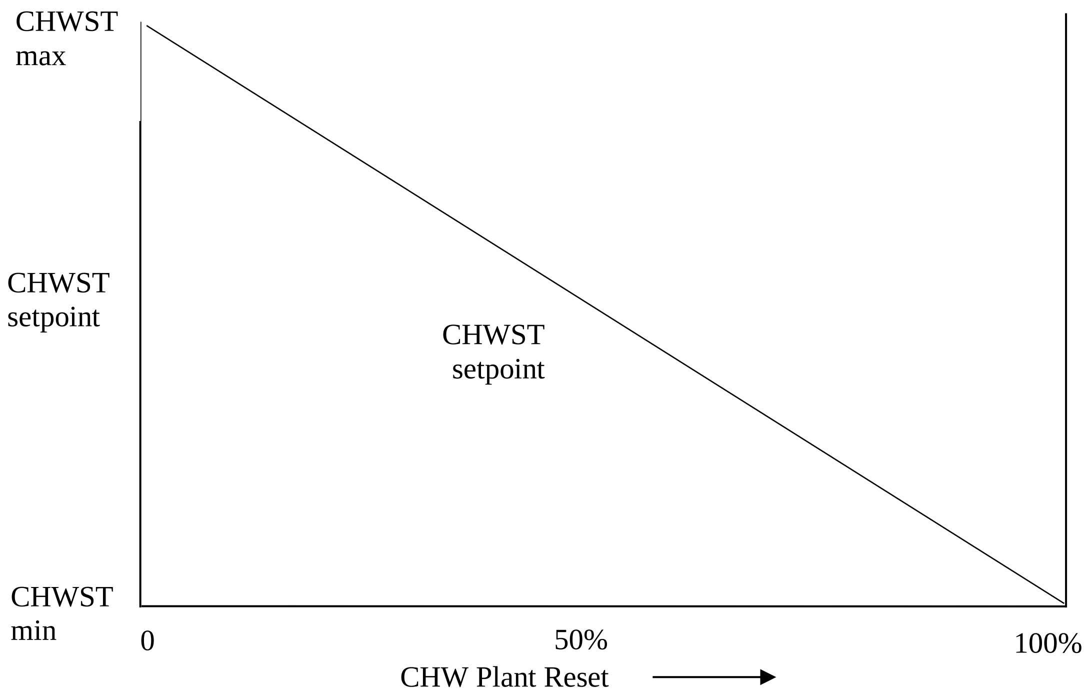
b. When the controller of the chiller being shut off indicates no request for chilled water flow or 3 minutes has elapsed, slowly close the chiller's CHW isolation valve to avoid a sudden change in flow through other operating chillers.

c. When the controller of the chiller being shut off indicates no request for condenser water flow or 3 minutes has elapsed. When the CW isolation valve is fully closed (as determined by nominal valve timing), shut off the last lag CW pump.

D. Chilled Water Plant Reset

1. CHWSTmin in the following logic shall be the lowest CHWSTminX of chillers in the plant.

2. Chilled water supply temperature setpoint CHWSTsp shall be reset based on the current value of the logic variable called "CHW Plant Reset" as shown below and described subsequently.



a. From 0% loop output to 100% loop output, reset CHWST setpoint from CHWSTmax to CHWSTmin.

b. CHW Plant Reset variable shall be reset using Trim & Respond logic with the following parameters:

Variable	Value
Device	Any CHW Pump Distribution Loop
SP0	100%
SPmin	0%
SPmax	100%
Td	15 minutes
T	5 minutes
I	2
R	Cooling CHWST Reset Requests
SPtrim	-2%
SPres	+3%
SPres-max	+7%
Informative note: The number of ignored requests can be adjusted to balance responsiveness to demand (fewer ignores) vs energy efficiency (more ignores). The value that is set should be considered as a function of the total number of downstream zones or systems that can send requests. As a default, set the number of ignored requests to 10% of the total downstream zones or systems, rounded to the nearest integer.	

The reset starts at CHWSTmin because starting at a high temperature often causes the chiller to bring down CHWST too quickly and pass the CHWST setpoint, leading the chiller to cycle *off. Additionally, if the loop reset starts at a CHWST that cannot satisfy the load at startup (e.g., CHWST setpoint = 60°F, but an AHU requires 55°F supply air), there is a resultant delay in satisfying the load as the reset loop winds up before CHWST setpoint resets down.*

c. CHWST Plant Reset loop shall be enabled when the plant is enabled and disabled when the plant is disabled.

d. When a plant stage change is initiated, CHW Plant Reset logic shall be disabled and value fixed at its last value for the longer of 15 minutes and the time it takes for the plant to successfully stage.

Locking out continued reset during a staging event prevents CHW loop instability resulting from staging from driving the plant reset.

E. Primary Chilled Water Pumps

1. Primary CHW pumps shall be lead/lag controlled per Section 3.1P.3.

2. Enable lead primary CHW pump when any chiller CHW isolation valve is commanded open. Disable the lead primary CHW pump when all chiller CHW isolation valves are commanded closed.

3. CHW pumps shall be staged as a function of CHWFR, the ratio of current chilled water flow, FLOWP, to design primary pump flow, PCHWFdesign. and the number of pumps, N-PCHWP, that operate at design conditions. Pumps are assumed to be equally sized.

$$\text{CHWFR} = \frac{FLOW_P}{PCHWF_{design}}$$

Flow is used, as opposed to speed, to keep the chilled water pumps operating near their best efficiency point. Staging at slightly less than design flowrate for operating pumps yields good results for most applications (note that when fewer than design pumps are enabled, pumps will be able to produce greater than design flow since they will be operating further out their curves). If desired, the stage down flow point can be offset slightly below the stage up point to prevent cycling between pump stages in applications with highly variable loads.

a. Start the next lag pump whenever the following is true for 10 minutes:

$$\text{CHWFR} > \frac{Number\ of\ Operating\ Pumps}{N} - 0.03$$

b. Shut off the last lag pump whenever the following is true for 10 minutes:

$$\text{CHWFR} \leq \frac{Number\ of\ Operating\ Pumps - 1}{N} - 0.03$$

F. Condenser Water Pumps

1. Condenser water pumps shall be lead/lag controlled per Section 3.1P.3.

2. Enable lead CW pump when any chiller enabled. Disable the lead CW pump when all chillers are disabled.

3. The number of operating condenser water pumps shall match the number of operating chillers.

4. See Section 3.13C~~3.11C~~ for lag condenser water pump on/off staging timing.

G. Cooling Towers

1. Fan Control

a. Condenser Water Return Temperature (CWRT) Control

1) Tower fan control is in part dictated by plant part load ratio, PLRplant, which is the ratio of current plant required capacity, Qrequired, to plant design capacity:

$$PLR_{plant} = \frac{Q_{required}}{Q_{design}}$$

2) CWRTdes in the subsequent logic shall be the lowest CWRTdesX of all chillers.

This sequence controls condenser water return temperature, as opposed to supply, since CWRT more closely correlates to chiller lift, which drives chiller efficiency and surge conditions.

3) Maximum tower speed shall be limited based on OPLR. Reset the variable PlrTowerMaxSpd linearly from 100% at 50% OPLR down to 70% at 0% OPLR.

Maximum tower speed is limited at low plant part load ratios to prevent tower energy waste when either (1) CHWST is reset low at low PLRs or (2) wet bulb is elevated at low PLRs. Both conditions can cause the CWRT setpoint output from the following equation to be unachievable.

4) CWRT setpoint, CWRTsp, shall be the output of the following equation.

$$CWRTsp = CHWSTsp + LIFTtarget$$

$$LIFTtarget = Max\left(LIFTmin, Min(LIFTmax, A * PLR_{Plant} + B)\right)$$

$$A = 1.1 * (LIFTmax - LIFTmin)$$

$$B = LIFTmax - A$$

a) Where chillers have different LIFTminX values, LIFTmin in the above equation shall reset dynamically to equal the highest LIFTminX of enabled chillers.

b) Where chillers have different LIFTmaxX values, LIFTmax in the above equations shall reset dynamically to equal the lowest LIFTmaxX of enabled chillers.

5) When any condenser water pump is proven on, CWRT shall be maintained at setpoint by a direct acting PID loop. The loop output shall be mapped to the variable CWRTTowerSpd. Map CWRTTowerSpd from minimum tower speed at 0% loop output to 100% speed at 100% loop output.

6) Tower speed command signal shall be the lowest value of CWRTTowerSpd, HpTowerMaxSpd from each chiller head pressure control loop, and PlrTowerMaxSpd. All operating fans shall receive the same speed signal.

7) Disable the tower fans if either

a) Any enabled chiller's HpTowerMaxSpd has equaled tower minimum speed for 5 minutes, or

b) Tower fans have been at minimum speed for 5 minutes and CWRT drops below setpoint minus 1°F.

8) Enable the tower fans if

a) They have been off for at least 1 minute, and

b) CWRT rises above setpoint by 1°F, and

c) All enabled chillers' HpTowerMaxSpd are greater than tower minimum speed.

9) When all condenser water pumps are commanded off, disable the PID loop and stop all tower fans.

10) Upon plant startup, hold CWRTsp at 10°F degrees less than CWRTdes for 10 minutes before ramping the setpoint to the calculated value above over 10 minutes.

This logic gives plant load an opportunity to stabilize prior to releasing control to the reset logic.

H. Emergency Chiller Off

1. Chillers shall be locked off (start/stop points overridden to off at highest protocol priority) upon closing of emergency chiller off switch located at chiller room entry. After 5 minutes, shut off all pumps and towers.

I. Performance Monitoring

1. All calculations listed below shall be performed at least once every 30 seconds. Time averaged values shall be recorded at least once every 5 minutes. The averaging period shall equal the trending interval.

2. Total plant power. Calculate total plant power as the sum of chiller power, pump power, and cooling tower fan power. For motors with VFDs, power shall be actual power as read through the VFD network interface. For fixed speed motors (e.g., CW pumps without VFDs), power shall be assumed to be fixed at BHP (from equipment schedule) * 0.746 / 0.93 (approximate motor efficiency).

3. Total Plant Load. Calculate plant load using flowrate through the primary circuit, FLOWP; chilled water return temperature upstream of the first HX or chiller, CHWRT; and primary loop chilled water supply temperature leaving the plant, CHWST.

$$Q_{Plant} = \frac{FLOW_P\ (CHWRT - CHWST)}{24}[tons]$$

4. Equipment Load. Calculate load for each operating chiller using flowrate through the equipment, FLOWD; chilled water return temperature entering the equipment,

CHWRTD; and chilled water supply temperature leaving the equipment, CHWSTD. Inputs to the below equation shall be determined per the following rules.

$$Q_D = \frac{FLOW_D\,(CHWRT_D - CHWST_D)}{24}\,[tons]$$

1) FLOWD shall be assumed proportional to design flow through all operating chillers in the circuit.

2) CHWRTD shall be the return temperature entering the equipment as read by a hardwired sensor if available. If a hardwired sensor is unavailable for a chiller, temperature shall be read from a sensor internal to the chiller through its network interface.

3) CHWSTD shall be a hardwired temperature sensor at the outlet of the equipment if available. If a hardwired sensor is unavailable for a chiller, temperature shall be read from a sensor internal to the chiller through its network interface. Only if neither of the above is available shall a common supply temperature sensor (i.e., one measuring the output from multiple chillers), be used.

5. Calculate plant efficiency as total plant power divided by plant load. Calculate efficiency for each chiller as chiller power divided by chiller load.

6. Summary Data. For each chiller, and for the total plant, statistics shall be calculated for runtime, kWh, average actual efficiency (kW/ton), peak demand (tons), average demand (tons) and average load (ton-hours), all on an instantaneous, year-to-date, and previous-year basis.

Below is an example summary of the performance monitoring parameters. Summary table should be edited based on plant configuration, available statistics and desired units of measurement.

	Instantaneous				Year-to-date						Previous Year					
	Lifetime Runtime (hours)	Electrical Demand (kW)	CHW Demand (ton)	Efficiency (kW/ton)	Runtime (hours)	Avg Daily Energy Use (kWh)	Avg Daily CHW Load (ton-hr)	Avg CHW Demand (ton)	Peak CHW Demand (ton)	Avg Efficiency (kW/ton)	Runtime (hours)	Avg Daily Energy Use (kWh)	Avg Daily CHW Load (ton-hr)	Avg CHW Demand (ton)	Peak CHW Demand (ton)	Avg Efficiency (kW/ton)
CH-1																
CH-2																
Total Plant																

J. Alarms

1. Maintenance interval alarm when pump has operated for more than 3000 hours as indicated by the Staging Runtime: Level 4. Reset the Staging Runtime interval counter when alarm is acknowledged.

2. Maintenance interval alarm when chiller has operated for more than 1000 hours as indicated by the Staging Runtime: Level 4. Reset the Staging Runtime interval counter when alarm is acknowledged.

3. Chiller alarm: level 2

4. Emergency off switch: Level 1

5. Tower level

a. If tower water level sensor indicates water level below T-level-low-alarm, generate a Level 2 alarm.

b. If tower water level sensor indicates water level above T-level-high-alarm, generate a Level 3 alarm.

6. Pump or tower 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 equipment has been commanded on for 15 seconds.

b. Commanded off, status on: Level 4. Do not evaluate the alarm until the equipment has been commanded off for 60 seconds.

7. Sensor Failure:

a. Sensor shall be deemed outside of its widest possible operating range if any of the following are true:

1) Feedback less than 2 mA from any 4 to 20 mA transducer; or

2) Temperature reading less than 0°F from any temperature sensor.

b. Any sensor that goes outside of its widest possible operating range.

1) If the sensor is used for monitoring only: Level 3.

2) If the sensor is used for control: Level 2.

K. Automatic Fault Detection and Diagnostics

The Automatic Fault Detection and Diagnostics (AFDD) routines for chilled water plants continually assess plant 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 of the plant, as determined by the positions of the isolation valves and statuses of pumps. 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 as alarms along with a series of possible causes.
These equations assume that the plant is equipped with isolation valves, as well as a pump status monitoring. If any of these components are not present, the associated tests, and variables should be omitted from the programming.
Note that these faults rely on reasonably accurate measurement of water temperature. Extra precision sensors installed in thermowells with thermal paste are strongly recommended for best accuracy.

1. AFDD conditions are evaluated continuously for the plant.

2. The Operating State (OS) of the plant shall be defined by the commanded positions of the valves and status feedback from the pumps in accordance with the following table.

The Operating State is distinct from and should not be confused with the chilled water plant stage.

OS#1 – OS#3 represent normal operating states during which a fault may nevertheless occur if so determined by the fault condition tests below.

Operating State	Chiller CHW Isolation Valves	Chiller CW Isolation Valves	CHW Pump Status	CW Pump Status
#1: Disabled	All Closed/Off	All Closed/Off	All Off	All Off
#2: One Chiller Enabled	One Open/On, All Others Closed/Off	One Modulating, All Others Closed/Off	Any On	Any On
#3: More than one Chiller Enabled	More than one Open/On	More than one modulating	Any On	Any On

3. The following points must be available to the AFDD routines for the chilled water plant:

   a. FLOWP = Primary chilled water flow

   b. SpeedCT = Cooling tower speed command; 0% ≤ SpeedCT ≤ 100%

   c. StatusCWP = Lead condenser water pump status

   d. StatusPCHWP = Lead primary chilled water pump status

   e. CHWST = Common chilled water supply temperature leaving the chillers

   f. CHWSTSP = Chilled water supply temperature setpoint

   g. CHWRT = Common chilled water return temperature entering the chillers

   h. CWST = Condenser water supply temperature

   i. CWSTdes = Lowest condenser water supply temperature at chiller selection conditions for chillers; CWSTdes shall be the lowest CWSTdesX of all chillers

   j. CHWSTCH-x = CH-x chilled water supply temperature (each chiller)

   k. CHWRTCH-x = CH-x chilled water return temperature (each chiller)

   l. CWSTCH-x = CH-x condenser water supply temperature (each chiller)

   m. CWRTCH-x = CH-x condenser water return temperature (each chiller)

   n. RefrigEvapTempCH-x = CH-x refrigerant evaporating temperature (each chiller)

   o. RefrigCondTempCH-x = CH-x refrigerant condensing temperature (each chiller)

   p. CHW-ISOCH-x = CH-x chilled water isolation valve commanded position (each chiller)

q. PGAUGE = Chilled water system gauge pressure

4. The following values must be continuously calculated by the AFDD routines:

a. 5-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) CHWSTAVG = rolling average of the common chilled water supply temperature

2) CHWRTAVG = rolling average of the common chilled water return temperature

3) CWSTAVG = rolling average of the common condenser water supply temperature

4) CWRTAVG = rolling average of the common condenser water return temperature

5) CWSTCH-x, AVG = rolling average of CH-x condenser water supply temperature (each chiller)

6) CWRTCH-x, AVG = rolling average of CH-x condenser water return temperature (each chiller)

7) CHWSTCH-x, AVG = rolling average of CH-x chilled water supply temperature (each chiller)

8) CHWRTCH-x, AVG = rolling average of CH-x chilled water return temperature (each chiller)

9) PGAUGE, AVG = rolling average of chilled water system gauge pressure

10) FLOWP, AVG = rolling average of primary chilled water flow

11) RefrigCondTempCH-x, AVG = rolling average of CH-x refrigerant condensing temperature (each chiller)

12) RefrigEvapTempCH-x, AVG = rolling average of CH-x refrigerant evaporating temperature (each chiller)

b. CHW-FlowCH-X (each chiller)

1) For plants with parallel chillers and headered primary chilled water pumps: 1 if CHW-ISOCH-x > 0, 0 if CHW-ISOCH-X = 0

c. ΔOS = number of changes in Operating State during the previous 60 minutes (moving window)

d. ΔStage = number of chilled water plant stage changes during the previous 60 minutes (moving window)

e. StartsCH-x = number of CH-x starts in the last 60 mins (each chiller)

5. The following internal variables shall be defined. All parameters are adjustable by the operator, with initial values as given below:

The default values have been intentionally biased towards minimizing false alarms 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 pump heat and sensor error can be measured in the field or derived from trend logs and hardware submittals. Likewise, the switch delays can be refined by observing the time required to achieve quasi steady state operation in trend data.

Other factors can be tuned by observing false positives and false negatives (i.e., unreported faults). If transient conditions or noise cause false alarms, increase the alarm delay. Likewise, failure to report real faults can be addressed by adjusting the temperature, pressure or flow thresholds.

Variable Name	Description	Default Value
ƐCHWT	Temperature error threshold for chilled water temperature sensors	2°F
ƐCWT	Temperature error threshold for condenser water temperature sensors	2°F
ƐFM	Flow error threshold for flow meter	20 gpm
Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.		
CHW-ETPreChargePress	Chilled water system expansion tank pre-charge pressure	See mechanical schedule (psig)
ApproachCOND	Condenser approach threshold	4°F
ApproachEVAP	Evaporator approach threshold	3°F
CHStartsMAX	Maximum number of chiller starts during the previous 60 minutes (moving window)	2
ΔOSMAX	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	2
ΔStageMAX	Maximum number of chilled water plant stage changes during the previous 60 minutes (moving window)	2
StageDelay	Time in minutes to suspend Fault Condition evaluation after a change in stage	30
AlarmDelay	Time in minutes that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

TestModeDelay ensures that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in Section 3.13K.11~~3.11K.11~~.

6. The following are 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 Operating State of the chilled water plant.

FC#2	Equation	FLOWP, AVG > ƐFM and StatusPCHWP = Off	Applies to OS #1
	Description	Primary chilled water flow is too high with the chilled water pumps off	
	Possible Diagnosis	Flow meter error	
FC#6	Equation	CHWSTAVG - ƐCHWT ≥ CHWSTSP	Applies to OS #2 – #3
	Description	Chilled water supply temperature is too high	
	Possible Diagnosis	Mechanical problem with chillers Primary flow is higher than the design evaporator flow of the operating chillers	
FC#7	Equation	CHW-PGAUGE, AVG < 0.9 * CHW-ETPreChargePress	Applies to OS #1 – #3
	Description	Chilled water system gauge pressure is too low	
	Possible Diagnosis	Possible chilled water system leak	
FC#8	Equation	ApproachCOND ≥ RefrigCondTempCH-x, AVG - CWRTCH-x, AVG	Applies to OS #2, #3
	Description	Condenser approach is too high	
	Possible Diagnosis	Possible condenser fouling or blocked condenser tubes Low condenser water temperature Low condenser water flow	
FC#9	Equation	ApproachEVAP ≥ CHWSTCH-x, AVG - RefrigEvapTempCH-x, AVG	Applies to OS #2, #3
	Description	Evaporator approach is too high	
	Possible Diagnosis	Possible evaporator fouling or blocked evaporator tubes Low refrigeration charge Contaminated refrigeration charge	

FC#10	Equation	$\lvert (\sum(\text{CHW-FlowCH-X} * \text{CHWSTCH-X}) / \sum\text{CHW-FlowCH-X}) - \text{CHWSTAVG} \rvert > \varepsilon\text{CHWT}$ and $\sum\text{CHW-FlowCH-X} = 1$	Applies to OS #2
	Description	Deviation between the active chiller chilled water supply temperature and the common chilled water supply temperature is too high.	
	Possible Diagnosis	A chilled water supply temperature sensor is out of calibration	
FC#11	Equation	$\lvert (\sum(\text{CHW-FlowCH-X} * \text{CHWRTCH-X}) / \sum\text{CHW-FlowCH-X}) - \text{CHWRTAVG} \rvert > \varepsilon\text{CHWT}$ and $\sum\text{CHW-FlowCH-X} = 1$	Applies to OS #2
	Description	Deviation between the active chiller chilled water return temperature and the common chilled water return temperature is too high.	
	Possible Diagnosis	A chilled water return temperature sensor is out of calibration	
FC#12	Equation	$\lvert (\sum(\text{CW-FlowCH-X} * \text{CWSTCH-X}) / \sum\text{CW-FlowCH-X}) - \text{CWSTAVG} \rvert > \varepsilon\text{CWT}$ and $\sum\text{CW-FlowCH-X} = 1$	Applies to OS #2
	Description	Deviation between the active chiller condenser water supply temperature and the common condenser water supply temperature is too high.	
	Possible Diagnosis	A condenser water supply temperature sensor is out of calibration	
FC#13	Equation	$\lvert (\sum(\text{CW-FlowCH-X} * \text{CWRTCH-X}) / \sum\text{CW-FlowCH-X}) - \text{CWRTAVG} \rvert > \varepsilon\text{CWT}$ and $\sum\text{CW-FlowCH-X} = 1$	Applies to OS #2
	Description	Deviation between the active chiller condenser water return temperature and the common condenser water return temperature is too high.	
	Possible Diagnosis	A condenser water return temperature sensor is out of calibration	

FC#14	Equation	CWSTAVG - ƐCWT ≥ DesCWSTdes and SpeedCT ≥ 99% - ƐVFDSPD	Applies to OS #2, #3
	Description	Condenser water supply temperature is too high with cooling tower(s) at full speed.	
	Possible Diagnosis	Problem with cooling tower VFD Mechanical problem with cooling tower(s) Cooling tower(s) undersized	
FC#18	Equation	ΔOS > ΔOSMAX	Applies to OS #1 – #3
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#19	Equation	ΔStartsCH-x > ΔCHStartMAX	Applies to OS #2, #3
	Description	Too many chiller starts	
	Possible Diagnosis	Chiller is cycling due to load loads. Chiller is oversized and/or has insufficient turndown capability. Chiller stage-up threshold may be set too low.	
FC#20	Equation	ΔStage > ΔStageMAX	Applies to OS #1 – #3
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

7. For each chiller, the operator shall be able to suppress the alarm for any Fault Condition.

8. Evaluation of Fault Conditions shall be suspended under the following conditions:

   a. When no pumps are operating.

   b. For a period of StageDelay minutes following a change in plant stage.

9. Fault Conditions that are not applicable to the current Operating State shall not be evaluated.

10. A Fault Condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

11. Test Mode shall temporarily set StageDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and to ensure normal fault detection occurs after testing is complete.

12. 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 3.13K.6~~3.11K.6~~.

~~3.12~~3.14 HOT WATER PLANT

A. See Section 1.2B for Design Setpoints. See Section 1.3D TAB Setpoints.

B. Plant Enable/Disable

1. The Boiler plant shall include an enabling schedule that allows operators to lock out the plant during off-hours, e.g. to allow off-hour operation of HVAC systems except the Boiler plant. The default schedule shall be 24/7 (adjustable).

2. Enable the plant in the lowest stage when the plant has been disabled for at least 15 minutes and:

   a. Number of Heating Hot-Water Plant Requests > I (I = Ignores shall default to 0, adjustable), and

   b. OAT<HW-LOT, and

   c. The Boiler plant enable schedule is active.

3. Disable the plant when it has been enabled for at least 15 minutes and:

   a. Number of Heating Hot-Water Plant Requests ≤ I for 3 minutes, or

   b. OAT>HW-LOT + 1°F, or

   c. The Boiler plant enable schedule is inactive.

4. When the plant is enabled:

   a. Open the HW isolation valve of the lead boiler.

   b. Stage on lead primary HW pump per Section D.2.

   c. Once the lead pump has proven on, enable the lead boiler.

5. When the plant is disabled:

   a. Shut off the enabled boiler(s).

   b. For each enabled boiler with headered primary HW pumps, close the HW isolation valve(s) after 3 minutes and disable the operating HW pump(s) per Section D.2.

C. Boiler Staging

1. Boiler stages shall be defined as follows:

Boiler Stage	Enabled Boilers
0	None
1	Any one boiler
2	Any two boilers
3	Any three boilers
4	Any four boilers

5	Any five boilers

2. Interchangeable boilers indicated with "or" in the table above shall be lead/lag controlled per Section 3.1P.3.

3. If a boiler is in alarm, the boiler shall be disabled and after 3 minutes, its HW isolation valve shall be closed.

4. Boilers are staged in part based on required capacity, Qrequired. Qrequired is calculated based on hot water return temperature (HWRT), active hot water supply temperature setpoint (HWSTSP), and measured flow through the primary circuit flow meter (FLOWP), as shown in the equation below. Qrequired used in logic shall be a 5-minute rolling average of instantaneous values sampled at a minimum of every 30 seconds.

$$Q_{required} = 0.49 * FLOW_P(HWST_{SP} - HWRT)\ \left[\frac{\text{kbtu}}{\text{h}}\right]$$

5. Boilers are staged in part based on the minimum output of a given stage, B-STAGEMIN. Calculate B-STAGEMIN as the largest B-FiringMinX of all boilers in the stage times design capacity of all boilers in the stage. Note that B-FiringMin and capacity may vary for each boiler, e.g. for unequally sized boilers with different minimum turndowns.

B-STAGEMIN defines the minimum load boilers can operate at in a given stage without any of them cycling. If minimum capacities of all boilers (e.g. B-FiringMinX for a given boiler times its design capacity) were summed directly instead of correcting for the highest B-FiringMinX among all enabled boilers in a stage, boilers with a higher B-FiringMinX would still cycle.

6. Staging events require that a boiler stage be available. A stage shall be deemed unavailable if the stage cannot be achieved because a boiler required to operate in the stage is faulted per Section 3.1P.5.b.1)c) or a hot water pump dedicated to that boiler is faulted per Section 3.1P.5.b.1)a); otherwise the stage shall be deemed available.

7. Staging shall be executed per the conditions below subject to the following requirements:

    a. Each stage shall have a minimum runtime of 10 minutes.

    b. Timers shall reset to zero at the completion of every stage change.

    c. Any unavailable stage (see Section 6) shall be skipped during staging events, but staging conditionals in the current stage shall be evaluated as per usual.

    d. Hot water supply and return temperatures used in staging logic shall be those located in common supply and return mains hardwired to plant controllers.

    e. Stage up if any of the following is true:

        1) Availability Condition: The equipment necessary to operate the current stage are unavailable. The availability condition is not subject to the minimum stage runtime requirement. Or

        2) Efficiency Condition: The following is true:

            a) Qrequired exceeds 200% of B-STAGEMIN of the next available stage for 10 minutes

3) Failsafe Condition: HW supply temperature is 10°F < setpoint for 15 minutes.

f. Stage down if all of the following are true:

1) Qrequired falls below 110% of B-STAGEMIN of the current stage for 5 minutes; or

2) The failsafe stage up condition is not true.

3) Qrequired is less than 80% of the design capacity, QbX, of the boilers in the next available lower stage for 5 minutes.

Condensing boilers are generally more efficient at low load since the ratio of heat transfer surface area to thermal mass flowrate is maximized, increasing flue gas condensation. Staging on boilers at low load therefore maximizes plant efficiency. However, the energy penalty from cycling losses due to staging on lag equipment prematurely, only to have them cycle off, may more than offset the part load efficiency gains.
Staging is delayed until the current stage output exceeds the minimum output of the next stage by 100% to avoid boiler short cycling following stage up, which dramatically decreases plant efficiency. The default stage up threshold for the efficiency condition is set to ensure sufficient load to prevent boilers from short cycling and to create an adequate hysteresis to prevent unnecessary boiler staging, but the optimal threshold will depend in part on the boiler turndown. The designer should consider adjusting this threshold based on plant attributes: higher for boilers with more turndown, lower for boilers with less turndown.
Staging is also dependent on minimum flow requirements. If minimum flowrate of the next stage is not satisfied under current operating conditions, then supply water will need to be bypassed to the return following a stage up, which raises return temperature. Elevated return temperature decreases condensation and boiler efficiency as a result, so staging up is inhibited under these conditions. For the same reason, a stage down is triggered if the minimum flow bypass valve is opened with more than one boiler in operation.

8. Whenever a lag boiler is enabled:

a. Open the next lag boiler's isolation valve.

9. Whenever a lag boiler is disabled:

a. Disable the last stage boiler.

b. After 3 minutes, close the disabled boiler's isolation valve.

D. Hot Water Supply Temperature Reset

1. Plant hot water supply temperature setpoint shall be reset using Trim & Respond logic with the following parameters:

Variable	Value
Device	Any HW Pump Distribution Loop
SP0	SPmax
SPmin	120ºF
SPmax	HWSTmax
Td	10 minutes
T	5 minutes

I	10
R	Hot-Water Reset Requests
SPtrim	-2ºF
SPres	+3ºF
SPres-max	+7ºF
Informative note: The number of ignored requests can be adjusted to balance responsiveness to demand (fewer ignores) vs energy efficiency (more ignores). The value that is set should be considered as a function of the total number of downstream zones or systems that can send requests. As a default, set the number of ignored requests to 10% of the total downstream zones or systems, rounded to the nearest integer.	

2. Include mapping of Hot-Water Reset Requests from existing hot water coils associated with AHU-8 Music controlled within ALC.

E. Primary Hot Water Pumps

1. Primary hot water pumps shall be lead/lag controlled per Section 3.1P.3.

2. Enable lead primary hot water pump when any boiler isolation valve is commanded open. Disable the lead hot water pump when all boiler isolation valves are commanded closed.

3. HW pumps shall be staged as a function of the ratio of current hot water flow, FLOWP, to design flow, PHWFdesign, and the number of pumps, N-PHWP, that operate at design conditions. Pumps are assumed to be equally sized.

$$\text{HWFR} = \frac{FLOW_P}{PHWF_{design}}$$

Flow is used, as opposed to speed, to keep the hot water pumps operating near their best efficiency point. Staging at slightly less than design flowrate for operating pumps yields good results for most applications (note that when fewer than design pumps are enabled, pumps will be able to produce greater than design flow since they will be operating further out their pump curves). If desired, the stage down flow point can be offset slightly below the stage up point to prevent cycling between pump stages in applications with highly variable loads.

a. Start the next lag pump whenever the following is true for 10 minutes:

$$\text{HWFR} > \frac{Number\ of\ Operating\ Pumps}{N} - .03$$

b. Shut off the last lag pump whenever the following is true for 10 minutes:

$$\text{HWFR} < \frac{Number\ of\ Operating\ Pumps - 1}{N} - .03$$

Note: VFDs are not required on HW pumps by Title 24 and only required on large HW pumps used in fossil fuel boiler plants by Standard 90.1. These provisions exist because pump energy is converted to heat through friction losses at the pump and in pipe, coils, valves; reductions in HW pump energy are made up by the boilers. Energy costs are reduced because fossil fuel costs less per BTU than electricity, but savings are minor. However, constant speed pumps are not recommended on pumps with design head greater than about 50 feet due to increased noise from control valves, reduced controllability, and increased valve and pump wear.

4. When any pump is proven on, pump speed shall be controlled by a reverse acting PID loop maintaining flow at setpoint of 369 gpm. All pumps receive the same speed signal.

PID loop output shall be mapped from minimum pump speed at 0% to maximum pump speed at 100%.

F. Performance Monitoring

1. All calculations listed below shall be performed at least once every 30 seconds. Time averaged values shall be recorded at least once every 5 minutes. The averaging period shall equal the trending interval.

2. Total Plant Gas Use. Convert measured gas usage to Btu/h by a user adjustable conversion factor (default value = 1000 Btu/h per ft3 of gas; actual value set by user from utility bill).

3. Total Plant Load. Calculate plant load using flowrate through the primary circuit, FLOWP; primary hot water return temperature, PHWRT; and primary hot water supply temperature, PHWST.

$$Q_{actual} = 0.49 * FLOW_P(PHWST - PHWRT)\ [\frac{\text{kbtu}}{\text{h}}]$$

4. Boiler Load. Calculate load for each operating boiler (as applicable) using flowrate through the boiler, FLOWB; hot water return temperature entering the boiler, HWRTB; and hot water supply temperature leaving the boiler, HWSTB. Inputs to the below equation shall be determined per the following rules.

$$Q_D = 0.49 * FLOW_B(HWST_B - HWRT_B)[\frac{kbtu}{h}]$$

   a. FLOWB shall be assumed proportional to design flow through all operating boilers in the circuit.

   b. HWRTB shall be the return temperature entering the boiler as read by a hardwired BAS sensor if available. If a hardwired sensor is unavailable, temperature shall be read from a sensor internal to the boiler through its network interface. If multiple boilers are enabled, the temperature shall be the average return temperature read from the operating boilers through the network interface.

   c. HWSTB shall be a hardwired temperature sensor at the outlet of the equipment if available. If a hardwired sensor is unavailable, temperature shall be read from a sensor internal to the boiler through its network interface. Only if neither of the above is available shall a common supply temperature sensor (i.e. one measuring the output from multiple boilers), be used.

5. Calculate plant thermal efficiency as equal to measured plant load divided by measured gas consumption.

6. Summary Data

   a. For each boiler, statistics shall be calculated for runtime, cumulative load (btu), average demand (btu/h), and peak demand (btu/h). All statistics shall be presented on an instantaneous, year-to-date, and previous year basis.

   b. For the total plant, statistics shall be calculated for runtime, energy use (btu), cumulative load (btu), average demand (btu/h), peak demand (btu/h), and actual efficiency (btu/btu). All statistics shall be presented on an instantaneous, year-to-date, and previous year basis.

Below is an example summary of the performance monitoring parameters. Summary table should be edited based on plant configuration, available statistics and desired units of measurement.

	Instantaneous				Year-to-date						Previous Year					
	Lifetime Runtime (hours)	Gas Demand (kBtu/h)	HW Demand (kBtu/h)	Efficiency	Runtime (hours)	Gas Use (MMBtu)	HW Load (MMBtu)	Avg HW Demand (kBtu/h)	Peak HW Demand (kBtu/h)	Avg Efficiency	Runtime (hours)	Gas Use (MMBtu)	HW Load (MMBtu)	Avg HW Demand (kBtu/h)	Peak HW Demand (kBtu/h)	A Effic
B-1																
B-2																
Total Plant																

G. Alarms

1. Maintenance interval alarm when pump has operated for more than 3000 hours as indicated by the Staging Runtime: Level 4. Reset the Staging Runtime interval counter when alarm is acknowledged.

2. Maintenance interval alarm when boiler has operated for more than 2000 hours as indicated by the Staging Runtime: Level 4. Reset the Staging Runtime interval counter when alarm is acknowledged.

3. Boiler alarm: Level 2

4. Low boiler leaving hot water temperature (more than 15°F below setpoint) for more than 15 minutes when boiler has been enabled for longer than 15 minutes: Level 3

5. 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 equipment has been commanded on for 15 seconds.

   b. Commanded off, status on: Level 4. Do not evaluate alarm until the equipment has been commanded off for 60 seconds.

6. Sensor Failure:

   a. Sensor shall be deemed outside of its widest possible operating range if any of the following are true:

      1) Feedback less than 2 mA from any 4 to 20 mA transducer; or

      2) Temperature reading less than 0°F from any temperature sensor.

   b. Any sensor that goes outside of its widest possible operating range.

      1) If the sensor is used for monitoring only: Level 3.

      2) If the sensor is used for control: Level 2.

H. Automatic Fault Detection and Diagnostics

The Automatic Fault Detection and Diagnostics (AFDD) routines for hot water plants continually assess plant 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 of the plant, as determined by the positions of the isolation valves and statuses of pumps. 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 as alarms along with a series of possible causes.
These equations assume that the plant is equipped with isolation valves, as well as a pump status monitoring. If any of these components are not present, the associated tests, and variables should be omitted from the programming.
Note that these faults rely on reasonably accurate measurement of water temperature. Extra precision sensors installed in thermowells with thermal paste are recommended for best accuracy.

1. AFDD conditions are evaluated continuously for the plant.

2. The Operating State (OS) of the plant shall be defined by the commanded positions of the valves and status feedback from the pumps in accordance with the following table. For hybrid plants, determine the Operating State for each primary loop.

The Operating State is distinct from and should not be confused with the hot water plant stage. OS#1 – OS#3 represent normal operation during which a fault may nevertheless occur, if so determined by the fault condition tests below.

Operating State	Boiler Isolation Valve	PHW Pump Status
#1: Disabled	All Closed/Off	All Off
#2: One boiler enabled	One Open/On, All Others Closed/Off	Any On
#3: More than one boiler enabled	Any Open/On	Any On

3. The following points must be available to the AFDD routines for the hot water plant:

   a. FLOWP = Primary hot water flow (each primary loop, where applicable)

   b. HW-MinFlowSP = Effective minimum hot water flow setpoint (equal to MinFlowRatio multiplied by the sum of HW-MinFlowX of operating boilers)

   c. SpeedHWP = Hot water pump speed command; 0% ≤ SpeedHWP ≤ 100%

   d. StatusPHWP = Lead primary hot water pump status (each primary loop, where applicable)

   e. HWST = Common hot water supply temperature

   f. HWSTSP = Hot water supply temperature setpoint

   g. HWRT = Average boiler entering water temperature (each loop)

   h. HWISOB-x = B-x hot water isolation valve commanded position (each boiler)

i. PGAUGE = Hot water system gauge pressure

4. The following values must be continuously calculated by the AFDD routines:

   a. 5-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) HWSTAVG = rolling average of the common hot water supply temperature (each primary loop, where applicable)

      2) HWRTAVG = rolling average of the average boiler entering water return temperature.

      3) PGAUGE, AVG = rolling average of hot water system gauge pressure

      4) FLOWP, AVG = rolling average of primary hot water flow (each loop, where applicable)

      5) HWSTB-x = rolling average of B-x hot water supply temperature (each boiler)

      6) HWRTB-x = rolling average of B-x hot water return temperature (each boiler)

   b. HWFlowB-X (each boiler)

      1) For plants with headered primary hot water pumps: 1 if HWISOB-X = open, 0 if HWISOB-X = closed

   c. ΔOS = number of changes in Operating State during the previous 60 minutes (moving window)

   d. ΔStage = number of hot water plant stage changes during the previous 60 minutes (moving window)

   e. StartsB-x = number of B-x starts in the last 60 mins (each boiler)

5. The following internal variables shall be defined. All parameters are adjustable by the operator, with initial values as given below:

The default values have been intentionally biased towards minimizing false alarms 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 pump heat and sensor error can be measured in the field or derived from trend logs and hardware submittals. Likewise, the switch delays can be refined by observing the time required to achieve quasi steady state operation in trend data.
Other factors can be tuned by observing false positives and false negatives (i.e., unreported faults). If transient conditions or noise cause false alarms, increase the alarm delay. Likewise, failure to report real faults can be addressed by adjusting the temperature, pressure or flow thresholds.

Variable Name	Description	Default Value
ƐHWT	Temperature error threshold for hot water temperature sensors	5°F
ƐFM	Flow error threshold for flow meter	20 gpm
ƐVFDSPD	VFD speed error threshold	5%
ETPreChargePress	Hot water system expansion tank pre-charge pressure	See mechanical schedule (psig)
CondTemp	Boiler condensing temperature threshold	135°F
BStartsMAX	Maximum number of boiler starts during the previous 60 minutes (moving window)	2
ΔOSMAX	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	2
ΔStageMAX	Maximum number of hot water plant stage changes during the previous 60 minutes (moving window)	2
StageDelay	Time in minutes to suspend Fault Condition evaluation after a change in stage	30
AlarmDelay	Time in minutes that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

TestModeDelay ensures that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in Section 3.14H.11~~3.12H.11~~.

6. The following are 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 Operating State of the hot water plant.

FC#2	Equation	FLOWP, AVG > ƐFM and StatusPHWP = Off	Applies to OS #1
	Description	Primary hot water flow is too high with the hot water pumps off	
	Possible Diagnosis	Flow meter error	
FC#7	Equation	PGAUGE, AVG < 0.9 * ETPreChargePress	Applies to OS #1 – #3
	Description	Hot water system gauge pressure is too low	
	Possible Diagnosis	Possible hot water system leak	

FC#8	Equation	HWRTAVG - ƐHWT > CondTemp	Applies to OS #2, #3
	Description	Hot water return temperature is too high for condensing to occur.	
	Possible Diagnosis	Hot water supply temperature setpoint is too high. Hot water load is too low. High bypass flow is raising the entering water temperature. Hot water coils are not designed for condensing at current loads.	
FC#10	Equation	$\lvert (\sum(\text{HW-FlowB-X} * \text{HWSTB-X}) / \sum \text{HW-FlowB-X}) - \text{HWSTAVG} \rvert > \text{ƐHWT}$	Applies to OS #2
	Description	Deviation between the active boiler hot water supply temperature and the common hot water supply temperature is too high.	
	Possible Diagnosis	A hot water supply temperature sensor is out of calibration	
FC#11	Equation	$\lvert (\sum(\text{HW-FlowB-X} * \text{HWRTB-X}) / \sum \text{HW-FlowB-X}) - \text{HWRTAVG} \rvert > \text{ƐHWT}$	Applies to OS #2
	Description	Deviation between the active boiler hot water return temperature and the common boiler entering water temperature is too high.	
	Possible Diagnosis	A hot water return temperature sensor is out of calibration	
FC#12	Equation	ΔOS > ΔOSMAX	Applies to OS #1 – #3
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#13	Equation	ΔStartsB-x > ΔBStartMAX	Applies to OS #2, #3
	Description	Too many boiler starts	
	Possible Diagnosis	Boiler is cycling due to load loads Boiler is oversized and/or has insufficient turndown. Boiler stage-up threshold may be set too low.	
FC#14	Equation	ΔStage > ΔStageMAX	Applies to OS #1 – #3
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

7. For each boiler, the operator shall be able to suppress the alarm for any Fault Condition.

8. Evaluation of Fault Conditions shall be suspended under the following conditions:

a. When no pumps are operating.

b. When all equipment associated with a fault condition in maintenance mode.

c. For a period of StageDelay minutes following a change in plant stage.

9. Fault Conditions that are not applicable to the current Operating State shall not be evaluated.

10. A Fault Condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

11. Test Mode shall temporarily set StageDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and to ensure normal fault detection occurs after testing is complete.

12. 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 3.14H.63.12H.6.

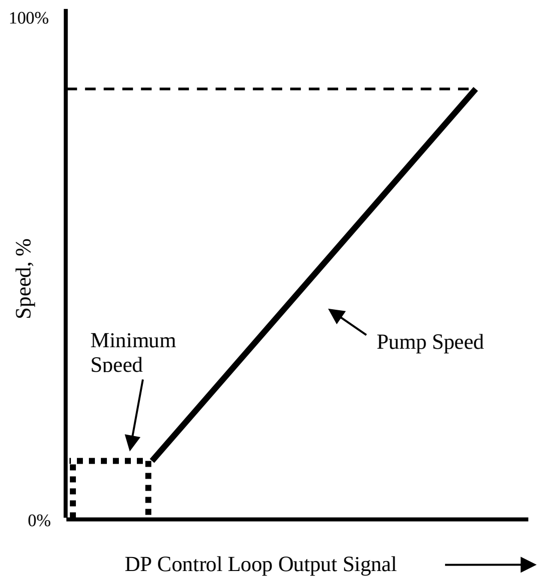
3.133.15 BUILDING CHILLED WATER PUMP

A. Enable/Disable

1. Enable the pumping system when it has been disabled for at least 15 minutes and the number of Chiller Plant Requests > I (I = Ignores shall default to 0, adjustable)

2. Disable the pumping system when it has been enabled for at least 5 minutes and the Number of Chiller Plant Requests ≤ I for 3 minutes

B. When the pumping system is enabled, the DP control loop is enabled. The loop shall be a reverse-acting loop maintaining the differential pressure (DP) sensor at setpoint. The output of the loop shall range from 0 to 100%, mapped to pump speed as shown in the figure and described below. The pressure from the plant may satisfy the building DP requirements, in which case the pumps will stay off. They will start only when the plant pressure is not adequate.



1. Pump speed will be controlled by a PID loop maintaining the differential pressure signal at a setpoint determined by the reset scheme described below. All pumps receive the same speed signal.

2. When the DP loop output is equal to the pump minimum speed setpoint (see Section 250000 Building Automation Systems), the pump shall start. Its speed shall be equal to the DP loop output. The pump shall stop when the pump has run for a minimum speed for 5 minutes. It shall stay off for a minimum of 5 minutes before restarting.

C. Differential pressure setpoint shall be reset using Trim & Respond logic (see Guideline 36) with the following parameters. See Paragraph 1.2E for DP-MAX.

Variable	Value
Device	Any CHW Pump
SP_0	DP-MAX
SP_{min}	1 psi
SP_{max}	DP-MAX
T_d	15 minutes
T	5 minutes
I	2
R	Chilled Water Reset Requests
SP_{trim}	-2%
SP_{res}	+3%
$SP_{res-max}$	+7%

D. Alarms

1. Generate a Level 4 maintenance alarm when pump has operated for more than 3000 hours. Reset interval counter when alarm is acknowledged.

2. 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.

3. Low differential pressure, below setpoint by 2 psi for 10 minutes with system enabled for 15 minutes.

3.143.16 BUILDING HOT WATER PUMP

A. Building HW system enable/disable

1. Enable the building HW system when they have been disabled for at least 10 minutes and:

   a. Number of building Heating Hot-Water Plant Requests > I (I = Ignores shall default to 0, adjustable), and

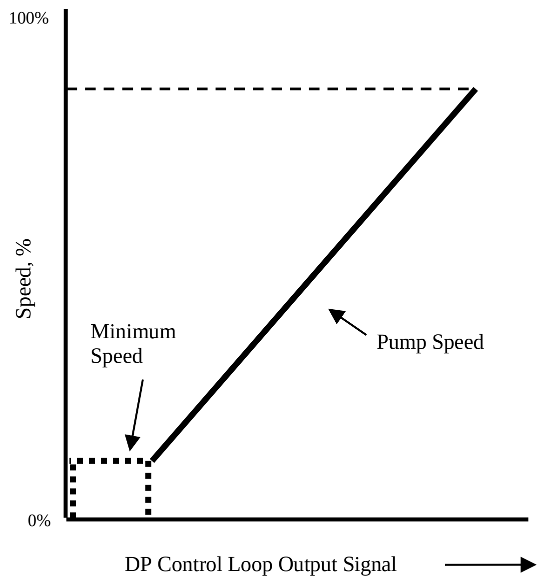
   b. OAT<HW-LOT (default to 70F, adjustable)

2. Disable the building HW system when they have been enabled for at least 3 minutes and:

   a. Number of Heating Hot-Water Plant Requests ≤ I for 3 minutes, or

   b. OAT>HW-LOT + 1°F

B. When the pumping system is enabled, the DP control loop is enabled. The loop shall be a reverse-acting loop maintaining the differential pressure (DP) sensor at setpoint. The output of the loop shall range from 0 to 100%, mapped to pump speed as shown in the figure and described below. The pressure from the plant may satisfy the building DP requirements, in which case the pumps will stay off. They will start only when the plant pressure is not adequate.



1. Pump speed will be controlled by a PID loop maintaining the differential pressure signal at a setpoint determined by the reset scheme described below. All pumps receive the same speed signal.

2. When the DP loop output is equal to the pump minimum speed setpoint (see Section 250000 Building Automation Systems), the pump shall start. Its speed shall be equal to the DP loop output. The pump shall stop when the pump has run for a minimum speed for 5 minutes. It shall stay off for a minimum of 5 minutes before restarting.

3. Differential pressure setpoint shall be DP-MAX (see Paragraph 1.2F).

C. Alarms

1. Generate a Level 4 maintenance alarm when pump has operated for more than 3000 hours. Reset interval counter when alarm is acknowledged.

2. 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.

3. Low differential pressure, below setpoint by 2 psi for 10 minutes with system enabled for 15 minutes.

~~3.15~~3.17 DOMESTIC HOT WATER HEAT EXCHANGER

A. Domestic hot water pump shall be enabled when any AHU serving the area that includes the toilet rooms served by the pump is in occupied mode.

B. The domestic hot water valve shall be modulated to maintain a DHWS temperature of 110°F (adj.)

C. Alarms

1. Generate a Level 4 maintenance alarm when pump has operated for more than 3000 hours. Reset interval counter when alarm is acknowledged.

2. 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.

3. Hot water supply temperature less than 107°F when recirculation pump is proven on: Level 2.

D. System Requests

1. Heating Hot-Water Plant Requests

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.

3.163.18 PNEUMATIC SYSTEM CONTROL

A. Enable pneumatic air valve if either the following are true:

1. It is a weekday between 4:32am and 11:11pm

2. It is a weekend between 5:55am and 11:11pm

B. Alarms

1. Low pressure, below 15 psi for 10 minutes with system enabled for 15 minutes.

3.173.19 METERING SUMMARIES

A. Provide metering summary separately for the following metering systems:

1. Electrical power

2. Potable water

3. Natural gas

B. Include all physical meters

C. Include all submeters including those mapped from equipment (e.g. VFDs, water treatment system, etc.)

D. Include "virtual meters" where loads are based on subtraction from or addition of other loads including:

1. Electricity

a. All HVAC equipment. Sum of all HVAC equipment meters (including those in VFDs)

E. Provide the following calculations for use in energy dashboards.

1. Electrical

a. For each meter, real and virtual:

1) Daily, monthly and annual total usage (kWh)

2) Daily, monthly and annual peak usage (kW)

b. For each sub-use (lighting, HVAC, IT, plug, etc):

1) Daily, monthly and annual energy use intensity (EUI).

c. For total building electrical power: Daily, monthly and annual average energy use intensity (EUI). EUI shall be calculated as follows:

$$EUI\ \left[\frac{kBtu}{ft^2}\right] = \frac{Energy\ Usage\ [kWh] * 3.412\ \left[\frac{kBtu}{kWh}\right]}{Building\ Area\ [ft^2]}$$

2. Water

a. For each meter, real and virtual:

1) Daily, monthly and annual total usage (gallons)

3. Natural Gas

a. For each meter, real and virtual:

1) Daily, monthly and annual total usage (Therms)

a) Convert cubic feet of gas to Therms (100 cubic feet = 1 Therm)

b. For total building heating: Daily, monthly and annual average heating energy use intensity (EUI). EUI shall be calculated as follows:

$$EUI\ \left[\frac{kBtu}{ft^2}\right] = \frac{Gas\ Usage\ [Therms] * 99.976\ \left[\frac{kBtu}{Therms}\right]}{Building\ Area\ [ft^2]}$$

4. Total Building Energy Usage

a. Calculate daily, monthly and annual building energy usage as the sum of electricity and natural gas usage in kBtu.

$$\begin{aligned} &Total\ Building\ Energy\ Usage\ [kBtu] \\ &\quad = Energy\ Usage\ [kWh] * 3.4121416 \left[\frac{kBtu}{kWh}\right] \\ &\quad + Gas\ Usage\ [Therms] * 99.976 \left[\frac{kBtu}{Therms}\right] \end{aligned}$$

b. Calculate daily, monthly and annual average building energy use intensity (EUI).

$$EUI \left[\frac{kBtu}{ft^2}\right] = \frac{Total\ Building\ Energy\ Usage\ [kBtu]}{Building\ Area\ [ft^2]}$$

3.183.20 EQUIPMENT NOT CONTROLLED OR MONITORED BY BAS SYSTEM

A. Chiller Room Exhaust Fan

1. Fan is enabled by emergency wall switch, wind-up timer switch or refrigerant monitor.

3.193.21 CAMPUS LIGHTS

A. Enable Parking lot C lights from 1 hour before sunset to 1 hour after sunrise, based on astronomical clock schedule.

B. Enable Police Lights from 1 hour before sunset to 1 hour after sunrise, based on astronomical clock schedule.

C. Latitude and longitude for Pittsburg is 38° 1’ 40” N and 121° 53’ 6” W.

3.203.22 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. Failure or disconnection of a sensor as indicated by signal widely out of range: Level 2.

C. Panel or LAN failure: Level 2

D. 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).

E. Emergency Generator Alarm: Level 2

F. Sewage Lift Station

END OF SECTION 259000

MEETING AGENDA

PROJECT NAME/NO.: **L-1240 Student Services and Equipment Plant BAS Upgrade**

PRE-BID MEETING, Mandatory

Date: March 5, 2024
Time: 2:00 PM
Location: Los Medanos College
Student Services, Main Entrance
2700 E Leland Rd., Pittsburg, CA 94565

I. INTRODUCTIONS AND SIGN IN

- Stefan Johnson, Construction Manager

a. Introduction of Project Team Members in Attendance:

Carlos Montoya, Ed.D.	Vice President of Business & Administrative Services
Jarrod Holcombe	Buildings and Grounds (B&G) Manager, LMC
Mike Bransford	Buildings and Grounds (B&G) Lead Technician, LMC
Hwakong Cheng	Taylor Engineers
Laura Van Rietema	Taylor Engineers
Stefan Johnson	Construction Manager – Wilsey Ham

b. Sign-in sheet will be circulated and collected by Stefan Johnson; It will be posted to the District's bids webpage.

II. WELCOME AND INTRODUCTORY REMARKS

a. L-1240 Student Services and Equipment Plant BAS Upgrade Project to convert the Student Services and Main Utility plant from the current Andover controls to ALC controls.
b. An on-site job walk/ field presentation follows this meeting.
c. Review bid documents and submit RFIs by Wednesday July 31, so responses can be provided in a timely manner.

III. INTRODUCTION & ADDITIONAL REMARKS

- **Public Safety**
  Most buildings will be occupied during the fall semester. Electrical/IDF rooms and the Main Plant are not occupied.

- **Dust Control**
  Dust control is critical around networking equipment.

IV. BRIEF PROJECT DESCRIPTION

- Laura with Taylor Engineers to go over project in detail:
  Provided brief overview of the scope of work within the various rooms:

V. PROJECT WORK RESTRICTIONS (see SECTION 01140 WORK RESTRICTIONS)

a. **Project is to take place after hours during the fall semester and normal hours over the winter break– goal is to issue NTP the week of September 23.**
b. Contractor may not use the bathroom facilities for the duration of the project and must provide porta-potties and cleaning stations. Location of bathroom facilities to be coordinated with District and approved prior to placement.
c. Staging of material & equipment by contractor to be secured and locked. Staging area or contractor's storage container to be coordinated with District in advance.
d. Interruptions to utility service shall be kept to a minimum and shall be as such times and durations as approved ahead of time by the District.
e. Bidders are encouraged to carefully review Division 0 & 1, specifically Section 00800, referencing Work Restrictions.
f. Additional work restriction information may be added by addendum.

VI. BID PHASE COMMUNICATIONS & CORRESPONDENCE:

a. All project-related questions/RFIs must be submitted in writing (email is preferable) to:
   Ben Cayabyab, Contracts Manager
   Contra Costa Community College District
   500 Court St., Martinez, CA 94553
   Email: bcayabyab@4cd.edu
b. **Deadline for receipt of RFIs is Tuesday July 31, 2024, prior to 5:00 PM**.

VII. ADDENDA UPDATE:

a. Addendum #1 to be issued to add AC-3 on ground floor, Addendum #2 to address any RFIs.

VIII. BID PHASE SCHEDULE MILESTONES

- **Last day for RFI:** **July 31, 2024, prior to 5:00 p.m.**
- Last Addendum Issued: August 7, 2024
- **Bid Opening:** **August 14, 2024, 2:00 p.m.**
- Award of Contract: September 12, 2024
- Notice to Proceed September 23, 2024 (approximate)

IX. BID OPENING:

a. **Bids must be received at the Contra Costa Community College District Office at 500 Court St, Martinez, CA by Wednesday August 14, 2024, prior to 2:00 PM.**
b. All bids will be time stamped at the reception counter in the building lobby.
c. Any bid received after the bid opening time will be rejected.

X. BID PACKAGE:

a. Review your bid package carefully before submitting it. Be sure to include all required documentation, or bid will be rejected.
   - Completed Bid Proposal Form (Section 00300), to include bidder's name and signature.
   - An active CLSB license number, as required in the bid documents.
   - Acknowledgement of any addenda issued.
   - Listing of actively-licensed subcontractors, including license numbers.
   - Bid Bond – 10% of bid Amount.
   - Non-Collusion Affidavit, fully executed.
   - Add/deduct for alternates must be indicated properly.
     1. Alternate 1 is split into labor and materials.
   - Other documents as required by the Contract Documents.

b. Bid bond must accompany bid; company checks can be accepted, but no cash will be accepted.

c. Contact **Ben Cayabyab** if you have additional questions.

XI. CONTRACT DURATION DISCUSSION

a. Review carefully Section 00600, Construction Agreement
b. 158 Calendar Days to Substantial Completion (SC)
c. 60 Calendar Days between SC and Final Completion
d. Award of contract (NOA) scheduled to be issued the day after approval by the District Board.
e. Successful Contractor will be required to submit bonds and insurance expeditiously.

XII. SUBSTITUTION REQUESTS MUST COMPLY WITH CONTRACT DOCUMENTS

a. Reference SECTION 00600, General Conditions, Article 1.4
b. Sample Substitution Request Form is included in bid package.

XIII. SITE JOB WALK/ FIELD PRESENTATION

- Stefan to give overall review of project scope.
- Review project site, electrical connections.

XIV. MISCELLANEOUS