SECTION 230000

HEATING VENTILATING & AIR CONDITIONING

PART 1 - GENERAL

1.1 DESCRIPTION

A. Project Overview:
   1. The Applied Arts Building is an 55,000 ft^2 2-story classroom-office building on the campus at Contra Costa College in San Pablo, CA built in 1979.
   2. The HVAC system consists of (7) multiple zone VAV chilled and hot water air handling units which were installed in 1979 and (4) single zone constant volume DX packaged units which were installed in 2018. Zones are served by a mix of pneumatic and DDC induction boxes and VAV terminal units, some with upstream heating and cooling coils.
   3. Cooling is provided by the existing primary-secondary chilled water plant with a single air-cooled chiller and two dedicated variable speed secondary pumps – one serving the AHUs and the other serving the 2nd floor cooling coils.
   4. Heating is provided by the existing primary-only hot water plant with a single condensing boiler and two dedicated constant speed hot water pumps – one serving the AHUs and the other serving the 1st and 2nd floor heating coils.

B. HVAC Work Scope Summary: This project will include the replacement of the following:
   1. Replace induction boxes and existing VAV boxes with new VAV terminal units
   2. Replace (7) existing VAV air handling units
   3. Demolish existing air compressor.
   4. Replace controls (by a separate Division 25 contractor subcontracted to Division 23).

C. Structural Work Scope Summary
   1. Rooftop AHU units (AHU-1-2, AHU-1-3, AHU-2-1, AHU-2-2, AHU-2-3, AHU-2-4)
      a. Preserve all the existing concrete curbs
      b. Install new AHU units and anchor into the existing concrete curbs.
   2. AHU-1-1
      a. Add new concrete curb and anchor new AHU-1-1 unit on the new curb.

1.2 SCOPE OF WORK

A. Design/Build Approach
   1. The work for this project will be built using a “design/build” approach. The design/build contractor (“Contractor”) and Taylor Engineering (“Engineer”) shall share design responsibilities as indicated herein.
   2. The table below indicates engineering responsibility assignments for the Contractor and the Engineer.

Item	Contractor	Engineer
Engineer-of-Record	P	–
Mechanical system program requirements	R	P
Equipment sizing	P	R
Equipment selection	P	R
Air distribution systems	P	R
Vibration and noise control	P	R
Control systems	N	P
Construction details (see note below)	P	R

Item	Contractor	Engineer
Seismic restraints	P	R
Completion of permit drawings	P	R
Title 24 Compliance Documentation	P	R
Project construction management	P	N
Construction and all field work	P	R
Construction quality control	P	N
Start-up & TAB	P	R
Commissioning	S	P

3. Explanatory notes:
   a. Primary (P) responsibility shall mean making all decisions and taking engineer/contractor-of-record responsibility for the item.
   b. Secondary (S) responsibility shall mean taking an active role assisting the party with primary responsibility for the item.
   c. Review (R) shall mean that the party shall review and comment on the work done by the party with primary responsibility for the item.
   d. No (N) responsibility shall mean the party will have no role with regard to the item.
   e. "Construction details" includes wall, roof, and floor penetration details, piping, ductwork, and equipment details and supports, vibration isolation details, housekeeping pad layouts and dimensioning, etc.
4. The Contractor shall be the engineer-of-record as well as the contractor of record and responsible for all required work.

B. Work Included: Design, furnish, and install all equipment and systems specified herein and as required for complete and fully functional systems. This is a turn-key project. There are no other contractors working on this project. All work that is required shall be performed by the Contractor, including but not limited to the following.
1. Division of the State Architect (DSA) submission and approval
2. Demolition
3. Any Abatement work
4. Rigging
5. New equipment
6. HVAC Controls. See 250000 Building Automation Systems.
7. Seismic restraints
8. New and/or expanding existing concrete curbs and bases as required
9. Roofing and wall penetration repair and sealing
10. Temporarily removing then repairing doors, wall, or roof sections for access as required
11. Temporary cooling for 24/7 areas served by auxiliary cooling systems if downtime occurs. See Paragraph 1.12B.
12. Temporary cooling and/or heating equipment for spaces served by retrofit systems. See limitations in Paragraph 1.12B.
13. Electrical power wiring, disconnects, etc. for new equipment
14. Test and balance
15. Operator training
16. Onsite superintendent. See RFQP.
17. Overtime labor if required

C. Work Excluded:

1. Cost of repairing existing equipment that is specified to be reused, if required.
2. Asbestos reports, provided as bid documents in an informative appendix.
3. Asbestos abatement monitoring, District will hire the monitoring company if needed.
4. Controls. Controls will be installed by a separate controls contractor at the same time as the AHUs are being replaced. No controls work is specified under this Division. However, the Division 23 contractor shall subcontract the Division 25 contractor so that work can be done simultaneously and the project can be delivered in a turn-key manner to the District. See Scope of Work coordination in 250000 Building Automation Systems.
5. Permit fees (paid by District)

1.3 CONTRACTOR PROPOSALS

A. See RFPQ for proposal submission requirements and schedule.

B. Contractor shall visit site prior to bid. Ascertain and check all conditions and take all measurements that may affect the work. Drawings provided with this specification are to be used at Contractor's risk; drawings are schematic and may or may not be drawn accurately. No allowance shall subsequently be made for any additional expenses or claims due to the failure or neglect under this section to make such examination, including examination of restricted working conditions or such other difficulties that can be visually observed during site visit.

C. By submitting a price, Contractor guarantees that the proposal is complete and turn-key, except where specific exceptions are provided herein or clearly noted in the Contractor's proposal.

D. Prior to bid, Contractor shall coordinate acceptable downtime periods with District Representatives. Prices shall include overtime as required for this project.

E. This specification is intended to

1. Specify system performance/design criteria. The HVAC Contractor's proposal shall not deviate from these Design Criteria without written approval. Questions regarding the appropriateness or correctness of requirements shall be directed to the District's Representative in writing prior to bid. See RFQP. Any changes in design or performance criteria will be disseminated to all bidders.
2. Establish the desired level of quality, including suggested design options that the Engineer feels will meet the performance requirements and design intent. HVAC Contractors' proposals may be based on the suggested approaches or on any other design of similar quality. If there is a question as to the appropriateness of any alternative system ideas, the HVAC Contractor shall review the proposed design and submit questions to the District per the RFQP.

F. See RFQP for proposal requirements.

1.4 REFERENCE STANDARDS

A. Requirements of Regulatory Agencies:

1. Nothing in Drawings or Specifications shall be construed to permit Work not conforming to applicable laws, ordinances, rules, regulations.
2. When drawings or Specifications exceed requirements of applicable laws, ordinances, rules and regulations, comply with documents establishing the more stringent requirement.
3. Applicable codes include the current version of those listed below, in addition to others specified in individual sections:
   a. CBC – California Building Code with DSA Amendments
   b. CMC – California Mechanical Code
   c. City of San Pablo Codes, Ordinances, and Code Amendments
   d. The State of California Codes

e. OSHA 1926 Fall Protection Standards Requirements

4. If any of above requirements is in conflict with one another, or with Specifications' requirements, the most stringent requirement shall govern. Where codes are silent on an issue, NFPA Standards shall apply.

B. Published specifications, standards, tests or recommended method of trade, industry or governmental organizations as listed below apply to all work in this Section:

1. AABC - Associated Air Balance Council
2. ACI – American Concrete Institute
3. ADC - Air Diffuser Balance Council
4. AMCA - Air Moving and Conditioning Association
5. ANSI - American National Standards Institute
6. ARI - Air Conditioning and Refrigeration Institute
7. ASHRAE - American Society of Heating, Refrigeration and Air Conditioning Engineers
8. ASME - American Society of Mechanical Engineers
9. ASTM - American Society for Testing and Materials
10. ETL - Intertek Semko (Formerly Electrical Testing Laboratories)
11. IEEE - Institute of Electrical and Electronic Engineers
12. NEMA - National Electrical Manufacturer's Association
13. NFPA - National Fire Protection Association
14. SMACNA - Sheet Metal and Air Conditioning Contractors National Association
15. UL - Underwriters' Laboratories

C. Industry standards and manufacturers' recommendations, diagrams or requirements shall be strictly adhered to for installation of materials and equipment.

1.5 QUALITY ASSURANCE

A. All equipment and accessories to be the product of a manufacturer regularly engaged in its manufacture.

B. All items of a given type shall be the products of same manufacturer.

C. Fire, smoke, and fire/smoke dampers shall be UL listed and constructed in accordance with UL Standard 555 Fire Dampers and UL Standard 555S.

D. Demonstrate operation of smoke dampers to authorities having jurisdiction and District's representative as part of life safety testing.

E. Supply all equipment and accessories new and free from defects.

F. Supply all equipment and accessories in compliance with the applicable standards listed in Paragraph 1.4 with all applicable national, state and local codes.

1.6 DEFINITIONS

A. “Provide": to supply, install and connect up complete and ready safe and regular operation of particular work referred to unless specifically noted.

B. "Install": to erect, mount and connect complete with related accessories.

C. "Supply": to purchase, procure, acquire and deliver complete with related accessories.

D. "Work": labor, materials, equipment, apparatus, controls, accessories, and other items required for proper and complete installation.

E. "Piping": pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation, and related items.

F. "Wiring": raceway, fittings, wire, boxes and related items.

G. "Concealed": embedded in masonry or other construction, installed in furred spaces, within double partitions or hung ceilings, in trenches, in crawl spaces, or in enclosures.

H. "Exposed": not installed underground or "concealed" as defined above.

I. "Indicated," "shown" or "noted": as indicated, shown or noted on drawings or specifications.

J. "Similar" or "equal": of base bid manufacture, equal in materials, weight, size, design, and efficiency of specified product, conforming to PART 2 Materials.

K. "Reviewed," "satisfactory," or "directed": as reviewed, satisfactory, or directed by or to Architect.

L. "Motor Controllers": manual or magnetic starters (with or without switches), individual pushbuttons or hand-off-automatic (HOA) switches controlling the operation of motors.

M. "Control or Actuating Devices": automatic sensing and switching devices such as thermostats, pressure, float, electro-pneumatic switches and electrodes controlling operation of equipment.

1.7 JOB CONDITIONS

A. Examine site related work and surfaces before starting work of any Section.
   1. Contractors shall be responsible for any conditions that can be visually observed at jobsite and in unconcealed, accessible areas.
   2. Contractor shall not be responsible for any conditions in concealed areas that could not be reasonably anticipated at time of bid. Any additional work caused by these conditions shall be by change order.

B. Roofing
   1. Roof is under warranty.

C. Parking and special traffic requirements
   1. See Appendix B: Special Conditions of Exhibit I – Agreement for Mechanical and Controls Design-Build Project for rigging requirements. Contact District for additional information and constraints.
   2. Obtain all City permits and clearances required for hoisting and rigging equipment.

1.8 REVIEW OF CONSTRUCTION

A. Work may be reviewed at any time by District or District’s representative.

B. Advise District or District’s representative that work is ready for review at following times
   1. When all requirements of Contract have been completed

C. Maintain a set of Specifications and Drawings including all change orders on the job for use by District's representatives.

1.9 DESIGN DOCUMENTS

A. An employee of the HVAC Contractor shall serve as Engineer-of-Record. (A third party consulting engineer is acceptable only if consultant has significant design/build experience; a record of working with the HVAC Contractor on past projects of this size and complexity; and is not the Engineer who prepared the criteria documents.)

B. All design documents shall be prepared under the supervision of the Engineer-of-Record.

C. Design Drawings
   1. Drawings are to be created in AutoCAD format, version 2010 or later.
   2. Areas Covered by Drawings:
      a. Entire roof level
      b. Mechanical rooms

c. Cooling tower well (new AHU-1-1 location)
d. First floor
e. Second floor

3. Drawings shall include:
   a. Schedules of all equipment, both new and existing.
   b. Floor plans for all covered areas, including only the following:
      1) All new and existing equipment
      2) All new and existing thermostats
   c. Zone plans for the first and second floors
   d. For roof level and AHU-1-1 only:
      1) All new and existing ducts
         a) Tag all ducts with duct sizes
      2) All new and existing piping
         a) Tag all piping with sizes and service.
4. Where required per preceding criteria, existing systems and equipment shall be shown with dashed lines.
5. Except where otherwise noted, tracing and redrawing existing first and second floor ductwork is NOT required per base bid scope. See Alternate 4 in 1.16A.4.

1.10 SUBMITTALS

A. Schedule: Allow 8 working days for approval, unless Engineer agrees to accelerated schedule. See RFQP.
B. Submit drawings, product data, samples and certificates of compliance required as hereinafter specified in this Section.
C. Submission Procedure:
   1. Initial submittal:
      a. Each submittal shall have a unique serial number such as “SUBMITTAL 230000-01”.
      b. Submittals may be submitted non-concurrently if required by the schedule.
      c. Submit one electronic copy of product data in word-searchable format such as Adobe pdf via email. Include electronic tabs/bookmarks for each drawing/equipment section. Provide one paper copy to the District.
      d. Submittal will be reviewed and comments returned to Contractor
   2. Resubmission:
      a. Each resubmittal shall have the original unique serial number plus unique revision number such as “SUBMITTAL 230000-01 REVISION 1”.
      b. Make any corrections or change in submittals as required
      c. Resubmit for review in both paper and electronic format described above until no exceptions are taken.
      d. The cost of Taylor Engineering’s review of submittals after first resubmittal will be borne by Contractor at Taylor Engineering standard billing rates
   3. Final approval: Once submission is accepted, Contactor shall provide an electronic copy and print one bound set of submittals for the District. Taylor Engineering does not require or desire paper copies.
D. Contents of Submittals
   1. Design Drawings

a. Each drawing in a single file in format described above

2. HVAC Equipment Submittals
   a. Manufacturer's name and model number
   b. All information required to completely describe materials and equipment and to indicate compliance with drawings and specifications, including, but not limited to:
      1) A schedule, for all items of the same type shall be supplied. The schedule shall include the manufacturer, the model, size, specific information that makes that item unique, the service of the item, the system served by the item.
      2) Physical Data, as applicable:
         a) Dimensions
         b) Weight
         c) Finishes and colors
      3) Performance Data, as applicable:
         a) Rated capacities
         b) Performance curves
         c) Operating temperature and pressure
      4) Electrical and plumbing requirements
      5) Flow and wiring diagrams as applicable
      6) Description of system operation
   c. All other pertinent information requested in individual paragraphs herein
3. Test, Adjust, and Balance (TAB) Submittal
   a. All test and report forms that will be submitted for the final TAB report
   b. A written description of the balance procedures
   c. Submit at least 30 days prior to any TAB work.

E. Operating Instructions & Maintenance Manuals
   1. Before requesting acceptance of work, submit in word-searchable format such as Adobe pdf via email for review by Engineer. File shall include bookmarks for each piece of equipment. Paper copies will not be accepted.
   2. After review and making corrections noted, furnish one printed and bound set for the District. Assemble with separate tabs for each piece of equipment in heavy three-ring binder. Provide one electronic copy of final Operating Instructions & Maintenance manuals in word-searchable format such as Adobe pdf via email. Include electronic tabs/bookmarks for each equipment section.
   3. O&M manual shall include all submittal data submitted herein above, as installed. The intent of this section is that a single document contains all relevant information about each piece of equipment.
   4. In addition to the submittal data, the O&M manual shall also include the following information:
      a. Manufacturer's name, model number, service manual, spare-parts list, and descriptive literature for all components
      b. Installation instructions
      c. Maintenance instructions
      d. Wiring diagrams
      e. Listing of possible breakdown and repairs
      f. Instruction for starting, operation and programming

g. Detailed and simplified one line, color coded flow and wiring diagram
h. Name, address and phone number of contractors equipment suppliers and service agencies
i. Guarantee period, including start and end period
j. Start up test readings, dated and signed by testing technician
k. Test & Balance reports

F. Record Drawings
1. Update design/shop AutoCAD drawings to "as-built" conditions:
a. Fully incorporate all revisions made by all crafts in course of work.
b. Include all field changes, adjustments, variances, substitutions and deletions, including all Change Orders
c. Include equipment schedules.
d. Exact location, type, and function of concealed valves, dampers, controllers, piping, air vents and piping drains
e. Exact size, elevations, and horizontal location of piping and ducts
f. Revise equipment schedules to reflect all substitutions
g. Base Scope: Complete drawings of all new HVAC systems, as well as points of connection to existing systems.
h. Alternate 4 (see 1.16A.4): Complete drawings of all HVAC systems, both new and existing.
2. Submit in electronic format per Submittals above for approval.
3. Once approved:
a. Provide one set of original CAD files including all referenced background drawings as well as Adobe pdf files of each drawing on portable media (e.g. flash drive).
b. Load complete PDF files onto the control system front end computer. (Viewing software by others.)
c. Provide one full size set of drawings on bond paper and one electronic copy to the District.

1.11 COMPLETION REQUIREMENTS

A. 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.
B. O&M Manual; see Paragraph 1.10E.
C. Record Drawings; See Paragraph 1.10F.
D. Test and Balance reports; see Paragraph 3.14
E. Inspection and permit: Provide one copy of inspection certificates signed and approved by the local code authorities.
F. Commissioning documentation and forms; see Paragraph 3.15
G. Training; see Paragraph 3.15G
H. Warranty: Provide written guarantee and warranty documents for all equipment and systems, including the start and end date for each.

1.12 SCHEDULE OF WORK

A. Design and construction work to be approved by the District prior to start.
1. Expected start date (award of contract): See RFQP.
2. Desired end date: See RFQP.

B. Schedule of Work Constraints
   1. The building will remain operational during construction. Changes to systems that affect these areas must be minimal in impact and time out-of-service as limited herein to prevent disruption of College operations (normal business hours, 7 am to 5 pm, and during scheduled classes). See RFQP Section II.C for schedules; coordinate all work with the District.
   2. Schedule test, balance, and acceptance testing of mechanical systems
      a. This phase must occur after completion of mechanical systems, including all control calibration and adjustment, and requires substantial completion of the building. Testing, Adjusting and Balancing work shall occur to prevent disruption to College operations (see 1.12B.1). Acceptance testing of mechanical systems may occur during normal hours.
   3. Elevator Access
      a. Access to and use of elevator shall be provided on a priority basis outside of College operations when work is being performed. Use of the elevator at other times will be subject to the District's sole approval.
   4. No system shutdown shall be permitted without the expressed written approval from the District's Representative. The Contractor shall submit requests for each shutdown at least two weeks in advance. The request shall state what system is to be shutdown, what areas will be affected, how long the period will be, and what contingency plan, including temporary heating and cooling, is provided if the work cannot be completed within the specified time.
   5. Limitations
      a. The central air handling systems shall be operational during College operations, except they may be shut off for occasional periods not exceeding 15 minutes. It is anticipated that air handling systems will be replaced on multiple weekends with demolition work started late Friday and new systems brought online late Sunday. If this weekend replacement cannot be achieved, temporary heating/cooling systems must be designed, controlled, maintained, provided and installed by contractor. Quantity of air handling units replaced during a single weekend period to be determined by Contractor as required to meet these requirements.
      b. The chiller plant may be shut down as follows:
         1) During College operations:
            a) For periods not exceeding 1 hour when the outdoor air temperature is >= 60°F; or
            b) Continuously when the outdoor air temperature is < 60°F
         2) Anytime outside of College operations.
      c. The boiler plant may be shut down as follows:
         1) During College operations:
            a) For periods not exceeding 2 hours when it is after 10 AM and outdoor air temperature is <=70°F; or
            b) Continuously when the outdoor air temperature is > 70°F
         2) Anytime outside of College operations.
            a) Exclusion: within 4-hours of scheduled occupancy
      d. Systems serving auxiliary 24/7 cooling loads shall not be down at any time. If downtime is unavoidable, coordinate with building engineering staff for temporary cooling needs and access. Costs for temporary cooling shall be included in this project's cost.
      e. Temporary cooling shall be provided for spaces served by retrofit systems as required to maintain space temperature between 66°F and 78°F when such systems are inoperative during occupied hours for periods extending beyond those previously coordinated with

and approved by the District. Temporary heating is subject to electrical capacity of existing infrastructure.

f. Domestic water systems shall be maintained fully functional during College operations.

C. Include any charges, including overtime wages, required to perform work within scheduling criteria specified above.

1.13 GUARANTEE

A. The HVAC Contractor shall guarantee the following:
   1. All new materials, new equipment, apparatus and workmanship shall be free of defective materials and faulty workmanship.
   2. All equipment and material will produce the results specified.
   3. All systems have been fully tested, adjusted, balanced, and commissioned.

B. The HVAC Contractor shall furnish written guarantee to replace all defective work, materials, and services furnished under this Section, at no additional cost to the District, for the warranty period

C. The warranty period shall be one (1) year from date of filing of Notice of Completion or beneficial system usage, whichever comes first.

D. The District reserves the right to make temporary repairs as necessary to keep equipment in operating condition without voiding the guarantees or relieving responsibility during the guarantee period.

E. The warranty shall not include:
   1. Standard maintenance items
   2. Repairs or replacement of equipment damaged as a result of misuse, abuse, or lack of proper maintenance.
   3. Existing equipment and materials not provided by this contract.

1.14 DESIGN CRITERIA

A. Design Temperatures

Design Condition	**Heating**	**Cooling**
Outside air drybulb	29°F	84°F
Coincident outside air wetbulb	–	64°F
Interior zones	70°F	75°F
Exterior zones	70°F	75°F
Maximum design supply air (at outlet)	95°F	65°F
Minimum design supply air (at outlet)	–	57°F
Existing design hot/chilled water supply	170°F	44°F
Design hot/chilled water temperature difference	40°F	23°F*
* Temperature difference shall be that which results from an 8 row, 10 fpi coil		

B. Design Relative Humidity
   1. No active control.

C. Sound and Vibration Control: Maximum noise levels shall be as indicated below. The HVAC Contractor shall retain an acoustical consultant to approve the system design as meeting the specified NC requirements. The acoustical engineer's calculations shall be submitted to the Engineer for review and comment prior to the end of the construction documents phase. Vibration in walls and floors shall not be perceivable to the touch in any occupied space.

Area	Maximum NC
Private offices	30
Open offices/Classrooms	40
General conference rooms	30
Storage	55
Corridor	40
Toilet rooms	40
Reception/lobby	40
Equipment rooms	55

1. Provide all necessary sound attenuation as part of replacement AHUs such that no external sound attenuators or sound boots are required.

D. Miscellaneous Design Constraints
   1. Louvers: Size and position to be determined by HVAC Contractor
   2. Ceiling clearance: Maintain 5.5" clearance above the finished ceiling height for all ducts and pipes, including flanges, seams, and insulation, to allow space for recessed light fixtures below ducts.
   3. Location of ceiling mounted systems and equipment
      a. Equipment shall be located where readily accessed for maintenance, not over light fixtures, ceiling height partitions, or large, difficult-to-move furniture such as cabinets and desks. Where possible, locate in corridors or over entry doors to rooms where it is assured no furniture will be located below.
      b. Where new equipment is being installed in a new location, or where existing equipment is being replaced and moved to a new location, do not locate any equipment requiring access doors above drywall or other inaccessible ceilings in public areas, conference rooms, etc. (Ceiling access doors are acceptable in toilet rooms and other back-of-house type spaces.)
      c. Where terminal units are relocated, VAV boxes shall not be located over conference rooms and other spaces NC 30 and below. Locate over corridors wherever possible.
      d. Access doors shall not be used for access to balancing dampers above inaccessible ceilings such as drywall ceilings; use instead remote control devices (e.g. Young's Regulator) or lay-in diffusers with plaster frame. For slot diffusers with plenums, locate remote control connection at top of plenum accessible through slot.
      e. Space shall be provided around all equipment for routine maintenance and inspection in strict accordance with recommendations of the manufacturer. Service and maintenance access space and access doors shall not be blocked by conduit, sprinkler lines, cable trays, ceiling hangers, etc.
      f. Ceiling and wall grilles and slots shall be centered with architectural elements and symmetrical.

E. Air Handling Units
   1. Supply Fan Requirements
      a. Single or multiple direct drive plenum fans at contractor's option
      b. Single variable speed drive
      c. Sizing (for bid purposes)
         1) AHU-1-1: 10,400 cfm, 1.5" ESP, <=15 HP
         2) AHU-1-2: 9,600 cfm, 2.5" ESP, <=10 HP
         3) AHU-1-3: 9,300 cfm, 1.9" ESP, <=10 HP
         4) AHU-2-1: 10,400 cfm, 2.1" ESP, <=15 HP
         5) AHU-2-2: 4,800 cfm, 2.3" ESP, <=7.5 HP
         6) AHU-2-3: 9,300 cfm, 2.7" ESP, <=15 HP

7) AHU-2-4: 4,500 cfm, 2.2" ESP, <=7.5 HP

2. Return Fan Requirements
   a. Single or multiple direct drive plenum fans at contractor's option
   b. Single variable speed drive
   c. Sizing (for bid purposes)
      1) AHU-1-1: 9,600 cfm, 0.5" ESP, <=5 HP
      2) AHU-1-2: 8,700 cfm, 0.6" ESP, <=5 HP
      3) AHU-1-3: 8,100 cfm, 2.0" ESP, <=5 HP
      4) AHU-2-1: 9,500 cfm, 1.5" ESP, <=5 HP
      5) AHU-2-2: 4,000 cfm, 1.7" ESP, <=3 HP
      6) AHU-2-3: 8,300 cfm, 1.0" ESP, <=5 HP
      7) AHU-2-4: 4,100 cfm, 0.9" ESP, <=3 HP
3. Coil Performance
   a. Airflow: Match supply fan design airflow
   b. Entering air dry bulb/entering air wet bulb (for bid purposes):
      1) AHU-1-1: 75.8°F/62.8°F
      2) AHU-1-2: 78.3°F/63.2°F
      3) AHU-1-3: 77.9°F/63.1°F
      4) AHU-2-1: 76.8°F/63.0°F
      5) AHU-2-2: 78.3°F/63.2°F
      6) AHU-2-3: 78.2°F/63.2°F
      7) AHU-2-4: 76.9°F/63.0°F
   c. Leaving coil air dry bulb: < 53°F
   d. Entering water temperature: 44°F
   e. Leaving water temperature: As high as possible given the other constraints here and in Section 2.1E.
4. Cabinet Requirements
   a. Must fit on existing curb rails with sufficient clearances for anchorage and service access to existing and new equipment.
      1) Exception: AHU-1-1 shall be mounted on a new equipment pad on grade
   b. 2" and 15" Filter Racks
5. Dampers
   a. Return Air
      1) 1,500 FPM maximum face velocity
   b. Outside Air
      1) 800 FPM maximum face velocity
   c. Exhaust Air
      1) 1200 FPM maximum face velocity
6. Duct Connections:
   a. Supply: Size supply opening for 1,500 FPM, provide and install duct transition fitting to connect to existing supply duct.
   b. Return: Remove existing return duct transition fittings which are to be removed as part of this project.
   c. Exception: AHU-1-1
      1) Supply and return from the top of unit and shall be connected to existing supply and return ducts
      2) Connect exhaust air duct to existing louver located in the cooling tower well
      3) Outdoor air intake shall be on the right-hand side of the unit (looking in the direction of supply airflow) utilizing the existing louver in the cooling tower well as the makeup air source.
7. Filters
   a. MERV 13 bag filter

b. MERV 6 construction pre-filter

8. Electrical
   a. 460 V/3 Ph/60 Hz
   b. Motor HP shall be less than or equal to existing to avoid upgrading electrical services

F. VAV Zones
   1. Provisions must be made to ensure the minimum air circulation requirements specified herein are maintained under low load conditions. Exceptions:
      a. Spaces with consistently high internal loads, such as server rooms, telecom, copy rooms, etc. Minimum volume setpoint shall be set to zero. (Minimum ventilation rates will be provided naturally by thermostatic controls.)
      b. Open office interior spaces open to exterior zones served by VAV reheat boxes (which can maintain minimum ventilation for both zones).
   2. VAV Box Sizing. Box sizes shall be selected based on design cooling airflow rate (see provided VAV schedule) as follows:

Inlet Size	Cooling-Only	Reheat (2-row)
6”	425	425
8”	785	715
10”	1200	1100
12”	1600	1560
14”	2325	2130
16”	3000	2730

   3. VAV Box Setpoints
      a. VAV box schedules shall include all of the following setpoints
         1) Zone maximum cooling airflow setpoint
         2) Zone minimum airflow setpoint
         3) Zone maximum heating airflow setpoint
         4) Zone occupant component of minimum outdoor air setpoint
         5) Zone building area component of minimum outdoor air setpoint
      b. Maximum airflow setpoints shall be taken from the provided VAV box schedule. If Contractor determines that provided maximum airflow setpoints are inadequate, new maximum airflow setpoints be determined from cooling load calculations. Provide cooling load calculations to the District’s Representative for review and approval.
      c. Minimum airflow setpoints shall be the largest of the following parameters
         1) Cooling-Only Boxes
            a) 15 cfm/person−not applicable to zones with CO_2 sensor
            b) 0.15 cfm/ft^2
         2) VAV Reheat Boxes
            a) 15 cfm/person−not applicable to zones with CO_2 sensor
            b) 0.15 cfm/ft^2
      d. Heating maximum airflow setpoint shall be the largest of the following parameters
         1) Minimum airflow setpoint as determined above
         2) As required to provide 95°F air to the space at design steady-state heating load but no larger than 50% of the maximum cooling airflow

G. Air Distribution System Design
   1. The following prescriptive requirements apply to “critical” ducts, those that determine the fan static pressure. For ducts branches that do not determine fan static pressure (e.g. those close to the fan), ducts may be smaller, but not so much that they become “critical.”
      a. Ducts from Mains to VAV Boxes

1) Flexible duct shall not be used upstream of VAV boxes including duct from taps of mains to VAV boxes.
2) Minimum straight duct at box inlet shall be 18" long; greater is preferred. Where duct to VAV box is larger than VAV inlet, provide sheet metal taper at inlet with maximum 15° angle.

2. Ductwork Downstream of VAV Boxes and All Return Air Ducts
   a. Flexible duct
      1) Allowed only where concealed from public view
      2) Length may be up to 5 feet per code
   b. Duct Sizing
      1) Sheet metal ducts shall be sized for average friction rates below 0.1" per 100 feet. (Note, sections of ducts may exceed this provided other sections are relatively oversized so that the average meets the limit.)
3. Ducts exposed to occupant view
   a. Use only spiral round or oval ducts; no rectangular duct or flex duct.
   b. Avoid reducers; unless not physically possible, size ducts downstream of VAV box for the design airflow and retain that size the entire length without any fittings.
   c. Use Gripple hangers.
   d. Duct sealant shall be clear and concealed in the joint, invisible to occupants.
   e. Run ducts parallel to the structure
   f. Ducts shall not to intersect wall corners or run parallel to and within a full height wall.
   g. Materials shall be de-greased or otherwise ready to paint (paint by others).
   h. Saddle taps and other taps to grilles, tees, wyes, etc.:
      1) Have flanges at duct connection inside the duct concealed from view
      2) Do not break the duct, i.e. use taps cut into a continuous spiral duct, not factory constructed tees.
4. Layout
   a. Ductwork shall not be run through electrical rooms, even where above ceilings, unless they serve the space and meet the restrictions in the Electrical Code.
   b. Rectangular ducts located outdoors shall be sloped so that water does not accumulate. See 3.5F.
5. Dampers: Mount so that actuators may be direct-coupled (not mounted to damper blade) one actuator per section. This applies to all dampers, including those in air handlers.
6. Balancing
   a. Air outlet balancing shall be through volume dampers located at the upstream end of the flex duct connection to the outlet or duct/plenum tap, except integral opposed blade dampers may be used for wall registers in exposed duct if only minor air balance is required.
   b. Do not use splitters, extractors, or devices other than manual balance dampers for balancing.
7. Air Outlets
   a. Styles listed are Price. Equals by Titus, MetalAire, etc. are acceptable.
   b. Select diffusers for 5 NC less than maximum room NC.
   c. Styles
      1) General Office, tee-bar ceilings
         a) Interior supply
            (1) NC-25 and lower: Price SPD plaque diffusers
            (2) NC-30 and higher: Price PDSP star-pattern perforated (with black painted back pan and deflectors) or SPD plaque diffusers, maximum 350 cfm, at Contractor's option
            (3) Maximum 12" neck size

b) Perimeter supply: Price TBDI3
c) Return: 2x2 perforated, Price PDDR with light shield or equal

2) General Office, no ceilings
a) Supply on exposed duct
(1) High duct elevation, bottom: Concentric round, adjustable (Price RCDA or equal)
(2) Low duct elevation, sidewall: Curved spiral duct double deflection (Price SDGE). Adjust rear blades horizontal 22 degree upward and splay front blades in 45 degree pattern at each end gradually rotating to be almost straight at blades in center of grille. Minimum 2 to 1 aspect ratio.
b) Return, sidewall: Single blade (Price 510Z-L or 530-L)

3) Conference rooms and Classrooms (all rooms with CO_2 sensors)
a) Supply: Price TBDI3
b) Return: Architectural slots around perimeter.

4) Exhaust Grilles
a) Perforated face
b) Black painted back pan and deflectors

b. Borders and Frames
1) Diffuser trim to match ceiling type
2) Provide center-tees for multiple slots in tee-bar ceilings
3) Use frames with concealed fasteners; no visible screw heads
4) For grilles in drywall ceilings, use lay-in diffuser with plaster frame (rather than drywall frame).

c. No opposed blade damper in grille neck, unless otherwise noted

d. All visible portions behind grilles shall be painted flat black including:
1) Back-pan and blades of perforated diffusers
2) Plenum boxes
3) Visible plenum duct liner pins

H. Water Distribution Systems

1. Piping shall be sized using either the performance or prescriptive procedure described below.

a. Performance Approach
1) Optimize pipe using life cycle costs using this spreadsheet: http://www.taylor-engineering.com/Websites/taylorengineering/images/guides/Pipe_Size_Optimization_Tool.zip. Provide spreadsheets for Engineer's review to confirm proper implementation.

b. Prescriptive Approach
1) Piping shall be designed in accordance with the table below. "Noise Sensitive" spaces are spaces designed for NC 40 and below.

Pipe Size	Hot and Chilled Water	
	Non-noise Sensitive	Noise Sensitive
½"	5.9	1.8
¾"	14	4.6
1"	22	8.9
1-1/4"	39	15
1-1/2"	67	24
2"	84	51
2-1/2"	120	81

Pipe Size	Hot and Chilled Water	
	Non-noise Sensitive	Noise Sensitive
3"	210	140
4"	360	280
5"	510	490
6"	800	770
8"	1,400	1,400
10"	2,200	2,200
12"	3,300	3,300
14"	4,600	4,600

2. Layout
   a. Piping shall not be run through server rooms, telecomm rooms, etc. where leaks can damage electronic equipment.
   b. Piping shall not be run through electrical rooms, even where above ceilings.
3. Balancing
   a. Variable flow systems (two-way modulating valves): No balancing required for two-way valve systems.
4. Hot water systems
   a. Use only two-way modulating valves, except for 3-ways as listed on bid VAV schedules to ensure minimum flow requirements through the boiler are met.
   b. Alternate 5: Minimum flow bypass sized for minimum flow requirement of the existing Aerco BMK 2000 boiler (25 gpm). See Section 1.16A.5 for Alternate 5 description.
      1) Use only two-way modulating valves at VAVs.
5. Chilled water systems
   a. Use only two-way modulating valves at all coils.

I. Indoor Air Quality Measures
1. Ventilation: Outdoor air rates shall be Title 24 Section 120.1 rates.
2. Coils: Individual finned-tube coils shall meet Standard 62.1 requirement (no greater than 0.75" pressure drop when dry (no condensation) and rated at 500 fpm) to ensure coil cleanability. Multiple finned-tube coils in series shall also meet this constraint together unless 1.5 feet minimum width access sections with access doors are placed in between each coil.
3. Dehumidifying Cooling Coils: Field assembled and custom factory assembled dehumidifying cooling coils shall be selected for no more than negligible water droplet carryover beyond the drain pan at design conditions. For the purpose of this section, negligible water droplet carryover is defined as 0.04 oz per ft^2 of coil area per hour. Drains and drain pans as specified below shall be provided under all dehumidifying cooling coils. Equipment and other obstructions in the air stream shall be located sufficiently downstream of the coil that it will not come in contact with water droplet carryover.
4. Drains and Drain Pans
   a. Drains located upstream of fans (those negatively pressurized relative to outdoors or those negatively pressurized to air in a mechanical equipment room) shall have traps having a depth and height differential between inlet and outlet equal to or greater

than the fan design static pressure, or otherwise sufficient to maintain a water seal and allow complete pan drainage with fans on or off.

b. Drain pans located in supply air ducts, plenums, and other locations shall be designed and field tested to ensure proper slope and drainage and to prevent conditions of water stagnation that result in microbial growth. Drainage shall be considered acceptable if after covering the entire pan with ½" water, the pan drains within 3 minutes with the fan system in operation to leave puddles no more than 2" in diameter and no more than 1/8" deep.

5. Access: Space shall be provided around all ventilation equipment as recommended by the manufacturer for routine maintenance and inspection including but not limited to filter replacement and fan belt adjustment and replacement. Access doors or panels shall be provided in ventilation equipment, ductwork and plenums as required for in-situ inspection and cleaning of the following:
   a. Outdoor air intake plenums
   b. Mixed air plenums
   c. Upstream of heating coils in VAV boxes
   d. Upstream and downstream surface of cooling coils
   e. Filters
   f. Drain pans
   g. Fans
6. Filtration
   a. All fans systems shall have a filter to protect ductwork and coils from particulate accumulation. This includes fan-powered mixing boxes (if used).
   b. Minimum filter efficiency as rated by ASHRAE Standard 52.2.
      1) Occupiable spaces with outdoor air supply: 15 inch, MERV 13 bag filters
   c. MERV 6 prefilters in front of high efficiency bag filters shall be provided only during construction. The prefilters shall be discarded prior to final TAB tests.
7. Duct liner
   a. On new supply air ductwork, use liner only where absolutely required for sound control. Suggest only using liner on exterior ductwork and 5' plenums downstream of VAV boxes.
   b. On new return ducts, use liner only as required for sound control.
   c. Liner shall have a resilient, cleanable coating as specified in Section 2.14.
8. Exhaust and economizer relief separation distances to outdoor air intakes shall be in accordance with ASHRAE Standard 62.1.
9. For VAV systems, provide a means to control outdoor air intake within 15% of minimum levels under all reasonably expected operating conditions.

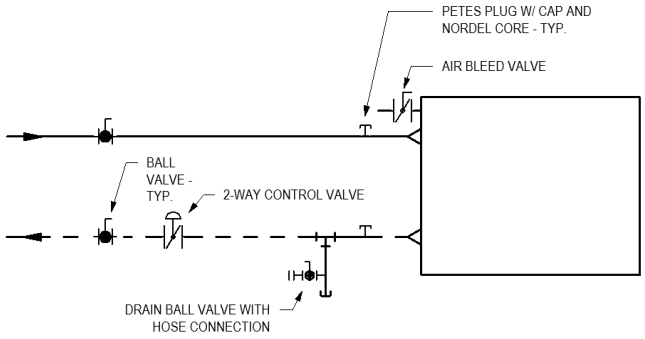
J. Structural Design Criteria
   1. Non-structural elements are design using Fp forces following Chapter 13 of ASCE7-16
   2. Seismicity:
      a. Importance Factor Ip = 1.5
      b. Risk Category = II
      c. Seismic Design Category = E
      d. Site Class = D
      e. Design Spectral Acceleration
         1) SDS = 1.652g
         2) SD1 = 1.167g
   3. All new AHUs on the roof shall have a maximum weight of 5000lbs each.
   4. All MEP units are supported on concrete curbs. Final size and location are provided by the Contractor's mechanical engineer. All anchorage of MEP units and distribution system is by the Contractor's design-build structural engineer.

5. Existing conditions
   a. There are existing drawings with the name "Applied Arts and Administration Complex, Contra Costa College" by Cometta and Cianfichi Confer Crossen & Nance Associated Architectural Firms (see RFQP Exhibit G):
      1) Mechanical drawings (sheets M1-M5) by n/a. Dated August 24, 1979.
      2) Structural drawings (sheets S1-S11) by Leong-Razzano & Associates, Inc. Consulting Civil & Structural Engineers. Dated August 27, 1979.
   b. All existing conditions and dimensions shall be verified in field.
   c. New anchorage must avoid existing rebar and threaded rods.
   d. If existing roof structure has any deterioration or damage, the Contractor shall bring this to the attention of the District for evaluation and remediation.
6. Special Inspection
   a. The special inspection requirements of Chapter 17 of the CBC with DSA amendments shall apply to the following:
      1) Concrete construction
      2) Steel construction
      3) Expansion anchors
   b. The Contractor shall notify the District's Testing Agency of work required to be tested and inspected. Notification shall be sufficiently in advance to allow scheduling of tests and inspections, but not less than 48 hours.
   c. The Contractor shall immediately notify the District if the District's Testing Agency indicates that quality assurance tests and inspection requirements have not been met.
7. Structural Observation
   a. Structural observation shall be provided by the Contractors structural engineer and shall be in accordance with CBC section 1704A.

1.15 DESCRIPTION OF RETROFIT MEASURES

A. Measure 1: Rooftop Air Handler Upgrade
   1. Schedule of Work:
      a. Each AHU replacement and startup, including rigging, demo, installation, flush-out, controls installation, and commissioning shall occur over a two-day weekend. AHUs shall be operational at least 2 hours before College operations (see 1.12B.1) on Monday morning to allow for flush-out and warm-up. This may occur over multiple weekends as required to complete the work. Specific weekends to be coordinated with class schedules and with the District.
   2. Existing equipment to be demolished:
      a. Air handlers
         1) AHU-1-2
         2) AHU-1-3
         3) AHU-2-1
         4) AHU-2-2
         5) AHU-2-3
         6) AHU-2-4
      b. Starters, disconnect switches, and wiring from MCC to starters and to equipment and disconnects for all demolished equipment
      c. All valves, including shut off and control valves, and all other piping system devices serving AHUs.
      d. All rooftop piping from AHUs back to below the roof line.
      e. HVAC Controls

3. Existing equipment to be reused:
   a. Existing concrete sleeper rails
   b. Existing unused conduit
   c. Existing unused piping supports
   d. Existing rooftop ductwork, excluding duct transition fitting used to connect supply duct to AHU.
   e. Existing ductwork inside building
   f. Existing duct-mounted smoke detectors
4. New work:
   a. Replace air handlers
   b. Piping:
      1) Provide and install new rooftop chilled water piping from new shutoff valves located below the roofline to new air handling unit chilled water coils.
         a) Line stop below the roofline or drain the piping to install new shutoff valves.
      2) Cut and cap existing rooftop hot water piping below roofline. Seal and patch existing hot water piping roof penetrations.
      3) Provide and install new piping accessories as follows:



      4) All valves and piping accessories shall be new. Locate in cabinet supplied with AHU, not exposed to weather.
      5) Extend condensate drains with trap to approved receptor per current code.
      6) Provide insulation on the new piping. Exterior insulation shall be jacketed with aluminum to protect it from weathering per Section 2.14D.5.
      7) Flush piping per Section 3.10C.
   c. Ductwork
      1) Demo existing return duct transition fittings at AHU, where applicable.
      2) Connect AHU discharge to existing risers with lined duct (2” internal lining).
      3) Connect existing rooftop ductwork directly to new AHUs. Do not install a flex connection. AHU supply fans are internally isolated so the AHU shall be hard ducted to the new rooftop ductwork
      4) Clean visible debris from existing ductwork per Section 3.10D.
      5) Protect outdoor ductwork per Section 3.5F.
   d. Supports
      1) Reuse existing rooftop duct supports.
      2) Reuse existing rooftop pipe supports.

3) Provide internal vibration isolation devices as required for no detectable vibration in spaces below mechanical area. Isolation restraints shall meet all seismic codes.

e. Electrical Work

1) All variable speed drives and disconnects shall be new.

2) Connect power from existing MCC/distribution panels to unit disconnect.

3) Reuse existing duct-mounted smoke detector. Existing duct detector shall be hardwired to stop supply fan upon smoke detection.

5. Start-up, test, and balance

a. Work shall be coordinated with the Division 25 Contractor to avoid downtime during College operating hours.

b. Test associated fire life safety systems, including reused interlock devices to verify functionality.

6. All other work required for a complete installation.

B. Measure 2: AHU-1-1 Replacement

1. Schedule of work:

a. AHU installation including extension of ductwork and piping may be assumed to occur during College operations (see 1.12B.1).

b. Connection between new and existing ductwork and piping shall occur over a two-day weekend – specific weekend to be coordinated with class schedules and the District.

c. AHU start-up, chilled water piping flush, installation of new controls, etc. shall occur over a two-day weekend – specific weekend to be coordinated with class schedules and the District.

d. Contractor shall develop a phasing plan for rigging, start-up, commissioning, etc. to ensure AHU is operational at least 2 hours before College operations on Monday morning to allow for flush-out and warm-up.

2. Existing equipment to be demolished:

a. AHU-1-1 and associated hanger supports

b. AHU-1-1 discharge damper and actuator

c. Outdoor air supply duct

d. Exhaust air duct and rooftop exhaust air vent

e. Starters, disconnect switches, and wiring from MCC to starters and to equipment and disconnects for all demolished equipment

f. All valves, including shut off and control valves, and all other piping system devices

g. Chilled and hot water piping at AHU from the shut-off valves to the coils, and piping that will no longer be used

h. HVAC Controls

i. Duct-mounted smoke detector

3. Existing equipment to be reused:

a. Existing supply and return ductwork inside building

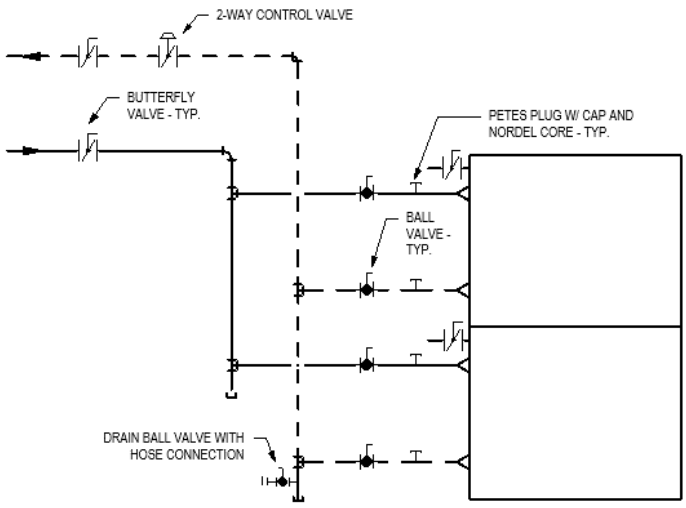
4. New work:

a. Replace air handler AHU-1-1

b. Piping:

1) Provide and install new chilled water piping with connection to chilled water distribution piping.

2) Provide and install new piping accessories as follows:



3) All valves and piping accessories shall be new. Locate in cabinet supplied with AHU, not exposed to weather.
4) Extend condensate drains with trap to approved receptor per current code.
5) Provide insulation on the new piping. Exterior insulation shall jacketed with aluminum to protect it from weathering per Section 2.14D.5.
6) Flush piping. See 3.10C.

c. Ductwork
1) Connect AHU discharge to new supply duct with lined duct (2" internal lining). Extend from tower well (Room 117F.2) to point of connection with existing supply ductwork over boiler room (Room 117F).
2) Connect AHU return to existing return. Extend from tower well to point of connection with existing return ductwork over boiler room.
3) Connect new ductwork directly to new AHU. Do not install a flex connection. AHU supply fans are internally isolated so the AHU shall be hard ducted to the new rooftop ductwork.
4) Clean visible debris from existing ductwork. See 3.10D.
5) Cap existing rooftop exhaust air vent.
6) Provide and install fire dampers as required at new penetrations of fire rated boiler room walls.
7) Protect outdoor ductwork per Section 3.5F.

d. Supports
1) Construct new equipment pad
2) Install new curb
3) Provide internal vibration isolation devices as required for no detectable vibration in occupied spaces. Isolation restraints shall meet all seismic codes.

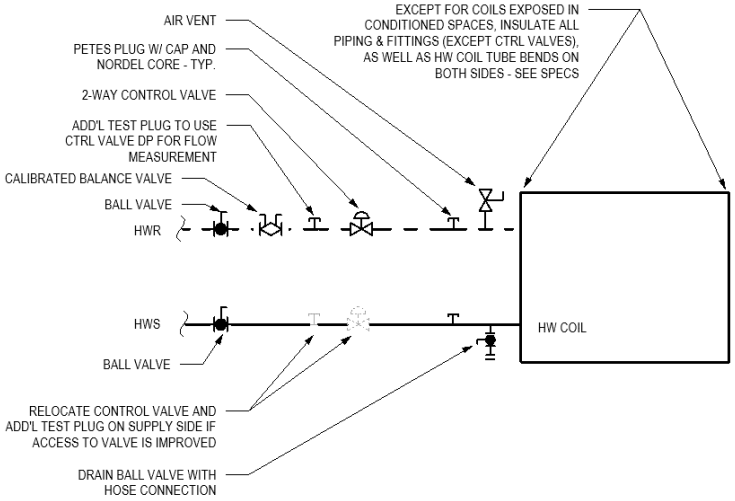
e. Electrical Work
1) All variable speed drives and disconnects shall be new.
2) Connect power from existing MCC/distribution panels to unit disconnect.
3) Provide and install new duct-mounted smoke detector. Duct detector shall be hardwired to stop supply fan upon smoke detection.

5. Start-up, test, and balance

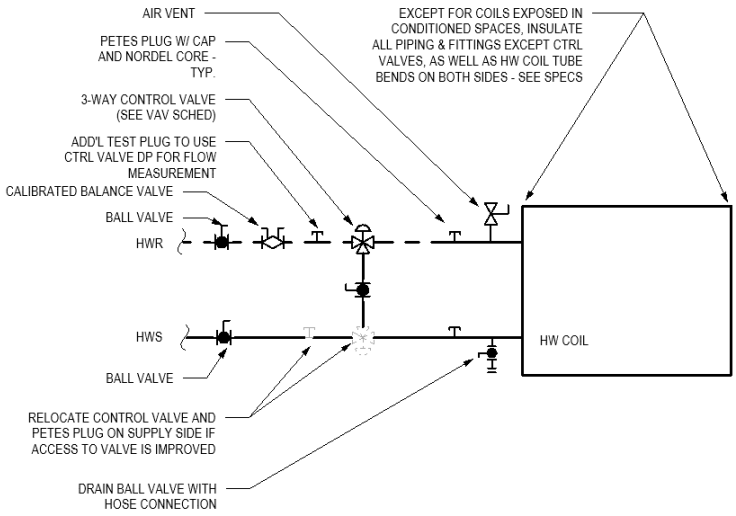
a. Work shall be coordinated with the Division 25 Contractor to avoid downtime during College operating hours.
b. Test associated fire life safety systems, including new interlock devices to verify functionality.

6. All other work required for a complete installation.

C. Measure 3: Replace Existing Induction Boxes with VAV Boxes
1. Schedule of work: Section 1.12B.1.
2. Existing supply distribution ductwork shall be assumed to allow for design airflow. If airflows are found to be restricted post-install, provide a case-by-case cost at that time to investigate and resolve airflow restrictions.
3. Existing equipment to be demolished:
a. Induction box
b. Damper actuator
c. Thermostat
d. Strainer
e. Hot water control valve
f. Return air grille and connection to induction box (if applicable)
4. Existing equipment to be reused:
a. Isolation valves
5. New work:
a. Replace induction box with VAV box. See zoning plan and VAV schedule.
b. Replace 2- or 3-way control valve. See VAV schedule for valve type. Control valve provided by Division 25 Contractor, installation by Division 23 Contractor.
c. Where existing cooling-only boxes are replaced with reheat boxes, provide and install hot water supply and return piping with connection to existing hot water piping mains.
d. For reheat boxes, provide and install piping accessories and insulation as follows:
1) Two-way valves (shutoff valves are existing if existing reheat box is replaced with a new reheat box, shutoff valves new if existing cooling-only box is replaced with a new reheat box):



2) Three-way valves (shutoff valves are existing if existing reheat box is replaced with a new reheat box, shutoff valves new if existing cooling-only box is replaced with a new reheat box):



e. Clean visible debris from existing ductwork per Section 3.10D.

f. Testing, adjusting and balancing per Section 3.14.

g. Replace ceiling tiles and dropped ceiling system if damaged.

D. Measure 4: For existing VAV reheat boxes and upstream heating coils with pneumatic actuators, replace control valves and remove strainers

1. Schedule of work: See Section 1.12B.1.
2. Existing supply distribution ductwork shall be assumed to allow for design airflow. If airflows are found to be restricted post-install, provide a case-by-case cost at that time to investigate and resolve airflow restrictions.
3. Existing equipment to be demolished:
   a. Pneumatic control valves
   b. Hot water strainer
   c. Pneumatic thermostats and actuators
4. Existing equipment to be reused:
   a. Isolation valves
5. New work:
   a. Replace 2- or 3-way control valve. Control valve provided by Division 25 Contractor, installed by Division 23 Contractor.
   b. Install pete's plugs on both sides of the control valve for testing.
   c. Replace ceiling tiles and dropped ceiling system if damaged.

E. Measure 5: Remove strainer basket from existing VAV boxes with electric actuators

1. Schedule of work: See Section 1.12B.1.

F. Measure 6: Remove Compressed Air System

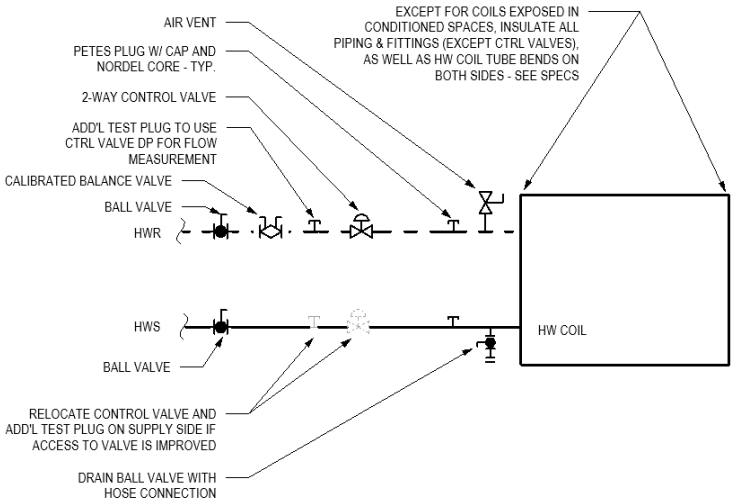
1. Schedule of work: Work shall occur after all pneumatic VAVs are upgraded to DDC and pneumatic induction boxes are replaced and DDC controls are installed. See Section 1.12B.1.
2. Existing equipment to be demolished:
   a. (3) Air compressors
   b. Starters, disconnect switches, and wiring from MCC to starters and to equipment and disconnects for all demoed equipment
   c. Air dryer
   d. Pressure reducing and air filter stations, including all valves

e. Compressed air piping upstream of shut-off valves at mains to building

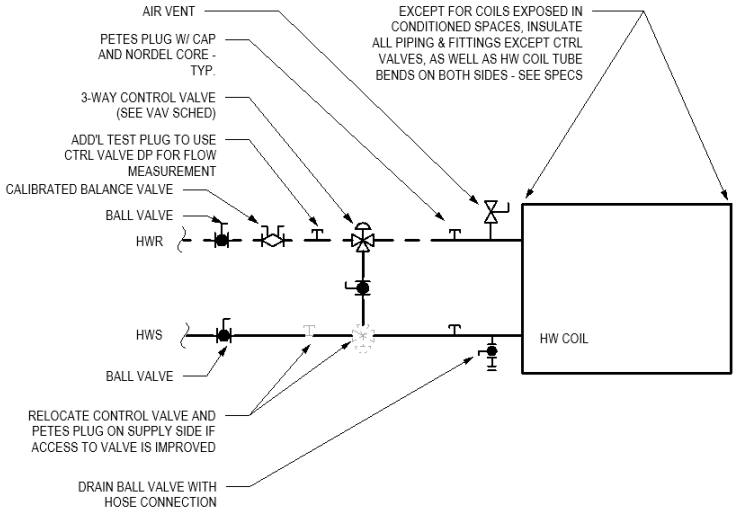
3. Existing equipment to be abandoned in-place
   a. Pneumatic lines from shut-off valves to terminal units. See Alternate 2 below.

G. Measure 7: Configure existing boiler mixing valve to be fixed in the normally closed (100% open to boiler, 0% bypass) position, remove mixing valve pneumatic actuator. See Alternate 1 below.
   1. Schedule of work: See Section 1.12B.5.

H. Measure 8: Replace existing VAV boxes with new VAV boxes.
   1. Schedule of work: See Section 1.12B.1.
   2. See VAV schedule for type and quantities.
   3. Existing supply distribution ductwork shall be assumed to allow for design airflow. If airflows are found to be restricted post-install, provide a case-by-case cost at that time to investigate and resolve airflow restrictions.
   4. Replace ceiling tiles and dropped ceiling system if damaged.
   5. Existing equipment to be demolished:
      a. VAV box
      b. Damper actuator
      c. Thermostat
      d. Strainer
      e. Hot water control valve
   6. Existing equipment to be reused:
      a. Isolation valves
   7. New Work:
      a. Replace existing VAV box with new VAV box. See zoning plan and VAV schedule.
      b. Replace 2- or 3-way control valve. See VAV schedule for valve type. Control valve provided by Division 25 Contractor, installation by Division 23 Contractor.
      c. Where cooling-only boxes are replaced with reheat boxes, provide and install hot water supply and return piping with connection to existing hot water piping mains.
      d. Provide and install piping accessories and insulation as follows (shutoff valves existing):
         1) Two-way valves (shutoff valves are existing if existing reheat box is replaced with a new reheat box, shutoff valves new if existing cooling-only box is replaced with a new reheat box):



2) Three-way valves (shutoff valves are existing if existing reheat box is replaced with a new reheat box, shutoff valves new if existing cooling-only box is replaced with a new reheat box):



8. Clean visible debris from existing ductwork per Section 3.10D.
9. Testing, adjusting and balancing per Section 3.14.
10. Replace ceiling tiles and dropped ceiling system if damaged.

I. Measure 9: Install new VAV boxes

1. Schedule of work: See Section 1.12B.1.
2. See VAV schedule for type and quantities.
3. Existing supply distribution ductwork shall be assumed to allow for design airflow. If airflows are found to be restricted post-install, provide a case-by-case cost at that time to investigate and resolve airflow restrictions.
4. Existing equipment to be demolished:
   a. Associated ductwork connected to existing supply diffusers in Offices 105, 107 and 109A.
5. Existing equipment to be reused:
   a. Supply diffusers in Offices 105, 107 and 109A.
6. New Work:

a. Provide and install insulated sheetmetal duct connection to medium pressure supply main, and flex duct connection to new supply diffusers.

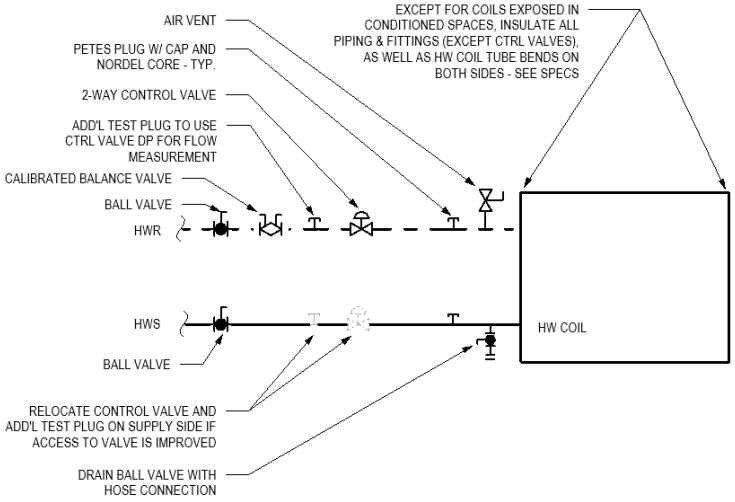
b. For reheat boxes, provide and install hot water supply and return piping with connection to existing hot water piping mains.

c. Install 2- or 3-way control valve. See VAV schedule for valve type. Control valve provided by Division 25 Contractor, installation by Division 23 Contractor.

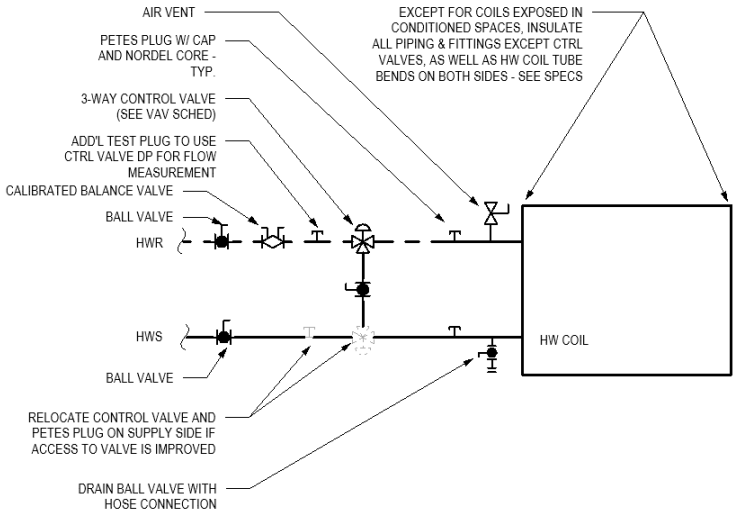
d. Provide and install new supply diffusers and return air grilles, as required.

e. For reheat VAVs, provide and install new piping accessories and insulation as follows:

1) Two-way valves:



2) Three-way valves:



f. Start-up, test, adjust, and balance.

g. Replace ceiling tiles and dropped ceiling system if damaged.

h. All other work required for a complete installation.

7. Submit drawings with proposed main tie-in, VAV box location, connection to existing supply diffusers and return air grille locations.

J. Measure 10: Drain, cut and cap hot and chilled water piping associated with hot water pump PHY-1 and chilled water pump CHP-2.

a. Schedule of work: See Section 1.12B.5.

b. Drain piping served by PHY-1 and CHP-2.

c. Cut and cap associated secondary loop supply piping in the mechanical room and return piping at the points of the connection to the main return risers at level 2.

K. Measure 11: Add supply diffuser and return grille to Office 216A.

1. Schedule of work: See Section 1.12B.1.
2. Provide and install flex duct connection between VC-2-13 low pressure VAV supply duct to new supply diffuser. See zoning plan.
3. Provide and install new return air grille, as required.
4. Replace ceiling tiles and dropped ceiling system if damaged.

L. Measure 12: Abandon HC-17 serving Rooms 201A, 201B and 201C in-place. Manually close supply and return isolation valves and drain coil.

1. Schedule of work: See Section 1.12B.1.

M. Measure 13: Control System Upgrade

1. See Section 250000 for control system details.

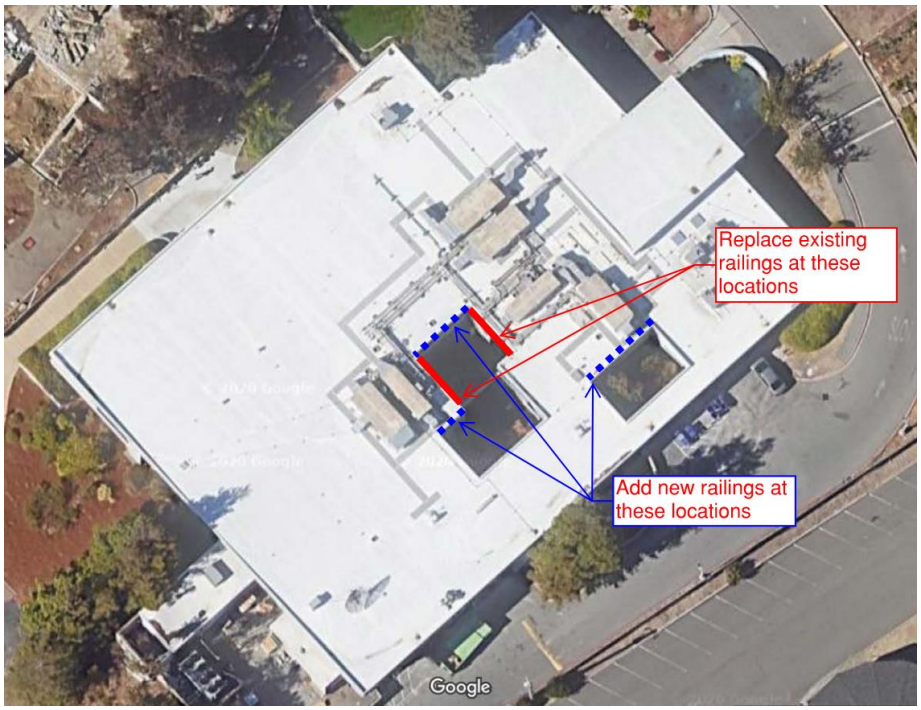
1.16 ALTERNATES

A. Alternate Pricing. Alternate prices shall include all equipment, material, labor, design engineering, balancing, start-up and testing costs necessary to provide a complete operational system. Provide a separate price for each alternate.

1. Alternate 1: If existing boiler mixing valve cannot be configured to be normally closed (100% open to boiler, 0% bypass), remove mixing valve, cut and cap bypass leg.
   a. Schedule of work: See Section 1.12B.5.
2. Alternate 2: Remove all existing pneumatic piping downstream of shut-off valves at mains to the building.
   a. Schedule of work: See Section 1.12B.1.
3. Alternate 3: Demolish heating hot water pump PHY-1 and chilled water pump CHP-2 .
   a. Schedule of work: See Section 1.12B.5.
   b. Demolish starters, disconnect switches, VFDs, and wiring from MCC to starters and to equipment and disconnects for all demoed equipment
4. Alternate 4: First and Second Floor As-Built Drawings
   a. Create full as-builts for the First and Second Floors including:
      1) All new and existing ducts and grilles
         a) Tag all ducts with duct sizes
         b) Tag all grilles with grille size and airflow
      2) All new and existing piping
         a) Tag all piping with sizes and service, exclude those abandoned in-place.
   b. Note: Base scope drawings exclude existing equipment, ducts and pipes.
5. Alternate 5: Install hot water minimum flow bypass either at plant or end-of-line just below the roofline, change all scheduled 3-way valves to 2-way valves.
   a. Schedule of work: See Sections 1.12B.1 and 1.12B.5.
   b. Install 2-way control valve. Control valve provided by Division 25 Contractor, installation by Division 23 Contractor.
   c. Exclude calibrated balance valves required in Measures 8A, 8B, 9A, 9B, 10A and 10B.
   d. Exclude base scope TAB for calibrated balancing valves. See 3.14C.1.

e. Install magnetic insertion type flow meter provided by Division 25 Contractor, installation by Division 23 Contractor.

6. Alternate 6: Determine Maximum Chilled Water Differential Pressure Setpoint (CHW-DPmax)
   a. Schedule of work: See Section 1.12B.11.12B.5.
   b. See Section 3.14C.3 for TAB procedures.
7. Alternate 7: New roof railings
   a. Schedule of work: This scope does not affect normal operation. Work shall be assumed to occur during College operations.
   b. Provide and install rooftop safety railings at locations indicated below:



   c. The roof rails shall be permanent and follow OSHA requirements for Fall Protection, standard number 1926.502 and as specified:
   d. Top rail height: 42-45 inches above finished roof deck.
   e. Top-Mid Rail spacing: 21 inches maximum.
   f. Upright post maximum spacing of 8 feet.
8. Any others proposed by the Contractor

B. Unit Prices. Unit prices shall include all equipment, material, labor, design engineering, balancing, start-up and testing costs necessary to provide a complete operational system. Prices may be used to add or deduct items from scope and shall be good for a period of at least one year from the date of contractor's proposal.

1. Unit Price 1: Replace terminal unit isolation valves. Assume pipe work is already being done on the zone (e.g. per Measure 3 or 4).
   a. Schedule of work: See Sections 1.12B.1 and 1.12B.5.
   b. Do not include cost to drain the system. That is included in separate unit price below.
2. Unit Price 2: Price per zone to rebalance air outlets downstream of VAV boxes so that at least one balancing damper is wide open. See 3.14B.1.c.
   a. Schedule of work: See Section 1.12B.1.

b. Assume a minimum of 10 zones if any zones are to be rebalanced.

3. Unit Price 3: Replace 3-way reheat valve with a new 2-way reheat valve provided by Controls Contractor. Cut and cap bypass leg.
   a. Schedule of work: See Sections 1.12B.1 and 1.12B.5.
   b. Assume isolation valves are operational.
4. Unit Price 4: Isolate and drain the hot water piping on a per-floor basis (1st Floor, 2nd Floor, Roof) as required to perform unit price replacements on isolation valves.
   a. Schedule of work: See Sections 1.12B.1 and 1.12B.5.
5. Any others proposed by the Contractor

PART 2 - MATERIALS

2.1 AIR-HANDLING UNITS

A. Alliance, Energy Labs, Silent Aire, BasX or equal

B. General
   1. Units shall be completely factory assembled and tested.
   2. Mount a permanent nameplate on the unit to display the manufacturer, serial number, model number, date of manufacture, current and voltage.
   3. All sound power level measurements and calculations shall be in complete accordance with the latest version of AMCA Standard 300 Reverberant Room Method for Sound Testing of Fans and AMCA Standard 301 Method for Calculating Fan Sound Ratings from Laboratory Test Data. Test and calculation procedures based on sound intensity measurements may be substituted for the above procedures, if directed in advance by the District's Representative.

C. Cabinet Construction
   1. Walls and roof shall be 2" thick double wall panels
      a. Outer panel shall be 16-gauge solid G90 galvanized
      b. Inner panel shall be:
         1) Minimum 20-gauge solid 304 stainless steel in the coil section, minimum 1 foot upstream and 3 feet downstream of coil.
         2) Minimum 22-gauge G90 perforated bright galvanized steel liner in all other sections.
      c. Construction shall comply with one of the following options:
         1) Option 1: All exterior panel seams shall be stitch welded and continuously sealed with a urethane sealant.
         2) Option 2: Exterior panels shall be mechanically connected with thermal break and sealed with an industrial EPDM gasket to form a water and airtight seal. Gasket seal shall not be exposed to UV light or the weather. Fasteners used to attach the panels shall be stainless steel, bolt-type construction that can be removed and refastened and shall not penetrate the air tunnel. Sheet metal screws are not acceptable.
         3) Option 3: Panels shall be of standing seam construction with seams turned inward to provide a smooth flush exterior. Panels shall be screwed together on maximum 8" centers with minimum 5/16" zinc plated screws sealed with a continuous bead of silicone caulking applied between the matching panel seams prior to assembly, and with a final bead following assembly on both the exterior and interior panel seams to produce an air tight unit. Wall to base skin and wall to roof panel seams shall be sealed with 1/2" x 1/8" Poron-Rubber strips and all exterior seams shall be continuously caulked to assure leak-proof integrity of the unit housing.
      d. Insulation:

1) Wall and roof panels shall be insulated with 3 pound density pre-molded rigid board fire-resistant with scrim-Kraft - PSK faced insulation or polyisocyanurate foam.
2) All panels shall feature a Class A thermal break.
3) Thickness to match panel wall thickness specified herein with the following minimum R-values including the impact of thermal short-circuits:
   a) 2 inch panel: R-12
4) Insulation to meet NFPA 90A, NFPA 90B and ASTM E 84 requirements for Flame Spread of 25 or less and Smoke Development of 50 or less.
5) Insulation shall have a thermal conductivity K factor of .23 Btu/hr/Sq. ft/degree F @ 75 F

e. Roof panels shall be flat with smooth exteriors the same as the side panels.
f. Stiffeners of angle steel shall be supplied as required to maintain a casing deflection criteria of 1/100 at 1.5 times the working pressure.

2. Access Doors
   a. Access doors shall be double wall construction using materials, thickness, and insulation matching those of the associated section. All doors installed downstream of the cooling coil shall include a Class A thermal break. Door-jam & frame shall be constructed of extruded aluminum with continuously welded corners for rigidity. Door panels shall be insulated with expandable foam insulation completely encapsulated and sealed between the door panels and frame. Provide doors located and sized to allow for routine maintenance including motor replacement and filter replacement, electrical components and any other sections or components requiring access or maintenance.
   b. Doors shall be provided with a minimum (2) dual acting heavy duty composite latches through 48” high, (3) latches through 72” high. Latches shall be operable from both the interior and exterior of the unit. Door latches on doors into fan sections shall be provided with a hasp or other mechanism to facilitate locking of the doors. Door hinge shall be heavy duty Stainless Steel.
   c. Doors shall be provided with double high performance closed cell replaceable neoprene bulb type gasket seals around the entire perimeter of the door / frame.
   d. Doors shall open against static pressure unless obstructed by internal components. If obstructed by internal components on the positive sections requiring access, the doors shall open with pressure and shall be provided with a safety restraining mechanism. Doors used to access rotating equipment shall be provided with an OSHA approved safety latching mechanism requiring a tool to open and shall also have a highly visible, permanently fixed, caution sign on the exterior of the door. Doors with access to moving parts must also have locking hardware and meet current UL mechanical protection guidelines. Standard door size shall be 24” wide by 60” high unless restricted by height or section width.
3. Internal walls
   a. Internal walls shall be single wall, fabricated of formed 16 gage solid galvanized steel panels except cooling coil blank-off plates, which shall be constructed of 16 gage solid stainless steel.
   b. Provide access panels in wall sections where components cannot be easily accessed or removed through the exterior access doors.
4. Bases
   a. Unit bases shall be constructed from structural steel channel iron around the entire perimeter of the unit and provided with intermediate structural tubing, channel and angle

iron as required to support all internal components. All tubing, channel and angle joints shall be solid welded. Bolted or formed channel bases are not acceptable.

b. Floor Construction
   1) The entire section base (component sections and service vestibule) shall have a floor of continuously welded minimum 12 gauge G90 galvanized steel or aluminum tread plate.
   2) Include a minimum 2 inch upturned lip around the section perimeter and all floor openings. No lips or flanges allowed in walking areas to prevent a trip hazard.
   3) Floor shall be capable of supporting a 300 lb. live load with maximum L/200 deflection at any floor seam.
   4) Fastener penetrations thru the floor sheets not acceptable.
   5) Base shall be insulated with water impervious foam under the base skin and covered with a minimum 20 gauge galvanized steel liner. Insulation R-value (including effect of thermal short circuits) shall meet same criteria as cabinet casing requirements specified herein.

c. Drain pans
   1) Under cooling coil section and extending under blank plenum section downstream and extending under all headers and return bends.
   2) Type 304 Stainless steel, minimum 16-gage
   3) Corners soldered, welded or brazed
   4) Pitched to drain flange to fully drain. Double broken, double sloped to ensure no standing water.
   5) Fully accessible for cleaning
   6) Drain connection
   7) Minimum size per code
   8) Extended to the exterior of the air handler
   9) Stainless steel or brass
   10) Welded or soldered into bottom of pan
   11) Intermediate pans shall drain to the bottom main pan
   12) Insulation on bottom drain pan: minimum 1 in. thick, coated fiber glass board or injected foam insulation, NFPA-90 or UL listed. (Intermediate drain pans need not be insulated.)

5. Multi Section Units
   a. Units shipped in multiple sections shall be engineered for field assembly using one of the following options.
      1) Option 1: Demount sealing gasket shall be required and provided. Demount gasket supplied with the unit shall be a high quality weather resistant closed-cell EPDM sponge rubber.
      2) Option 2: Walls and roof shall be reassembled with 3” stitch welds on approximately 12” centers. After welding, seams will be caulked and a sealing strip will be screwed on over the seam.
6. Floor splits shall be reassembled with a continuous weld.
7. Assembly lugs, fabricated from structural steel with appropriate assembly clearance holes, shall be electrically welded to the base frame. All necessary assembly hardware shall ship loose with unit.

8. Manufacturer shall provide a factory trained service engineer to supervise equipment assembly and inspect assembly once complete.

D. Fan Assemblies
   1. Supply and Return fans
      a. Unhoused Airfoil Plenum Fan: Fans shall be airfoil centrifugal type, designed for industrial duty and suitable for continuous operation.
      b. Direct drive
      c. Fan shall be licensed to bear the AMCA Air & Sound Performance seal with performance ratings based on tests conducted in accordance with AMCA Standard 211 and comply with the requirements of the AMCA Certified Ratings Program.
      d. Fan wheels shall be furnished with die-formed airfoil blades. The airfoil blades shall be continuously welded to the back-plate and rim. All wheels shall be statically and dynamically balanced before shipment.
      e. Discharge safety cage and inlet screens: not required. Provide a sign on fan section door stating WARNING: FANS ARE NOT PROTECTED. STOP FANS BEFORE ENTERING THIS SECTION.
      f. Fan discharge section shall include sound absorbing acoustic baffles as required to meet specified sound power levels.
      g. Vibration Isolation
         1) Each individual fan assembly shall be free-floating at all four corners on minimum 2” deflection spring type isolators with seismic restraints. The spring isolators shall be mounted to structural steel members and shall be rated for a minimum of 1G. The fan discharge shall be isolated from the cabinet by means of a neoprene-coated flexible connection.
         2) Each assembled fan shall be tested by the factory at the design RPM. Vibration signatures shall be taken on each bearing in the horizontal, vertical, and axial direction. The maximum allowable fan vibration shall be 0.15 in/sec. peak velocity. Certified fan vibration test reports shall be provided.
      h. Airflow measurement: None required in base bid.
   2. Motors: Comply with Motors herein.

E. Chilled water coil
   1. Stacked coils shall be mounted in racks to allow individual coil removal without interference to other coils. All coils shall be removable from the accessible side of the unit by easily removable end panels. Individual end panels shall be supplied for each coil on the supply and return side of the cabinet to allow single coil piping breakdown for coil removal.
   2. Coil supply and return piping connections extending through the cabinet wall shall be sealed by rubber grommets with caulking on the exterior of the casing. The escutcheon plate shall have a rolled collar around the pipe opening to protect the pipe and be equipped with an "O" ring rubber gasket between the collar and the pipe to prevent chaffing and provide an air tight seal around the opening.
   3. Copper Tubes
      a. Brazed or welded joints
      b. Minimum thickness: 0.020 inches
      c. Outside diameter: 1/2 inch or 5/8 inch
      d. The use of internal restrictive devices such as turbolater springs or ribbons to obtain turbulent construction is not acceptable.
   4. Plate fins of aluminum

a. Minimum thickness 0.0075 inches

5. Rows and fin spacing
   a. 8 Rows
   b. Selected with tube fouling factor of 0.0001
   c. Minimum fins per inch: 10 fins per inch
   d. Maximum air side pressure drop: Meet Standard 62.1 maximum pressure drop requirement (≤0.75 in.w.c. at 550 fpm, dry coil)
   e. Maximum coil face velocity: 550 feet per minute
   f. Maximum wet side pressure drop: 20 ft.
6. Circuiting: As few feeds as possible to maximize chilled water delta-T subject to the constraint that maximum allowable wet side pressure drop is not exceeded.
7. Headers
   a. Cleanable/removable: cast iron with steel piping connections
   b. All other: Copper with red brass piping connections
8. Certified by ARI per current Standard 410
9. For field installed coils, coil frame designed for bolting to other sections or ductwork:
10. Coil Casing
    a. Minimum 16-gage
    b. Type 304 stainless steel casing and tube sheet
    c. Intermediate supports of same material as casing
11. Design for 200 pounds per square inch, 250 degrees Fahrenheit
12. Factory tested to 300 pounds per square inch for water coils
13. Factory cleaned, degreased, and flushed. Piping connections shall be capped with removable caps.

F. Filters
   1. Holding Frame Assemblies
      a. Holding frames shall be constructed from heavy gauge galvanized steel. They shall be equipped with polyurethane foam gaskets, fasteners and filter centering dimples. The inline depth shall not be less than 2.75 inches in order to effect adequate bearing surface for built-up filter banks.
      b. Filter fasteners shall be capable of being installed without the requirement of tools, nuts or bolts. The holding frame shall be designed to accommodate standard size filters with the application of the appropriate type fastener.
      c. The filter racks shall be designed to use standard 24 inches x 24 inches filters only. Holding frame assemblies shall be sized to accommodate enough filter area to yield 550 FPM or less at design airflow through the filters.
         1) Exception: Filters of one size other than 24 inches x 24 inches shall be allowed in AHU-1-1 if needed to satisfy spatial constraints in AHU enclosure.
      d. Accessible: Front or side.
   2. Media: 15” Bags
   3. Filter gauges: Provided under Division 25.

G. Dampers
   1. Low leakage parallel blade dampers
   2. Linkage concealed in frame (exposed linkage not acceptable)
   3. Return air

a. Equal to Ruskin CD-60
b. Parallel blade

4. Economizer Outdoor air
   a. Equal to Ruskin CD-50
   b. Parallel blade
5. Relief air
   a. Equal to Ruskin CD-60
   b. Parallel blade
6. Damper configuration
   a. Each section shall be designed to be operated by a separate direct coupled actuator. Jackshafts and external linkage shall not be used. Provide space between damper sections to allow for side-mounted direct-coupled actuator.
   b. Do not interlink economizer outdoor air and return air dampers. Each shall operate independently.
   c. Economizer outdoor air and return airflow shall be directed into each other. Provide vertical blades if required.
7. Actuators are specified under Section 250000 BAS.

H. Electrical Power and Controls
1. Power connection
   a. Single point 460/3/60 power connection for AHU.
   b. Provide non-fused disconnect.
2. Provide stepdown transformer with 120V/1 connection for lighting and controls.
3. Provide overcurrent protection for all branch circuits.
4. VFDs are specified with integral circuit breakers and do not need upstream fuses/circuit breakers. If multiple fans are provided downstream of VFDs, each shall have its own motor circuit protector.
5. All wiring and electrical equipment supplied by the manufacturer shall conform to and be installed in accordance with the requirements of UL 1995.
6. Provide copper wires, bus bars, and fittings throughout, except internal wire of the control transformer may be aluminum if copper termination is provided. Identify power supply terminals with permanent markers. The maximum temperature of terminals shall not exceed 167 degrees Fahrenheit when the equipment is tested in accordance with its rating.
7. Service Lights
   a. Marine style in each section with external switches
   b. If unit requires splitting, boxes shall be furnished at each section to allow the electrical contractor to make final connections in the field. Wiring shall be clearly labeled at junction points to facilitate reconnection.
8. Variable speed drives
   a. Comply with Variable Speed Drive herein.
   b. Mounted on unit exterior.
9. Controls
   a. Controls specified under Division 25 Building Automation Systems
   b. Coordinate control panel location with Division 25 contractor.

2.2 FANS (GENERAL)

A. Fans shall be tested and rated in accordance with AMCA Standards and shall bear AMCA Labels
B. Wheels shall be balanced statically and dynamically, free from vibration or noises
C. Bearings self-aligning, ball-bearing type, complete with grease fittings, extended to single point on drive side or to accessible location
D. Actual brake horsepower of fan and drive shall not exceed nameplate rating of motor driving fan
E. Provide adjustable sheaves for one-to-two-strand belt drives on motors 15 HP or less. Sheaves shall be selected to operate at mid-point of fan curve to allow adjustment in both directions. For belt drives with more than two strands serving motors over 15 HP, provide fixed sheaves. Replace fan sheaves as necessary to obtain desired results.

2.3 MOTORS

A. General:
   1. In accordance with NEMA, IEEE, and ANSI C50 standards
   2. Sized to operate driven devices under all conditions without overload
   3. Minimum service factor: 1.15
   4. Type:
      a. 1/2 horsepower and smaller: AC motor single-phase, 60 hertz, NEMA rated for 110 volt, with built-in overload protection
      b. 3/4 horsepower and larger: AC motor 3 phase, 60 hertz, AC motor, NEMA rated for 460 volt or as available
      c. Motors 50 horsepower and over: Reduced voltage start, suitable for star-delta starting
B. Enclosure:
   1. Open drip-proof (ODP): Provide ODP motors unless otherwise indicated
   2. Totally enclosed (TEFC):
      a. Motors outside the building or otherwise exposed to the weather
      b. Non-ventilated: under ½ horsepower
      c. Fan-cooled: ½ horsepower and larger
C. Efficiency:
   1. Motors 1 horsepower and larger shall be NEMA Premium™ labeled and have guaranteed efficiencies equal to or exceeding NEMA Table 12-6D.
D. Motors driven by variable frequency drives:
   1. Shall meet the requirements of NEMA MG-1 part 31.40.4.2.
   2. Where used for pumps or fans (variable torque), shall have minimum 10:1 turndown and be capable of operating at 10 percent speed indefinitely.

2.4 VARIABLE SPEED DRIVES

A. ABB, Danfoss, Cerus, equal
B. Electrical Characteristics
   1. Efficiency shall be not less than 97% at rated voltage, current, and frequency and fundamental power factor shall not be less than 98% at all speeds and loads.
   2. Provide as a minimum 5% impedance line reactors. The 5% impedance may be from dual (positive and negative DC bus) reactors or 5% AC line reactors. VSDs with only one DC reactor shall include AC line reactors.
   3. VSD shall automatically mitigate harmonics throughout the effective load range using Swinging chokes or other devices designed to lower harmonics when VSD is at partial loads.

4. Include Ferrite Core EMI/RFI/Common mode filters. The onboard filters shall allow the VSD assembly to be CE Marked and the VSD shall meet product standard EN 61800-3 for the First Environment restricted level (Category C2).

C. Features and Accessories
1. Plain language LCD display (code numbers not acceptable); all set-up parameters, indications, faults, warnings, and other information must be displayed in words, not codes
2. Displays and meters for the following
   a. Output voltage
   b. Output frequency
   c. Motor rpm
   d. Motor current
   e. Motor watts
   f. Speed signal input
   g. Last three faults
3. HOA switch and speed potentiometer
4. Input line fuses
5. Adjustable or multiple carrier frequencies up to 12 kHz. Include a carrier frequency control circuit that reduces the carrier frequency based on actual VSD temperature that allows the highest carrier frequency without derating the VSD or operating at high carrier frequency only at low speeds.
6. Isolated 4-20 mA or 0-10 Vdc speed signal input. If the input reference is lost the VSD shall, based on user selectable option, either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the speed based on the last good reference received, or (4) cause a warning to be issued.
7. Analog outputs for kW and speed; kW shall be accurate to ±3%
8. Digital outputs for alarm and motor on/off status; latter shall be based on field adjustable motor current that can indicate broken belt or coupling
9. Auto-restart after trip due to
   a. Overcurrent
   b. Under-voltage
   c. Over-voltage
   d. Over-temperature
   e. Auto-restart upon correction of causative condition
   f. Include a maximum of 3 restart attempts for over-current only, with VFD shutting down and requiring manual restart after the third attempt; the attempt counter shall reset after 10 minutes of successful operation
10. Automatic limit speed to prevent over-current on pumps or fans with overloading characteristics
11. Provide manual bypass as indicated in Energy Conservation Measures above
12. Controls
    a. Provide a minimum of three digital outputs that can be programmed for multiple purposes and also controlled through the BAS network interface device by the BAS independent of other VSD functions or status. Control sequence possibilities shall include:
       1) Contact to open fan discharge damper either with fan start or independent of fan operation, controlled via the BAS and wait for the damper end switch to make before

starting the drive; this shall function in the normal drive mode, bypass mode (if bypass is provided), and life safety mode (if part of smoke control system).

D. Equipment Protection and Safeties
   1. VFDs short-circuit interrupting rating shall equal or exceed the fault current available at the drive.
   2. VFD shall protect itself against all normal transients and surges in incoming power line, any grounding or disconnecting of its output power, and any interruption or run away of incoming speed signal without time delay considerations. Protection is defined as normal shutdown with no component damage.
   3. The VSD shall be capable of sensing a loss of load (broken belt / broken coupling) and signal the loss of load condition. The VSD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. Relay output shall include programmable time delays that will allow for drive acceleration from zero speed without signaling a false underload condition.
   4. VFD must protect itself against all phase-to-phase or phase-to-ground faults.
   5. VFD shall be able to start into a rotating load at all speeds (forward or reverse) without trip.
   6. Anti-regeneration circuit shall match the deceleration rate of the drive to that of the motor to prevent high bus voltage shutdown common to high inertia loads, such as fans.
   7. VFD shall ride through an input power dip of 3 cycles without trip.
   8. VSD shall operate properly at a -35% to +30% voltage fluctuation from rated voltage.
   9. VSD shall operate properly at a 10 percent frequency variation from rated frequency.
   10. VFD shall employ three current limit circuits to provide trip-free operation: slow current regulation, rapid current regulation, and current limit switch-off limit. VFD shall be designed so that overcurrent trip shall be at least 315% of the drive's current rating.
   11. VSD shall have the ability to set a maximum current available to the motor.
   12. VSD shall withstand unlimited switching of the output under full load, without damage to the VSD. Operation of a disconnect switch between the motor and VSD shall not have an adverse effect on the VSD, whether the motor is operating or not. Controls conductors between the disconnect and the VSD shall not be required for the safe and reliable operation of the VSD.
   13. The VSD shall withstand switching of the input line power up to 20 times per hour without damage to the VSD.
   14. The VSD shall be capable of operating continuously at full load in the following service conditions
       a. Ambient temp: 30 to 104 degrees Fahrenheit
       b. Relative humidity: 0 to 95 percent, non-condensing

E. Start-Up/Warranty
   1. Certified factory start-up shall be provided. A certified start-up form shall be filled out for each drive with a copy to the District and a copy kept on file by the manufacturer.
   2. Warranty shall be 24-months from date of start-up certification including all parts, labor, travel time, and expenses.

2.5 VARIABLE AIR VOLUME BOXES

A. Titus, Price Industries, Krueger, Trane, Metal Aire, Envirotech or equal
B. Maximum damper leakage at damper closure to be 3% of rated CFM at 2" static pressure
C. Maximum casing leakage: 7 cubic feet per minute leakage at 1.50 inches water column.

D. No cooling-only box requiring greater than 0.4 inches of total pressure drop at design air flows will be accepted. No greater than 0.5 inches total pressure drop shall be allowed for reheat boxes. (Total pressure drop is static pressure drop plus velocity pressure drop.)
E. Provide access doors to all boxes for inspection of internal components such as dampers and reheat coil
F. Standard internal liner
G. Velocity pressure sensor with a minimum average amplification factor of 2 for box sizes 6” to 16”
H. Single duct
    1. Price SDV or equal
    2. Reheat coils where used: 2 row
    3. HW coils and discharge plenum shall be one size larger than standard (Price HSG option; e.g. for an 8” inlet, use plenum and coil normally used with 10” inlet box). The discharge plenum OD may be equal to the coil OD. The intent is to reduce pressure drop of the coil and plenum and improve HW ΔT.
I. Digital Controls: See Section 250000.

2.6 AIR OUTLETS

A. Titus, Price, Krueger, Metal-Aire
B. See Paragraph 1.1G.71.1G.7 for styles.

2.7 PIPE MATERIALS AND JOINING SYSTEMS

A. Piping materials shall be Schedule 40 Black steel or Type "L" Copper at contractor’s option.
B. Joint System:
    1. Steel: welded or grooved (Victaulic)
    2. Copper:
        a. Hard temper
        b. Wrought-copper, solder joint fittings, ANSI B16.22
        c. 95/5 tin/antimony solder
C. Piping may be run exposed on the roof provided:
    1. Insulation is protected from weather
    2. The overall height of piping is not visible from the street level or from any window
    3. Piping does not interfere with access to any equipment on the roof

2.8 PIPE FITTINGS & ACCESSORIES

A. Piping system components shall be selected for maximum design operating pressure based on static head, shutoff pump head, and pressure relief valve setting.
B. Gauges:
    1. Pressure/Temperature Test Plugs: "Pete’s Plug" fittings, solid brass with Nordel valve core (or neoprene valve core for chilled water or condenser water) fitted with a color coded and marked cap with gasket.
C. Shut-off Valves:
    1. Nibco or equal
    2. Ball or butterfly valves only
    3. Valves used for balancing shall have infinite position handles with memory stop
    4. Ball valves

a. Full Port 1/2 to 1 inch; Standard Port 1-1/4 and larger
b. Stainless steel ball and stem

5. Butterfly valves
   a. Removable seats
   b. Valve stem shall be fastened to the disc so that no liquid can reach the stem
   c. External fasteners such as roll pins, cotters, keys, or set screws will not be allowed
   d. Butterfly valves shall be lug type; no wafer type valves allowed
   e. Provide manual gear operator for butterfly valves 8" and larger
6. Extended neck model for all insulated lines
7. Provide chain operators on all valves located higher than 7 feet above access level

D. Pipe Supports:
   1. Kin-line, Superstrut, or equal
   2. Where pipe is insulated, protect insulation at hangers by installing a 22 gauge shield and clamp sized to allow pipe insulation to pass continuously through the hanger. For piping 2" and larger, provide 360 degree high density calcium silicate insert within shield.

E. Escutcheons: Provide stainless steel escutcheons at piping penetrations of walls where exposed public view and required for proper appearance. Provide galvanized steel escutcheons at penetrations of masonry walls elsewhere. Escutcheons not generally required at drywall penetrations where not exposed to public view.

F. Sleeves:
   1. Provide sleeves where pipes pass through floors above grade, roofs, poured-in-place masonry walls, and exterior walls.
   2. Sleeves shall be standard weight steel pipe, except sleeves for concealed piping through floors not in structural members may be 25-gauge galvanized sheet metal.
   3. Floor sleeves for piping shall extend from the bottom of the slab to 2-inches above the finished floor.
   4. Seal between piping and sleeve with fire-rated caulk at all penetrations of fire-rated partitions and floors.
   5. Make sleeves through outside walls watertight. Caulk between uninsulated pipe and sleeve.
   6. Size sleeves for insulated pipes to allow full thickness insulation.

G. Flexible Pipe Couplings
   1. Mason Industries Masonflex model SFDEJ or equal, Multi-Layered Kevlar Peroxide Cured EPDM, twin-sphere connector with limit bolts or cables.

H. Strainer
   1. None required.

2.9 VIBRATION ISOLATION & SUPPORTS

A. Manufacturers
   1. Vibration Isolation:
      a. Mason Industries, Inc.
      b. Kinetics Noise Control, Inc.
      c. M.L. Saussé & Co. (Vibrex).
      d. Or equal
   2. Seismic Restraints:

a. Hangers and Snubbers: Any manufacturer who can verify compliance with SMACNA standards and the California Building Code
b. Strut: Channel Framing: Any manufacturer who can verify compliance with the CBC standards
c. Anchors: Drill in, wedge type: Any manufacturer within the ICBO standards approved for seismic
d. Snubbers: Any manufacturer within the CBC standards

B. Vibration Isolator Types:
1. Housed isolation
2. Size for weight of unit and associated items that hang from the springs
3. Spring isolators shall incorporate following:
a. All springs to be single coil steel with minimum spring coil outer diameter 0.8 of loaded operating height
b. Horizontal spring stiffness within 0.8 to 1.25 times rated vertical spring stiffness
c. Corrosion resistance where exposed to corrosive environment with:
1) Springs neoprene coated
2) Hardware cadmium plated
3) All other metal parts hot dip galvanized
d. Reserve deflection (from loaded to solid height) of 50 percent of rated deflection
e. Minimum 6mm (1/4") thick neoprene acoustical base pad on underside, unless designated otherwise
f. Designed and installed so that ends of springs remain parallel; neoprene cups not acceptable
g. Noise pads of ½ inch or 1 inch thickness below the spring base to reduce the chance that the springs shall be resonant with equipment forcing frequencies or support structure natural frequencies
h. Leveling device
i. Where operating weight differs from installed weight provide built-in adjustable limit stops to prevent equipment rising when weight is removed. Stops shall not be in contact during normal operation

C. Anchors, Inserts and Fasteners:
1. All anchors and inserts shall be installed according to the CBC standards
2. Do not use any anchor or insert in concrete which does not have a signed structurally engineered design value based on its installed application and one of the following:
a. ICBO evaluation report
b. Lab test report verifying compliance
3. Powder Actuated Anchors:
a. Hardened steel stud with threaded shank; size of shank to match hanger rod size
b. Use only with non-shock loads
c. Maximum load safety factors:
1) Maximum anchor load: 100 pounds
2) Static loads - 5
3) Vibratory loads - 8-10
d. For concrete and steel; not to be used for light weight concrete, brick or concrete block
e. 10% testing rate required, testing by contractor

4. All over-head concrete anchors or inserts shall be selected to comply with the ICBO report or CBC table for the anchor or insert
5. Torque testing of anchors shall be allowed to verify compliance of anchor installation. However, torque testing shall not justify usability of anchor. Only load or pull testing shall be allowed to justify usability of anchors. Failure of torque shall constitute failure of anchor.

2.10 DUCTWORK AND ACCESSORIES

A. Materials and joints
1. Ductwork shall be galvanized sheet metal except as noted below
   a. General: minimum G-60
   b. Exposed to weather: G-90
2. The gauge of metal, type of joints, hanging, reinforcing, and other details of construction shall conform to the SMACNA HVAC Duct Construction Standards.
3. Static pressure classes shall be as required by the fan system and acoustical requirements with the following minimums: amend this for fan duty
   a. Medium pressure within shafts: 3”
   b. Medium pressure over occupied spaces: 2”
   c. Low pressure downstream of VAV boxes: 1”
   d. Low pressure return air and exhaust air: associated return/exhaust fan static pressure
   e. Transfer ducts and other ducts not connected to fans: 0.5”
   f. Outside air ductwork: 0.5”
4. Joints
   a. Rectangular Duct
      1) Longitudinal seams shall be Pittsburgh.
      2) Transverse Joints:
         a) Medium pressure (2” and greater pressure class) ductwork shall be TDC, TDF or Duct-Mate
         b) Low pressure ductwork (<2” pressure class) shall be TDC, TDF, Duct-Mate or "S" and drive as allowed by SMACNA
   b. Round and Oval Duct
      1) Spiral
   c. Snap-lock joints not allowed
5. Fiberglass Duct: not allowed
6. Flexible Duct
   a. Flexible duct shall be listed by UL under Class One air duct and UL 181. All flexible ducts, even low pressure ducts, shall be minimum 4” pressure class to increase longevity.
   b. Insulated Flexible Duct
      1) Chlorinated polyethylene (CPE) inner liner duct permanently bonded to a vinyl or zinc coated spring steel wire helix
      2) Fiberglass insulating blanket; minimum R-value
         a) Ducts outside the conditioned space and in conditioned envelope: 4.2
         b) Ducts outside conditioned space and conditioned envelope: 8.0
      3) Low permeability outer vapor barrier of fiberglass bi-directional reinforced metallized film laminate
      4) Thermaflex M-KE or equal

c. Uninsulated Flexible Duct
   1) Woven fiberglass fabric with flame retardant coating permanently bonded to a vinyl or zinc coated spring steel wire helix
   2) Thermaflex S-LP-10 or equal
d. Aluminum duct is also acceptable provided noise criteria can be met.

2.11 FIELD-MOUNTED HEATING COILS

A. Certified by ARI per current ARI Standard 410
B. Materials
   1. Tubes:
      a. Copper
      b. Minimum 0.020" wa=ll thickness
      c. Minimum ½" OD
   2. Fins:
      a. Aluminum
      b. Minimum thickness: 0.008"
   3. Headers:
      a. Copper preferred, brass, steel or cast iron acceptable
C. Circuiting: full row
D. Mount coil section in stainless steel casing designed for bolting to other sections or ductwork.
E. Access panel for coil inspection and cleaning
F. Manufacturer
   1. Trane
   2. Carrier
   3. McQuay
   4. Temtrol
   5. Or equal

2.12 FIRE DAMPERS

A. Ratings (test conditions and label) per UL Standard 555
   1. 250 degrees Fahrenheit minimum
   2. 1-1/2 hour fire rating, unless otherwise indicated in the Drawings
   3. Dynamic (closes against air flow) where required by code or where scheduled
B. Factory sleeve
C. Damper
   1. Multi-bladed, equipped with fusible link, spring loaded type
D. Fusible link
   1. UL listed
   2. Fusible links on fire dampers shall be constructed to UL Standard 33 – Fusible Links for Fire Protection Service
   3. Temperature rating: Per code
E. Manufacturer
   1. Ruskin
   2. Greenheck

3. Air Balance Inc.
4. Pottorff
5. Or equal

2.13 FILTERS

A. Farr, Flanders, or equal
B. See Design Criteria for efficiency requirements. See Paragraph 1.1E.7
C. Construction Filters: Provide minimum 2" MERV 6 pleated filters
D. Start-up Procedures:
   1. Supply fans shall not be operated unless filters are installed.
   2. Install construction filters in front of final filters for use during test and balance period.
   3. Just prior to occupancy, remove construction filters and do not replace; only final filters will be used for normal operation.

2.14 INSULATION

A. Certainteed, Owens Corning, Manville, Knauf or equal
B. Insulation shall:
   1. Meet minimum thickness requirements of Section 120.4 of Title 24 and CMC 604.1
   2. Meet mold, humidity, and erosion resistance requirements of CMC 605.0
   3. Have flame spread not more than 25 and smoke density of not more than 50 when tested as a composite installation per CMC 602.2
C. Ductwork and Plenums
   1. In concealed spaces, including ceiling plenum: Shall be insulated with 1-1/2" Fiberglas, 3/4 lb./cubic-foot faced Duct Wrap.
   2. Exposed to outdoors: Shall be internally lined with Certainteed Toughgard Duct Liner, 1-1/2 lb. density, 2" thick.
D. HW & CHW Piping
   1. Fiberglass molded pipe insulation with all service jacket.
   2. Thickness per Title 24 requirements.
   3. All piping and devices through which water flows in normal operation shall be insulated.
      a. Exceptions:
         1) Hot water control valves
         2) Hot water piping, fittings, valves and accessories located between coils and isolation valves (for coils with 2-way valves) and between coils and control valve and bypass connection (for coils with 3-way valves) where located in the conditioned space the coil serves and exposed to occupant view
   4. Fittings
      a. Hot water: Fittings on pipe over 1/2" shall be insulated with fiberglass and finished with one piece PVC fitting cover (Zeston). Valves, flanges and irregular surfaces shall be insulated with oversized pipe covering with ASJ jacket. Exposed ends shall be finished with four ounce canvas jacket saturated in Arabol.
      b. Chilled water: Elbows shall be insulated with PVC fitting covers (Zeston) with all joints and overlaps taped with Zeston PVC vapor barrier tape. Valves and fittings shall be insulated with fiberglass oversized insulation or molded fittings and shall be coated with two coats of Foster vapor barrier mastic reinforced with glass fabric. Butt ends of insulation shall be sealed off at 21 ft. intervals maximum or at fittings, with Foster 30-

35, or equal. Vapor barrier is to be continuous. Insulation is not required at coil headers where condensation will drip into coil drain pan.

5. Weatherproof jacket for outdoor piping
   a. Corrugated aluminum jacket
      1) 0.016 inch thick
      2) Moisture barrier adhered to inside face
      3) Longitudinal seams on bottom
   b. Secure to insulation with aluminum or stainless steel bands

2.15 ELECTRICAL WORK:

A. All electrical materials and installation provided under this division shall comply with the requirements of the California Electrical Code.

B. Wiring in exposed areas (e.g. outdoors or in electrical and mechanical rooms) shall be in conduit. Plenum cable may be used for low voltage wiring above ceilings or in ductwork as allowed by code.

C. All control wiring shall be 120V and less. All wiring for voltages higher that 30 volts shall be installed by a licensed electrician.

2.16 STRUCTURAL MATERIALS:

A. Expansion anchors
   1. Provide all material, labor, equipment and services necessary for the installation of post-installed expansion anchors.
   2. Standards: Comply with the following applicable standards unless otherwise specified herein:
      a. CBC - California Building Code, 2019 Edition with DSA amendments.
      b. ACI, American Concrete Institute Standards.
   3. Tests and Inspections:
      a. Notification:
         1) The Contractor shall notify the District's Testing Agency of work required to be tested and inspected. Notification shall be sufficiently in advance to allow scheduling of tests and inspections, but not less than 24 hours.
         2) The Contractor shall immediately notify the Architect if the District's Testing Agency indicates that quality assurance tests and inspection requirements have not been met.
      b. District's Quality Assurance Tests and Inspections:
         1) General: Quality assurance tests and inspections shall be the responsibility of the District. The District shall retain a testing agency, referred to herein as the District's Testing Agency, who shall perform the required tests and inspections, prepare written summary reports of tests and inspections, and review submittals.
         2) The District's Testing Agency shall provide special inspection to verify compliance with the specifications and the product's ICC-ES or IAPMO-UES report the for following items:
            a) Drill type, diameter, bit type, and setting.
            b) Hole diameter, depth, and accuracy of location.
            c) Cleanliness and surface preparation of holes.
            d) Expansion anchor type and size.
            e) Installation of expansion anchors.
            f) Measured maximum installation torque.

3) The District's Testing Agency shall conduct static tension load tests on installed anchors. Test 50% of each diameter of anchor, or test as scheduled on the Drawings. Tests shall be in accordance with ASTM E 488, "Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements".
4) Tests shall not begin until one full day after anchor installation.
5) Scheduled test load shall be applied for 15 seconds during which the maximum allowable slip shall be 1/8 inch.
6) If an anchor fails the tension load test, additional expansion anchors shall be tension load tested until 20 consecutively successful tests have been performed.
7) Engineer of Record should be contacted immediately to be informed of failed anchor tension tests. Contact Engineer for tension load tests for replacement expansion anchors.
8) The District's Testing Agency shall develop and utilize an effective method of field marking locations and results of expansion anchor tests.
   a) Field marking for test locations shall not affect exposed concrete appearance.
   b) A detailed drawing record of test locations and results shall be acceptable.

4. Anchors shall be wedge-type anchors made from carbon steel or stainless steel as indicated on the contract documents, and shall have been tested in accordance with ACI 355.2 'Cracked Concrete' (seismic) requirements. Anchors shall be carbon steel or stainless steel.
5. Expansion anchors for use in normal weight concrete:
   a. Hilti Corporation's "Kwik Bolt TZ" (ICC-ES Report ESR-1917).
   b. Simpson Strong-Tie's "Strong-Bolt 2" (ICC-ES Report No. ESR-3037).
6. Patching Mortar: BASF's "EMACO S66 CI", Sika Corporation's "SikaRepair 223", Simpson Strong-Tie's 'FX-263' or equal.
7. Damaged Reinforcement:
   a. Damage to existing reinforcement shall be considered defective work.
8. Surface repairs and filling of abandoned holes
   a. Clean and repair surfaces damaged by drilling or installation. Cleaning and repairing requirements shall be as directed by the District's Representative.
   b. Where expansion anchors have been removed, abandoned holes shall be filled with patching mortar in accordance with the manufacturer's recommendations.
9. Correction of defective work
   a. Correction of defective work shall be the responsibility of the Contractor.
   b. Work not in compliance with the requirements of the Contract Documents shall be considered defective, unless otherwise directed in writing by the District's Representative.
   c. Corrected work shall conform to the requirements of the Contract Documents.
   d. The Contractor shall prepare a submittal documenting the defective work and proposed corrections and submit to the District's Representative for review. The submittal shall include a description of the defective work, the location of defective work, and shall be accompanied by supporting sketches, photographs, or both. Additionally, the submittal shall include similar documentation of the Contractor's proposed corrections.
   e. Correction of defective work shall not commence until the District's Representative has reviewed and accepted the submittal.
   f. Correction of defective work shall be inspected by the District's Testing Agency.

B. Concrete

1. Provide all material, labor, equipment and services necessary for the installation of all concrete work.
2. Standards: Comply with the following applicable standards unless otherwise specified herein:
   a. CBC - California Building Code, 2019 Edition with DSA amendments.
   b. ACI, American Concrete Institute Standards.
3. Tests and Inspections: Tests and inspections to be done by the District's Testing Agency shall include the following:
   a. Review of materials and mix design
   b. Special inspection of concrete placement
   c. Make concrete cylinder specimens and perform compression tests
   d. Make slump tests
4. Cement: Portland cement, ASTM C150, Types I or II.
5. Fly Ash: ASTM C618, Class F, as supplied by Pozzolanic International, Western Ash, or equal. At the Contractor's option, fly ash may be added to all concrete at the maximum rate of 25% replacement by weight of the scheduled amount of cement.
6. Aggregate: ASTM C33.
7. Water: Clean, potable and free from deleterious material.
8. Admixtures:
9. Water Reducing Admixtures: ASTM C494, Type A.
10. Concrete Classes:

Concrete Class and Location	**Maximum Size of Aggregates (inches)**	**Minimum 28-day Strength (psi)**	**Special Requirements**
Stone Aggregate Concrete			
Slabs-on-grade and curbs, sitework	1	4,000	

11. Construction practices and workmanship shall conform to Code Requirements for Reinforced Concrete, ACI Standard 318, and these specifications.

C. Concrete reinforcement
1. Provide all material, labor, equipment and services necessary for the installation of all concrete reinforcement, complete, as shown and as specified.
2. Standards: Comply with the following applicable standards unless otherwise specified herein:
   a. CBC - California Building Code, 2019 Edition with DSA amendments.
   b. ACI, American Concrete Institute Standards.
   c. CRSI, Concrete Reinforcing Steel Institute, "Manual of Standard Practice."
   d. ASTM, American Society for Testing and Materials.
   e. AWS, American Welding Society, D1.4 "Structural Welding Code Reinforcing Steel."
3. Tests and Inspections: Tests and inspections to be done by the District's Testing Agency shall include the following:
   a. Review of mill certificates.

b. Inspection of welding of reinforcing steel.
c. Inspection of reinforcing steel placement.
d. Inspection of mechanical splice installation.

4. Reinforcing Steel: ASTM A615 Grade 60. ASTM A706 with carbon equivalent not to exceed 0.55 for welded bars.
5. Reinforcing bars shall be of size shown on the Drawings, accurately placed as to spacing and clearance and securely tied at intersections and supports with wire, and in such a manner as will preclude displacement during pouring of concrete. Placing tolerances shall be in conformance with the requirements of ACI 301.

D. Concrete formwork
1. Provide all material, labor, equipment and services necessary for the installation, shoring, bracing and removal of all concrete formwork.
2. Standards: Comply with the following applicable standards:
a. CBC - California Building Code, 2019 Edition with DSA amendments.
b. ACI, American Concrete Institute Standards.
c. CCR - California Code of Regulations, Title 8, Division 1, Chapter 4, Subchapter 4, "Construction Safety Orders," 1990 Edition with latest amendments.
d. APA, American Plywood Association, "US Product Standard PS-1 for Construction and Industrial Plywood."
3. Wood forms:
a. Wood forms shall be Douglas fir plywood, 5 ply, 3/4 inch, B-B plyform, Class I, exterior type, edges sealed. Oiling of forms will not be permitted.
4. All concrete work, except footings and grade beams where forming is optional, shall be formed to the shapes, sizes, lines and dimensions shown on the Drawings.
5. The design, construction and maintenance of the formwork shall insure compliance with the tolerance limits specified in ACI 347.

E. Structural steel
1. Provide all materials, labor, equipment and services necessary for the fabrication, erection and completion of all structural steel.
2. Exposed structural steel shall have the following requirements:
a. Special paints and primers.
b. Welds to be ground smooth.
3. Standards: Comply with the following applicable standards:
a. CBC - California Building Code, 2019 Edition with DSA amendments.
b. AISC - American Institute of Steel Construction's "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings," latest edition.
c. AISC - American Institute of Steel Construction's "Code of Standard Practice for Steel Buildings and Bridges," latest edition.
d. AWS - American Welding Society's "Structural Welding Code AWS D1.1, 2011 Edition.
e. ASTM - American Society for Testing and Materials.
f. SSPC - Steel Structures Painting Council.
4. Tests and Inspections to be done by the District’s Testing Agency shall include the following:
a. Review of mill certificates
b. Review of welding procedures and welder’s qualifications
c. Review of certificates for welding electrodes

d. Inspection of all welding

5. Structural Steel Shapes and Plates: ASTM A572 Grade 50, typical unless noted.
6. Steel Tubing: ASTM A500, Grade B.
7. Steel Pipe: ASTM A53, Grade B
8. Machine Bolts: ASTM A307
9. Arc-Welding Electrodes: Filler metals shall conform to Table 3.1 of AWS D1.1.
10. Hot-dip galvanize all exterior exposed steel in accordance with ASTM A123. Thickness of galvanized coating shall be in conformance with Tables 1 and 2 of A123.
11. Workmanship and details of structural steel work shall conform to the Uniform Building Code and the AISC Specification for Design, Fabrication and Erection of Structural Steel for Buildings.
12. The quality of materials and the fabrication of all welded connections shall conform to the American Welding Society's Structural Welding Code, AWS D1.1.

PART 3 - EXECUTION

3.1 RECORD DRAWINGS

A. Keep an accurate dimensional record of installed systems and equipment. Maintain a set of record ("as-built") drawings up-to-date as construction progresses. Drawings shall be maintained at the jobsite and available for inspection by the Engineer, and District's representatives.

3.2 PROTECTION OF WORK DURING CONSTRUCTION

A. Protect from damage, water, dust, etc., material, equipment and apparatus provided under this Division, both in storage and installed, until Notice of Completion has been filed.

B. Provide protective covers, skids, plugs or caps to protect equipment and materials from damage and deterioration during construction. Protect exposed coils with plywood or other suitable rigid covers to avoid damage to fins.

C. Protect existing walls, doors, carpeting, etc. from damage. Any damage must be repaired at no cost to the District.

D. Cover motors and other moving machinery to protect from dirt and water during construction.

E. During transport to and storage on the construction site, and during rough-in until final connections are made, all ductwork and other related air distribution component openings shall be covered with plastic to prevent contamination from dust, water, and debris.

F. Keep openings in piping closed to prevent entrance of foreign matter.

G. Material, Equipment or Apparatus:

1. Material, equipment or apparatus damaged because of improper storage or protection will be rejected.
2. Remove damaged material, equipment or apparatus from site and provide new, duplicate, material, equipment or apparatus in replacement of that rejected.
3. Porous materials, such as duct liner, shall be protected from weather. If such material becomes wet during construction, it shall be removed and replaced at no cost to the District; drying is not sufficient due to possible microbial contamination.

3.3 INSTALLATION AND WORKMANSHIP

A. All equipment and material shall be installed in a neat and workmanlike manner.

B. Repair all damaged or temporarily removed walls, roofs, roofing, equipment, etc.

C. Follow manufacturer's installation instructions and recommendations.

D. All equipment must be anchored to the building. All hung equipment shall incorporate vibration isolation.

3.4 PIPING

A. Install pipes and pipe fittings in accordance with recognized industry practices which will achieve permanently leak resistant piping systems, capable of performing each indicated service without piping failure. Install each run with minimum joints and couplings but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated by use of reducing fittings. Align piping accurately at connections, within 1/16-inch misalignment tolerance.

B. Escutcheons: Provide stainless steel escutcheons at piping penetrations of walls where exposed public view and required for proper appearance. Provide galvanized steel escutcheons at penetrations of masonry walls elsewhere. Escutcheons not generally required at drywall penetrations where not exposed to public view.

C. Sleeves:
   1. Provide sleeves where pipes pass through floors above grade, roofs, poured-in-place masonry walls, and exterior walls
   2. Sleeves shall be standard weight steel pipe, except sleeves for concealed piping through floors not in structural members may be 25-gauge galvanized sheet metal
   3. Floor sleeves for piping shall extend from the bottom of the slab to 2-inches above the finished floor
   4. Seal between piping and sleeve with fire-rated caulk at all penetrations of fire-rated partitions and floors
   5. Make sleeves through outside walls watertight. Caulk between uninsulated pipe and sleeve
   6. Size sleeves for insulated pipes to allow full thickness insulation

D. Application of Piping Accessories
   1. This section establishes minimum requirements for installation of valves and other piping accessories. Additional devices may be installed as deemed necessary by the Contractor.
   2. Thermometers
      a. Heat exchanger inlet and outlet
   3. Test plugs
      a. Inlet and outlet of all heat exchange devices including where fixed gauges are installed
      b. At piping temperature sensor wells (for sensor calibration)
   4. Coils, condensers, and heat exchangers
      a. Isolation valves for each coil (individually at multi-coil banks)
      b. Test plugs at inlet and outlet coil (individually at multi-coil banks)
      c. Drains with ball valve and hose connection with cap
      d. Control or auto-isolation valves (if required herein), with reducers as required
      e. Balancing Valves (as required): Do not use balance valves as isolation valves unless valves have handles and memory stops.

3.5 DUCTWORK

A. Install per SMACNA Standards.

B. Rectangular and medium pressure duct bends greater than 45 degrees shall be curved sections, the center line radius of which shall not be less than 1-1/2 times the width of the duct in the plane of the bend. Where required due to space constraints, short radius elbows with duct splitter(s) may be used. No capped “bullhead” tees or short-radius tees permitted. On low pressure ducts, square

elbows with single width turning vanes may be used. Round duct elbows may be adjustable type on low pressure systems only, with gores sealed.

C. Flexible Duct
   1. Flexible duct length shall be not exceed 5 feet.
   2. Ducts shall be supported as required by the CMC.
   3. Flexible duct shall not be used on medium pressure duct systems upstream of VAV box connections. (Hard duct connections to VAV boxes are required to improve inlet conditions to VAV box, reduce break-out noise, and to ensure that pressure drop is low.)

D. Grille connections (except grilles exposed to occupant view)
   1. Provide flexible duct connections, minimum 5 feet.
   2. Provide at entry to diffuser collar either:
      a. Straight duct for 1 duct diameters or greater
      b. Full radius elbow
      c. Side inlet plenum
         1) Height: 4 inches minimum taller than top of grille to provide room for uniform airflow to grille
         2) Width/length: 2 inches wider than duct or round diffuser collar, whichever is larger
         3) Internal surfaces lined with minimum 1/2 inch thick duct liner as specified herein.
         4) At contractor's option, where plenum is required at round neck diffuser, square neck diffuser with length and width equal to diffuser diameter may be substituted
      d. Equal to Thermaflex FlexFlow Elbow
   3. Connections at grilles shall be insulated to the extent the duct is insulated including the final register box
   4. Seal connections at grilles per seal class of upstream ductwork

E. Ductwork Sealing
   1. Comply with
      a. Title 24 Energy Standards
      b. UL 181, 181A and 181B
   2. Ductwork shall be sealed per SMACNA sealing classes as follows
      a. Return air ducts and low pressure supply air ducts exposed in conditioned space: Seal Class C
      b. Transfer boots: None
      c. All else: Seal class A
   3. The gores of gored elbows and end caps shall be sealed.
   4. Seal using one of the following:
      a. Duct Sealing Compound
      b. Gasketed TDC or Duct-Mate
      c. Two-Part Hard-Setting Joint Tape
      d. Rolled Elastomeric Duct Sealant if and only if
         1) Joint is not exposed to occupant view
         2) Pressure class is less than 2 inches
         3) Surface is clean, dry, and grease/oil-free
         4) Extensive pressure is applied, working the tape into the duct surface using an application tool recommended by the Rolled Elastomeric Duct Sealant manufacturer.

5. Flexible ducts shall be connected using Panduit strap on the inner liner, sealed with tape, then the outer liner shall be sealed with tape.

F. Ducts exposed to weather
   1. Make ducts subject to rain watertight.
   2. Construct as follows to assure water run-off
      a. Arrange standing seams to not act as dams
      b. Longitudinal seams at bottom of duct
      c. Construct all ducts subject to rain watertight and to ensure water runoff by one or more of following techniques
         1) Slope entire top of duct down toward side
         2) Vertical struts within duct to bow top panels of duct into convex shape
         3) Provide vee-shaped “hat” over top of duct
   3. Seal as follows:
      a. TDC or Duct-Mate joints: Utilize interior joint gasket material plus a bead of butyl rubber sealant at the joint and continuous metal clip or cleat over the top of all four joints (top bottom and sides).
      b. Apply two part hard-setting joint tape to
         1) Horizontal joints
         2) Transverse joints
         3) TDC or Duct-Mate joints
         4) Duct penetrations
         5) Screws through duct

3.6 FIRE DAMPERS

A. Install fire dampers in accordance with manufacturer’s written installation instructions

B. Provide access door in duct adjacent to each location where damper may be inspected and internal fusible link of fire-stat may be replaced.

3.7 SEISMIC CONTROL

A. Install seismic restraints for pipes, ducts and equipment per CBC and SMACNA or Mason Industries Guidelines for pipe and duct bracing.

B. Design and provide restraints to prevent permanent displacement in any direction caused by lateral motion, overturning, or uplift:
   1. Calculations required for supports and bracing for situations not covered by referenced guidelines.
   2. Include horizontal and vertical reaction loads at connections to building structures for all seismic restraints, including those covered by referenced guidelines. Coordinate reaction loads and attachment details with structural engineer for building.
   3. Calculations made and signed by registered structural engineer knowledgeable in seismic design:
      a. Hired under this Section of work
      b. Cost of calculations borne under this Section

C. Provide resilient restraining devices as required to prevent equipment motion in excess of 1/4 inch

D. Coordinate seismic bracing requirements to result in:
   1. Vertical pipe and duct restraints to coincide with and take place of required hangers

2. Longitudinal pipe bracing to coincide with required pipe anchors

E. Bracing shall not short circuit vibration isolation systems or transmit objectionable vibration or noise

3.8 VARIABLE AIR VOLUME BOX MOUNTING AND ALIGNMENT

A. Support VAV boxes at four corners with minimum, 1" x 18 gage sheet metal straps or 3/8 inch all-thread rod. Secure lower end of strap to the side of unit casing with minimum two #10 sheet metal screws, or bolt through casing with washers to prevent leakage. Bend end of strap and secure to bottom of casing with one #10 sheet metal screws.

3.9 VIBRATION ISOLATION

A. Vibration isolation requirements shall be as required to meet sound and vibration design constraints. See Section 1.1C.

B. Installation:

1. Install isolators and seismic restraints in accordance with manufacturer's written instructions
2. Vibration isolators must not cause any change of position of equipment or piping resulting in piping stresses or misalignment
3. Make no rigid connections between equipment and building structure that degrade noise and vibration isolation system herein specified:
    a. Electrical conduit connections to isolated equipment shall be flexible liquid tight conduit of sufficient length to incorporate a right angle bend, an offset of not less than 8 inches or a loop to allow free motion of isolated equipment.
    b. Coordinate work with other trades to avoid rigid contact with the building. Inform other trades following work, such as plastering or electrical, to avoid any contact which would reduce the vibration isolation.
4. Verify that all installed isolators and mounting systems permit equipment motion in all directions

3.10 CLEANING

A. Thoroughly clean all equipment, ducts, etc. free of dust, scale, filings, plaster, grease, oil, paint and other construction debris.

B. No construction materials, debris, dirt, etc. shall remain in any area, including both tenant areas and mechanical areas, during College operations. Clean up all areas prior to start of College operations. See 1.12B.1.

C. Water systems

1. Flush and drain all new rooftop piping with a temporary hose connection before connecting to existing system. Coordinate with building engineering staff to add chemical inhibitors to account for added water in new piping.
2. After all first and second floor piping components have been replaced, test water chemistry and add chemical inhibitors as necessary.
3. The cost of chemical treatment and testing resulting from retrofit work shall be borne by contractor.

D. Ducts:

1. Vacuum any visible debris from inside ducts, duct plenums and grille boxes.
2. Use connected fan(s) to blow air through all duct systems until they are free of all foreign materials.

3.11 EQUIPMENT AND PIPING IDENTIFICATION

A. Equipment:
   1. All mechanical equipment shall be identified by nameplates securely fastened in a clearly visible location to the equipment housing or frame. Nameplates shall include the equipment design plan mark and brief description of the area or system served, such as: "AC-1: SOUTH LOBBY". Provide additional nameplates on face of starters or variable speed drives provided under this Section.
   2. Nameplates shall be 2-1/2" x 3/4" minimum, either 1/6" thick Bakelite with engraved white core letters and beveled edge, or aluminum with black enameled background and etched or engraved natural aluminum lettering.
   3. Manufacturer's nameplate shall be clean and legible and installed in a clearly visible location.

B. Piping:
   1. Identify piping with symbol identification (e.g. CHWS) and direction of flow arrows, complying with ANSI A 13.1 color standards.
   2. Identify piping at approximately 25' centers where unconcealed Concealed piping above inaccessible ceilings shall be identified at each access panel. Concealed piping above accessible ceilings shall be identified within 10 feet of each wall penetration (both sides of walls).
   3. Where capped piping is provided for future connections, provide legible and durable metal tags indicating symbol identification.
   4. Printed labels with colored background and attaching strap: Seton, W. Brady, or equal.

C. Valves: Tags not required

D. Warning Signs:
   1. Provide warning signs at all equipment driven by electric motors which are controlled by fully automatic starters, General Industry Safety Orders.
   2. Provide refrigeration system labeling per ASHRAE Standard 15-1992, section 13.1.

3.12 PAINTING

A. Painting under this Section:
   1. Interior of ductwork at new air outlets as far back as visible from occupied spaces:
      a. Flat black
   2. Marred surfaces of factory painted equipment:
      a. Spot coat to match adjacent coat

B. Execution:
   1. Protect flooring and equipment with drip cloths
   2. Paint and materials stored in location where directed
   3. Oily rags and waste removed from building every night
   4. Wire brush and clean off all oil, dirt and grease areas to be painted before paint if applied
   5. Workmanship:
      a. No painting or finishing shall be done with:
         1) Dust laden air
         2) Unsuitable weather conditions
         3) Space temperature below 60 degrees F
      b. Pipes painted containing no heat and remain cold until paint is dried

c. Paint spread with uniform and proper film thickness showing no runs, sags, crawls or other defects
d. Finished surfaces shall be uniform in sheen, color, and texture
e. All coats thoroughly dry before succeeding coats are applied, minimum 24 hours between coats
f. Priming undercoat of slightly different color for inspection purposes

6. Piping continuously painted in all exposed areas

C. Paint:
1. High gloss medium or long alkyd paint
2. Best grade for its purpose
3. Deliver in original sealed containers
4. Apply in accordance with manufacturers instructions

D. Colors:
1. Color coding as follows on Sherwin Williams, "Kem Lustral" or "Metalalistic II" name and figure numbers
a. Condenser water piping --- PALE GREEN, F65G42
2. Interior of ductwork as far back as visible from outside: flat black
3. Uncoated hangers, supports, rods and insets: dip in zinc chromate primer

E. Factory finish:
1. Steel air outlets in acoustical tile ceilings: baked white enamel
2. Aluminum air outlets: anodized
3. Exposed fan coil units: baked enamel
4. Unit ventilators and unit heaters: baked enamel

F. Marred surfaces of prime coated equipment and piping: spot prime coat to match adjacent coat

3.13 LEAKAGE TESTING

A. Testing of hydronic systems: Pressure test new rooftop piping at 1-1/2 times operating pressure, hold for one hour. No loss in pressure will be permitted. All leaks shall be repaired by tightening, rewelding or replacing pipe and fittings. Caulking of joints will not be permitted. Retest as required.

B. Duct leakage testing: Duct leakage tests are not required but the District may elect to conduct one at his cost. If tests are performed, they shall be in accordance with the SMACNA Duct Leakage Testing Manual. If duct systems do not meet the leakage classes listed in this manual at applicable duct rating pressure, leaks shall be sealed and tests rerun, both at the HVAC contractor's expense.

3.14 TESTING, ADJUSTING, AND BALANCING

A. Test and adjust all items of heating, ventilating and air conditioning system to provide design conditions
1. Testing, adjusting, and balancing 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.
2. In general, systems shall be balanced so that one or more balancing valves/dampers remains wide open; if further flow reduction is required, fan or pump speed shall be reduced or impellers trimmed (in the case of pumps).

B. Air Systems
1. Air Outlets

a. Adjust new diffusers' throw pattern prior to balance as indicated below unless otherwise indicated on Drawings. Review manufacturer's instructions for proper diffuser blade or weir gate positions to provide this throw pattern as it is not always intuitive. It is TAB contractor's responsibility to adjust throw patterns for all adjustable throw diffusers. If diffuser has a fixed throw pattern and is incorrectly installed, HVAC contractor shall correct pattern prior to balance.
    a) Star pattern diffuser deflectors shall be adjusted for corner blow pattern unless otherwise indicated on Drawings.
b. Test and adjust each new diffuser, grille and register to within plus or minus 10 percent of design requirements.
c. Unit Price 2: Test and adjust each diffuser, grille and register in a zone to within plus or minus 10 percent of design requirements. Where existing design requirements are unknown, design airflows for all equally sized diffusers served by the same terminal unit shall be assumed equal. (E.g. if a VAV box's design airflow is 1200 CFM and it serves 4 diffusers, each diffuser shall be assigned 300 CFM).
    1) Start with all dampers wide open.
    2) Adjust dampers, starting with nearest to terminal unit or fan. Make adjustments using duct mounted volume dampers rather than dampers at diffuser face (if any) unless absolutely required.
    3) At least one damper shall remain wide open at end of balance.
d. Each adjusted grille, diffuser and register shall be identified as to locations and area. Size, type and manufacturer of diffusers, grilles, and registers shall be identified and listed. Readings and tests of diffusers, grilles, and registers shall include design, initial test, and final adjusted FPM velocity and CFM.

2. Terminal Boxes
    a. Balancing contractor shall provide laptop computer or other device for communicating with BAS system, using software provided by BAS installer. Cooperate with BAS installer to learn how to use software to calibrate BAS zone controller.
    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.
    c. Use BAS terminal "commissioning" software where available and record all calibration and test data through the BAS.
    d. Zero transmitter prior to each test.
    e. Adjust 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) Zero flow
        2) Maximum airflow setpoint, ±5%
        3) Minimum airflow setpoint, ±10%
    f. 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
3. VAV AHU Duct Static Pressure Setpoint

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

b. Test Conditions

1) Set all boxes/air valves to operate at maximum airflow setpoints; allow controls to stabilize.

c. Procedure

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

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

a) This reading becomes the maximum static pressure setpoint.

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

d. Convey to the BAS installer

1) Static pressure setpoints

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

e. Report

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

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

3) Concurrent fan data

a) Volts and amps

b) Amps and kilowatts from variable speed drive(s)

c) Variable speed drive speed in hertz

d) Entering and leaving fan static pressure

e) Flow rate, summed from BAS terminals

f) Fan airflow sensor reading from BAS, where applicable

4. Air Handler Pressure Profiles

a. Test with system operating at design airflow at both 100% outside air and minimum outside air flow conditions. For both configurations, report the following on a schematic of the system:

1) Tag of AHU

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 (for belt driven fans only)

5) Fan airflow rate as measured by supply pitot traverse

6) Final measured fan speed and amps from all fans

7) Amps and kilowatts from variable speed drives

8) Variable speed drive speed in hertz

9) Static pressures measured at

a) Return fan inlet

b) Discharge of return fans
c) Mixed air plenum
d) Downstream of filter
e) Downstream of coils
f) Discharge of supply fans
g) At static pressure sensor

10) Concurrent airflow rate readings from sum of VAV box airflow rates through BAS
11) BAS outdoor air control setpoints
12) Return and economizer outside air damper positions

5. BAS Airflow Measuring Stations (AFMS)
   a. For outdoor air AFMS associated with VAV system
      1) Test Conditions
         a) Command all VAV boxes to full open.
         b) Configure the outside air damper 100% open and return air damper 0% open.
         c) Start supply fan at 10% speed. Increase fan speed in 10% increments with a pause at each step to allow time for the VAV boxes to communicate. At each 10% speed step, measure and report:
            (1) Sum of VAV box airflows (should be displayed on BAS AHU graphic)
            (2) Airflow measurement station airflow reading
            (3) Traverse across supply air duct, filter bank, or other location where the most accurate airflow reading is possible
      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. If AFMS measured airflow and BAS readings differ by more than 10% with the return air damper shut, consult with District's Representative for recalibration instructions. Do not change factory calibration without written direction.

C. Chilled Water and Hot Water Systems

1. Coil Test

   a. Base Scope: Test and adjust flow through all coils within 10% of design requirements with all control valves open to coil.

   b. Alternate 6: System is self-balancing. Two-way or three-way control valves at coils prevent each coil from being over-supplied with water, other than minor excursions during transients such as cool-down or warm-up. Conventional balancing (throttling of balancing valves) will increase pump energy use by not allowing aggressive differential pressure setpoint reset. Hence, do not adjust any valves on any coil or pump, except temporary adjustments where noted. All manual valves at coils and pumps shall be wide open when test and balance work is complete.

   c. Report with all control valves open to coils and all pumps operating at full speed

      1) Coils with modulating two-way or three-way control valves

         a) Terminal tag

b) Control valve model number and serial number

c) Pressure drop across coil

d) Flow as calculated from pressure drop across the control valve using valve manufacturer's submitted Cv.

2. Hot Water 3-way Control Valve Bypass Balance Valves

a. At all 3-way valves serving coils with a design coil pressure drop exceeding 2 feet, adjust balance valve in bypass leg as required to make pressure drop across the coil-valve assembly when valve is in full-bypass position equal to that when control valve is in through-coil position.

b. Report

1) Differential pressure across coil-valve assembly when control valve is in full-bypass position

2) Differential pressure across coil-valve assembly when control valve is in through-coil position

3) Position of bypass balance valve (% open)

3. Alternate 5: Chilled Water Pump Variable Speed Drive Setpoint Determination

a. For systems with variable speed drives, determine maximum differential pressure setpoint (CHW-DPmax) in conjunction with the BAS installer as follows.

1) Fully open all control valves serving coils that are located downstream of the differential pressure sensor.

2) Fully close all control valves serving coils that are located upstream of the differential pressure sensor.

3) Start pump. Manually adjust speed slowly until design flow (as measured by DP across the control valves) is just achieved through all open coils. One coil should be just at design flow, while others should be at or above design flow.

4) Once flow condition in previous step is achieved, note the BAS system differential pressure reading at the differential pressure sensor. This reading becomes the differential pressure setpoint. Using pressure taps at differential pressure sensor and handheld digital pressure sensor, verify accuracy of BAS reading.

b. Convey to the BAS installer

1) Differential pressure setpoint

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

c. Report at condition described above

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

2) Tag of coils downstream of differential pressure sensor, along with the following for each

a) Design flow rate and coil pressure drop

b) Control valve pressure drop, corresponding tested flow rate, and coil pressure drop with differential pressure at setpoint determined above

D. Provide upon completion of running tests, two (2) complete sets of data listed above for incorporation in District's Operation and Maintenance Manual for the job. Additionally provide:

1. Name and address of testing agency and name of individual responsible for the work

2. Make, model and latest calibration date of testing equipment

3. Sketches or written descriptions sufficient to identify individual devices tested

3.15 COMMISSIONING

A. Commissioning (Cx) activities shall be coordinated by a representative of the Contractor who shall serve as the Commissioning Coordinator (CxC).

B. The commissioning responsibilities of the HVAC Contractor are as follows:

1. Include requirements for submittal data, commissioning documentation, O&M data and training.
2. Attend a commissioning scoping meeting, assist in commissioning schedule development and other meetings necessary to facilitate the Cx process.
3. Attend regular commissioning meetings during the start-up, pre-functional test and functional test periods as scheduled by the CxC.
4. Assist and cooperate with the TAB contractor by putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
5. Develop and complete pre-functional checklists and submit for review.
6. Develop a full start-up and initial checkout plan and schedule using manufacturer’s and specified start-up procedures for all commissioned equipment. Submit for review and approval prior to startup.
7. Provide skilled technicians to execute starting and pre-functional testing of equipment, and to assist in executing functional performance tests and interpret the data, as necessary. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
8. Develop functional performance test procedures to fully test all HVAC control sequences. Submit to the District for review and approval.
9. Perform functional tests, retesting until all are satisfactorily complete, and complete test forms. Submit to the District for review and approval.
10. Prepare an outline and schedule for training programs for approval.
11. Include start up, pre-functional, and functional test documentation in the Operations and Maintenance Manual.

C. Equipment:

1. HVAC Contractor shall provide all test equipment necessary to fulfill the testing requirements of this Division.
2. The contractor shall provide all standard testing equipment required to perform pre-functional tests, startup, and required functional performance testing.
3. The contractor shall provide two-way radios to facilitate communications during commissioning.
4. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance within the specified tolerances. All equipment should be calibrated according to the manufacturer's recommended intervals.

D. Controls Commissioning
1. Calibration: Factory calibration is acceptable. Obviously inaccurate sensors must be replaced if calibration is not possible.
2. Each control loop shall be tuned as required to maintain setpoint within specified accuracy requirements during normal operating conditions and to achieve this stability within 15 minutes after an abrupt system or setpoint change.
3. Each digital output point shall be tested to ensure the controlled device starts and stops properly. Each digital input status point shall be tested to ensure the input device is properly adjusted (e.g. adjust current setpoint on current switches) and wired.
4. Each control sequence shall be tested for proper operation. Trend logs shall be collected during the test period accordingly.
5. Maintain a test log of all testing and calibration.

E. Functional Tests:
1. Summary
   a. Functional testing is performed to verify proper operation of the mechanical systems, rather than just the verification of each component. The objective of the functional performance testing is to demonstrate that each system is operating according to the documented design intent and contract documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.
   b. Each system shall be operated through all modes of operation where there is a specified system response. Verification of each sequence in the sequence of operation is required. Proper responses to such modes and conditions shall also be tested.
2. Prerequisites
   a. All pre-functional testing must be successfully completed before beginning functional testing.
   b. All HVAC equipment must be successfully started, and Testing, Adjusting, and Balancing work completed before beginning functional testing.
   c. Calibration and Loop Tuning must be successfully completed before any functional testing can begin.
   d. All systems should be running according to normal sequence of operations unless commanded otherwise as part of functional testing.
3. Procedure
   a. Functional tests shall be conducted by the Controls Contractor with the assistance of the HVAC Contractor, witnessed by the CxC.
   b. Functional test forms shall be submitted to the District's Representative for review and approval.

c. Demonstration tests: A subset of functional tests selected by the District shall be performed by the Controls Contractor and witnessed by the District's representatives. The test period shall not exceed 3 days.

F. Trend Reviews

1. See Section 250000 Building Automation Systems for trend configuration requirements.
2. Following successful completion of functional tests, a minimum of three weeks of trend data shall be collected and submitted to the District's Representative for review and approval. Data shall be in electronic format such as CSV, Excel, Access, or SQL.
3. If any but very minor glitches are indicated in the trends, the verification period will start over until there are two continuous weeks of error free operation. Contractor shall reimburse District's representative at normal billing rates for all time spent reviewing trend reviews after the first set.
4. Final payment and system acceptance will only be made if the trend reviews indicate proper system operation.

G. Training

1. HVAC Training: Upon completion of work, provide District's operating personnel two instruction periods in operation and maintenance of material and equipment. Each period shall be 3-hours continuous; first period to be immediately upon completion, and second period within 30 days of completion. Training shall be video recorded with a copy provided to the District.
2. Control System Training: See Division 25 specification.

END OF SECTION

SECTION 250000

BUILDING AUTOMATION SYSTEMS

PART 1 GENERAL

1.1 Summary

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

1.2 Coordination with other Trades

A. Consult all other Sections, determine the extent and character of related work and properly coordinate work specified herein with that specified elsewhere to produce a complete and operable installation. This section is provided to assist Contractor in coordination of work scope but shall not be construed to limit Contractor's scope of work encompassed by the contract documents.

1.3 Integration with Existing System

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

B. Procedure

1. Provide all controls work within the building as indicated on Drawings and in this Section.

2. Develop all building level control system databases and control programming using existing standards and standard programming.

3. Install building databases 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.

4. Once the building BAS has been fully commissioned and accepted by the College, merge database and programming with those existing on the Control System Servers. Confirm that the merge was successful by sample testing points and sequences and approve final installation in writing.

5. 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.

1.4 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, submit an email to the District's

Contract manager 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.

D. Base Bid

1. Core & Shell and TI work, as shown on Drawings and specified herein.

2. Alternates. Alternate prices shall include all equipment, material, labor, design engineering, balancing, start-up and testing costs necessary to provide a complete operational system. Provide a separate price for each alternate.

a. Alternate 1: Add chilled water DPT-1 differential pressure transducer, five-valve manifold, and provide new PCH-1 speed output and network interface to PCH-1 VFD.

b. Alternate 2: Provide new natural gas meter on main building gas supply line, associated programming and graphics. Installation by Division 230000 Contractor.

c. Alternate 3: Provide minimum flow hot water bypass valve and magnetic insertion type flow meter, associated programming and graphics. Installation by Division 230000 Contractor.

d. Alternate 4 (deduct): Exclude chilled water and heating hot water plant programming.

e. Alternate 5 (deduct): Provide 2-way valves for all reheat coils in lieu of 3-way valves, where scheduled. Installation by Division 230000 Contractor.

f. Alternate 6: Relocate existing power meter and reinstall on main building service. Assume work will occur during off-hours to allow for de-energizing of building power. De-energizing of building to be coordinated with the District.

g. Any other at the Contractor's option.

E. 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 new construction during normal design and construction schedule; for retrofits or compression, additional costs may be added.

1. DDC Control of existing Exhaust Fan – assume start/stop and status (CS-1)

2. CS-1 current switch for monitoring of existing exhaust fans.

3. Cost add to upgrade VAV box thermostat from TS-3A to TS-3C

4. Replacement line size 2-way control valve – installation by Division 230000 Contractor.

5. Replacement line size 3-way control valve – installation by Division 230000 Contractor.

1.5 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 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.

3. IEEE 802.4 – Token Bus Working Group (ARCNET – Based) LAN.

1.6 Definitions

A. Acronyms

AAC	Advanced Application Controller
AH	Air Handler
AHU	Air Handling Unit
AI	Analog Input
ANSI	American National Standards Institute
AO	Analog Output
ASC	Application Specific Controllers
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
A-to-D	Analog-to-Digital
BACnet	Data Communications Protocol for Building Automation and Control Systems
BC	Building Controller
BIBB	BACnet Interoperability Building Blocks
BTL	BACnet Testing Laboratory
CAD	Computer Aided Drafting
CHW	Chilled Water
CHWR	Chilled Water Return
CHWS	Chilled Water Supply
COV	Change of Value
CSS	Control Systems Server
CU	Controller or Control Unit
CV	Constant Volume
CW	Condenser Water
CWR	Condenser Water Return
CWS	Condenser Water Supply
DBMS	Database Management System

DDC	Direct Digital Control
DHW	Domestic Hot Water
DI	Digital Input
DO	Digital Output
D-to-A	Digital-to-Analog
BAS	Building Automation System
EMT	Electrical Metallic Tubing
EP	Electro-Pneumatic
ETL	Edison Testing Laboratories
GUI	Graphical User Interface
HHD	Hand Held Device
HOA	Hand-Off-Automatic
HVAC	Heating, Ventilating and Air-Conditioning
HTTP	Hyper-Text Transfer Protocol
I/O	Input/output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LAN	Local Area Network
LANID	LAN Interface Device
MAC	Medium Access Control
MHz	Megahertz
MS/TP	Master-Slave/Token-Passing
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
ODBC	Open Database Connectivity
OI	Operator Interface
OWS	Operator Workstation
P	Proportional
PC	Personal Computer
PI	Proportional-Integral
PICS	Protocol Implementation Conformance Statement
PID	Proportional-Integral-Derivative
POT	Portable Operators Terminal
PTP	Point-to-Point
RAM	Random Access Memory
SOO	Sequence of Operation
SQL	Standardized Query Language
SSL	Secure Socket Layers
TAB	Test, Adjust, and Balance
TDR	Time Delay Relay
UFT	Underfloor Fan Terminal Box
UL	Underwriters' Laboratories, Inc.
XML	Extensible Markup Language

B. Terms

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

Term	Definition
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.
IT LAN	Reference to the facility's Information Technology network, used for normal business-related e-mail and Internet communication.
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.
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.
District	The Contra Costa Community College District or their designated representatives.
Piping	Pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation and related items.

Term	Definition
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 Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs.
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.
Reviewed, approved, or directed	Reviewed, approved, or directed by or to District's Representative.
Router	A device that connects two or more networks at the network layer.
Secondary Controlling LAN	LAN connecting AACs and ASCs.
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 Controller 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.

1.7 Quality Assurance

A. Materials and Equipment

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

B. Installer

1. The following are approved BAS contractors:

a. Sunbelt. Marc Annicchero mannicchero@sunbeltcontrols.com

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

c. ASG: Tony Skibinski tskibinski@asgbms.com

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

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

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

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

6. Installer's Response Time and Proximity

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

   b. Installer must demonstrate the ability to meet the emergency response times listed in Paragraph 1.13B.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.

1.8 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 District's Representative.

B. Submit drawings and product data as hereinafter specified. Conditions in this Section take precedence over conditions in Section 230000 Heating, Ventilating and Air Conditioning.

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

1. Allow 8 working days for approval, unless District'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 District 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 (Functional Testing) shall be submitted no less than 30 days prior to conducting tests.

6. Submittal Package 4 (Training Materials) shall be submitted no less than 14 days prior to conducting first training class.

7. Submittal Package 5 (Post-Construction Trend Logs) shall be submitted after demonstration tests are accepted and systems are in full automatic operation. The list of points to be trended shall be submitted for approval 14 days prior to the start of the trend collection period.

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 District Representative for review and comment prior to formal submission. Comments provided by the District Representative 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 paper copy to the District and 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. District's Representative will return a memo or mark-up of submittal with comments and corrections noted where required.

6. Make corrections

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

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

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

7. Resubmit revised submittals until no exceptions are taken.

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

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

b. Photocopies or electronic copies for coordination with other trades, if and as required by the District's Representative.

E. Submittals Packages

1. Submittal Package 0 (Qualifications)

a. Provide Installer and Key personnel qualifications as specified in Paragraph 1.7B.

b. Format: Word-searchable format per Paragraph 1.9C.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) Format: Word-searchable format per Paragraph 1.9C.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 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. SOO shall be fully consistent with the graphical programming. (An electronic version of the sequences of controls in Paragraph 3.12 will be provided to the Contractor upon request.)

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 1.9C.3.

2) Programming: Native ALC Eikon.

3) Programming and operating manual: Word-searchable format per Paragraph 1.9C.3.

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

4. Submittal Package 3 (Functional Testing)

a. Provide pre-functional test forms as required by Paragraph 3.14B.1.a.

b. Provide functional test forms as required by Paragraph 3.14B.2.

c. Format: Word-searchable format per Paragraph 1.9C.3.

5. Submittal Package 4 (Training Materials)

a. Provide training materials as required by Paragraph 3.15.

b. Format: Word-searchable format per Paragraph 1.9C.3.

6. Submittal Package 5 (Trend Logs)

a. Provide a list of points being trended along with trend interval or change-of-value per Paragraph 3.14I.2.d.

b. Provide trend logs as required by Paragraph 3.14I.

1.9 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 the District.

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

B. Completion Documents

1. Operation and Maintenance (O & M) Manuals. Provide in both paper and electronic format per Paragraph 1.9C.

   a. Include 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.

   b. As-built versions of the submittal product data. Submittal data shall be located in tabs along with associated maintenance information.

   c. 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.

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

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

   f. 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.

   g. 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.

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

   i. 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.

   j. English language control sequences updated to reflect final programming installed in the BAS at the time of system acceptance.

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

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 District sign-off.

4. Project Record Drawings

   a. As-built versions of the submittal drawings in reproducible paper and electronic format per Paragraph 1.9C.

   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 3.14B.

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 3.15.

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.	Project database including all source files	–	1	1
3.	Project Record Drawings	2	1	1
4.	Control sequences	1	1	1
5.	Commissioning Reports	2	1	1
6.	Inspection Certificates	1	1	1
7.	Warranty documents	1	1	1
8.	Training materials	1 per trainee	1	1
9.	Contact information	1	1	1

D. Permanent On-site Documentation

1. In panels, provide the following in a sufficiently permanent manner such that documentation cannot be easily removed (and lost):

a. Point list of all points in panel.

b. Shop drawings for devices in panel.

1.10 BAS Design

A. System Architecture

1. General

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

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

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

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

2) To communicate with the central CSS (and internet via VPN), the building Supervisory LAN shall connect via the existing LGR, to the existing Campus IT LAN, provided by the 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.

2. BAS Network Architecture

a. Supervisory LAN: The LAN shall be an Ethernet-based, 100 or 1000 Mbps network connecting the server and OWS(s) and to certain gateways as specified herein. Provide this as a dedicated LAN for the control system; the Campus IT LAN shall not be used for this purpose. LAN shall be IEEE 802.3 Ethernet with switches and routers that support 100 Mbps minimum throughput. Power-line carrier communication are not acceptable for communications. 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.

b. Primary Controller LAN (Primary LAN): High-speed, peer-to-peer communicating LAN used to connect BCs, AACs, and certain gateways where specified herein. The Primary LAN communicates exclusively control information. Acceptable technologies include and are limited to:

1) Ethernet (IEEE802.3)

2) ARCNET (IEEE802.4)

c. Secondary Controller LAN (Secondary LAN): Network used to connect ASCs and certain gateways where specified herein. These may be Master Slave/ Token Passing (MS/TP) in addition to those allowed for Primary Controller LANs. Network speed versus the number of controllers on the LAN shall be dictated by the response time and trending requirements.

3. Operator Interfaces and Servers. The Control Systems Server (CSS) and Operator interface devices are existing. No additional CSS, OWS, or POT shall be provided as a part of this project. See Paragraph 1.3 for temporary CSS requirements.

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

5. Gateways

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

b. Where gateways are used, critical points shall be hardwired from the BAS to the controlled device, rather than using the gateway, to avoid problems with gateway failures, currently a common problem. Critical points are those that are essential for proper operation and are listed in points list as separate points. Where listed, 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 3.14I.) 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 at central plant mains only	±0.2ºF
Chilled and Condenser Water Temperature − general	±0.5ºF
Hot Water Temperature	±1ºF
Chilled Water Delta-T (supply to return) at central plant main supply or return 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

Measured Variable	Reported Accuracy
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

1.11 Ownership of Proprietary Material

A. All project-developed software and documentation shall become the property of the District. 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

1.12 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 District and if all completion requirements per Paragraph 1.9B have been fulfilled, the District 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 District 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 District. Contractor shall respond to the District's request for warranty service within 24 hours during College operations.

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 District 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 District during this period.

1.13 Warranty Maintenance

A. The District 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 District, 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 District, 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 District 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 District'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 District's site within eight hours of the District'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 District 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 District'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 District's site within three working days of the District's initial request for such services, as specified.

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

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

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

PART 2 PRODUCTS

2.1 Primary BAS Manufacturer

A. Automated Logic Corp.

B. No Equal

2.2 General

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

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

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

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

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

2.3 Controllers

A. Building Controller (BC)

1. ALC Optiflex line

B. Advanced Application Controller (AAC)

1. ALC SE-series

C. Application Specific Controller (ASC)

1. ALC ZN-series

2.4 Communication Devices

A. Supervisory LAN Routers

1. ALC Optiflex line

B. BACnet Gateways & Routers

1. Gateways shall be provided to link non-BACnet control products to the BACnet inter-network. 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. Gateway and Routers

Equipment/System	Interface			
	Type	Specified Under Division:	Location	Connect to this Network:
Variable Speed Drives	BACnet/MSTP	23	Each VFD	Secondary
Chiller	BACnet/MSTP	Existing	Each Chiller	Supervisory
Boiler	Modbus RS-485	Existing	Each Boiler	Secondary
Power Monitoring	Modbus RS-485	Existing	Existing location (unknown)	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, Routers, Gateways, AACs, ASCs and local and remote peripherals (such as operator workstations and printers).

2. Ethernet LAN: Use Fiber or Category 5 or 6 of standard TIA/EIA 68 (10baseT). Network shall be run with no splices and separate from any wiring over 30 volts.

3. ARCnet and MS/TP LAN: Communication wiring shall be individually 100% shielded pairs per manufacturers recommendations for distances installed, with overall PVC cover, Class 2, plenum-rated run with no splices and separate from any wiring over 30 volts.

Shield shall be terminated and wiring shall be grounded as recommended by BC manufacturer.

B. Analog Signal Wiring

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

2.8 Control Cabinets

A. All control cabinets shall be fully enclosed with hinged door and quarter-turn slotted latch.

B. Construction

1. Indoor: NEMA 1

2. Outdoor: NEMA 3R

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 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. Invensys

d. Delta

e. Or equal

2. Modulating Characterized Ball Valves

a. Valves shall be specifically designed for modulating duty in control application with guaranteed average leak-free life span over 200,000 full stroke cycles.

b. Industrial quality with nickel plated forged brass body and female NPT threads.

c. Blowout proof stem design, glass-reinforced Teflon thrust seal washer and stuffing box ring with minimum 600 psi rating (2-way valves) or 400 psi rating (3-way valves). The stem packing shall consist of 2 lubricated O-rings designed for modulating service and requiring no maintenance.

d. Valves suitable for water or low-pressure steam shall incorporate an anti-condensation cap thermal break in stem design.

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

f. Ball: stainless steel

g. Stem: stainless steel

h. Characterizing disk held securely by a keyed ring providing equal percentage characteristic

3. Minimum valve assembly pressure ratings

a. Chilled water: 125 psi at 60ºF

b. Hot water: 125 psi at 200ºF

4. Valve Selection

a. Valve type

1) Modulating 2-way or 3-way valves

a) 6 inch and less: characterized ball type

2) Bypass valve at primary-only variable flow pumping system: same as modulating 2-way valve.

b. Valve Characteristic

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

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

c. Valve Sizing

1) Modulating Water, except minimum flow bypass: 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) unless protected by strainer. Verify from piping schematics that a strainer is being provided.

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

2) Minimum flow bypass: For variable primary hot water system with constant speed pumps, select for boiler minimum flow (25 GPM) at design pump head less 5 psi.

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

C. 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 2.9C.4, an internal mechanical, spring return mechanism shall be built into the actuator housing. Electrical capacitor type fail-safe are also acceptable. All fail-safe actuators shall be capable of both clockwise or counterclockwise spring return operation by simply changing the mounting orientation.

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

o. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 inch-pound torque capacity shall have a manual crank for this purpose.

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

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

4. Normal and Fail-Safe Position

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

Device	**Normal Position**	**Fail-Safe Position**
Outside air damper	CLOSED	CLOSED
Return air damper	OPEN	OPEN
Exhaust/relief air damper	CLOSED	CLOSED
AHU cooling coil valves	CLOSED	LAST
Hot water reheat coil valves	CLOSED	LAST
VAV box dampers	OPEN	LAST

5. Valve Actuator Selection

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

b. Water

1) 2-way valves

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

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

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

6. Damper Actuator Selection

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

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

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

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

D. 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 1.10B.2.

E. Temperature Sensors (TS)

1. General

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

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

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

d. Manufacturers

1) Mamac

2) Kele Associates

3) Building Automation Products Inc.

4) Automated Logic Corp.

5) Or equal

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

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

b. TS-1B: Averaging. Sensor length shall be at least 1 linear foot for each 2 square feet of face area up to 25 feet maximum. Sensor probe shall be bendable aluminum.

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 1.10B.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		
Display	Blank	Blank w/ Temperature Adjustment Slider	LCD
Temperature only	TS-3A	TS-3B	TS-3C
With CO_2	TS-3AC	TS-3BC	TS-3CC

1) Display

a) Blank: Blank cover

b) Slider: Blank cover with temperature adjustment slider and schedule override button

c) 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 District within 5 years of purchase date.

c) Meet Title 24 requirements including calibration interval

3) For room sensors connected to terminal box controllers (such as at VAV boxes) that require calibration: Include a USB port or some other means for connection of POT for terminal box calibration. Alternative means of terminal calibration are acceptable provided they result in no cost to Testing, Adjusting, and Balancing work performed under Section 230000 Heating, Ventilating and Air Conditioning.

b. See equipment schedules for thermostat type.

5. TS-4: Outdoor Air Sensor

a. Enclose in fan-aspirated radiation shield that combines both active and passive aspiration to minimize the effects of radiation.

1) Motor-driven fan draws air through the sensor chamber and exhausts it through the top of the shield.

2) Triple-walled sensor chamber shielded by flow-through plates.

3) Aspiration rate: minimum is 220 feet per minute.

b. Sensor

1) Electronics mounted in watertight gasketed enclosure to prevent water seepage

2) TS-1A

c. Manufacturer

1) Davis Instruments 7747

2) Kele A21

3) Or equal

6. 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.

F. Differential Pressure Transmitters (DPT)

1. DPT-1: Water, General Purpose

a. Fast-response capacitance sensor

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

c. Accuracy

1) Overall Accuracy (at constant temp) ±0.25% full scale (FS).

2) Non-Linearity, BFSL ±0.22% FS.

3) Hysteresis 0.10% FS.

4) Non-Repeatability 0.05% FS.

d. Long Term Stability 0.5% FS per year

e. Only 316 stainless steel in contact with fluid

f. Pressure Limits

1) 0 to 100 psid range: 250 psig maximum static pressure rating, 250 psig maximum overpressure rating.

2) 100 to 300 psid range: 450 psig maximum static pressure rating, 450 psig maximum overpressure rating.

g. Include brass 5-valve assembly for single sensor devices. See Paragraph 3.11E.7.

h. Manufacturers

1) Setra 209 or 230

2) Modus W30

3) Or equal

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. Manufacturers.

1) Setra

2) Modus

3) Invensys

4) Dwyer

5) Or equal

4. DPT-4: Air, Low Differential 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) General: ±1% FS

2) Underfloor: ±0.5% FS

3) Minimum outdoor air damper DP used for minimum outdoor airflow: ±0.25% FS

d. Range

1) Fixed (non-switch selectable)

2) Minimum Range: 0, -0.1, -0.25, -0.5, or -1.0 inches water column

3) Maximum Range: +0.1, 0.25, 0.5, or 1.0 inches water column

4) Range shall be as specified in points list or, if not listed, selected such that specified setpoint is between 25% and 75% full-scale.

e. Housing: Polymer housing suitable for surface mounting

f. Static Sensing Element

1) Ambient sensor: Dwyer A-306 or 420, BAPI ZPS-ACC-10, or equal

2) Space sensor: Kele RPS-W, BAPI ZPS-ACC-01, Dwyer A-417 or 465, Veris AA05 or equal wall plate sensor

3) Filter or duct pressure sensor: Dwyer A-301 or equal

4) Plenum pressure sensor: Dwyer A-421 or equal

g. DPT-4A: Include LCD display of reading

h. Manufacturers

1) Setra 267

2) Modus

3) Air Monitor

4) Paragon

5) Or equal

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 1.5 in.w.c.

f. Housing: Polymer housing suitable for surface mounting.

g. Manufacturer

1) Automated Logic

2) No equal

G. 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-300 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

H. Current Transformers (CT)

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

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

    b. Trip Point: Adjustable

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

    d. Accuracy: ±0.2% from 20 to 100 Hz.

    e. Manufacturers: Kele SC100, Veris 722, or equal

I. Airflow Measuring Stations (AFMS)

1. General. AFMS provided under this Section shall be licensed to bear the AMCA Certified Rating Seal for Airflow Measuring Stations. Ratings shall be based on tests and procedures performed in accordance with AMCA Publication 611 and comply with requirements of the AMCA Certified Ratings Program.

2. AFMS-1: Not used.

3. AFMS-2: Not used.

4. AFMS-2: Not used.

5. AFMS-3

    a. Differential pressure type with uniframe DP sensor

        1) Provide quantity of DP sensors per manufacturer’s recommendations

    b. Extended flow (2 transducers, 0.05” and 0.25” range)

c. Station mounted with expanded metal screen

d. Analog outputs for airflow and temperature

e. Manufacturers

1) Air Monitor

a) Transmitter: OAM-II-2221-1Bnnn

2) No equal

J. Flow Meters

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) FloCat YD20-A

3) Marsh McBirney MultiMag 284

4) SeaMetrics 100/200 Series

5) Or equal

3. FM-3: Displacement Gas Meter

a. Positive displacement, rotary type gas meter designed for volumetric measurement of widely varying flow rates of low pressure natural gas

b. Permanent, non-adjustable calibration, not affected by low or varying line pressure and independent of the gas specific gravity, temperature, and pressure

c. Manufactured in accordance with ANSI B109.3 for Rotary Type Gas Displacement Meters

d. Operating temperature range: -40°F to +140°F

e. Temperature compensating with a corrected reading for temperatures ranging from -20°F to +120°F

f. Low frequency pulse output

g. Rangeability at ±1% accuracy: Minimum 40 to 1

h. Glass enclosed 8 digit totalizer, re-zeroed with on-board device

i. Manufacturer

1) Dresser Roots B3

2) Or equal

K. Electric Control Components

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

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

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

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

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

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

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

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

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

3. Control Transformers and Power Supplies

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

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

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

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

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

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

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

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

2.10 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 District.

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. Graphics shall be visible on all OWS displays in full screen mode without the use of scroll bars.

e. Graphics shall be printable with white background.

f. 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 1.9B.

2. O&M and submittal information for the devices on the graphic. See Paragraph 1.9B. This includes links to electronic O&M and submittal

information for mechanical equipment supplied under Section 230501 Basic Mechanical Materials and Methods.

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.

g. 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.

h. 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.g) shall be clearly displayed on graphics for each point, such as by changing color or flag.

i. 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 District'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

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. Trend Logging

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

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

c. Trend Basis

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

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

5. Calibration

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

b. HH = field calibrate with handheld device. See Paragraph 3.14E.5.a.2)

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

1. Points mapped through gateways and network interfaces

2. Variable speed drives

a. Note: Variable speed drives for AHUs are new. Variable speed drive for PCH-1 is existing.

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Fault reset	DO	X	X*	Through network	COV	COV	–
On/off status	DI	X	X*	Through network	COV	COV	–
Fault (Critical Alarm)	DI	X	X*	Through network	COV	COV	–
Minor Alarm	DI	X	X*	Through network	COV	COV	–
Fault Text	DI	X	X*	Through network (convert code to plain English text)	COV	COV	–
Alarm Text	DI	X	X*	Through network (convert code to plain English text)	COV	COV	–
Keypad in hand/auto	DI	X	X*	Through network	COV	COV	–
Minimum frequency setpoint	AO	X	X*	Through network	±5%	±5%	–
Maximum frequency setpoint	AO	X	X*	Through network	±5%	±5%	–
Acceleration rate	AO	X	X*	Through network	±5%	±5%	–
Deceleration rate	AO	X	X*	Through network	±5%	±5%	–
Actual frequency	AI	X	X*	Through network	1 min	15 min	–
AC output voltage	AI	X	X*	Through network	±10%	±10%	F
Current	AI	X	X*	Through network	15 min	60 min	F
VFD temperature	AI	X	X*	Through network	60 min	60 min	F
Power, kW	AI	X	X*	Through network	1 min	15 min	F
Energy, MWh	AI	X	X*	Through network	15 min	60 min	–
Note*: Provide new network connection to new AHU variable speed drives. Alternate 1: Variable speed drive for PCH-1 is existing. Provide new network connection to existing PCH-1 variable speed drive.							

3. Air-Cooled Chiller

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Active demand limit	AI			Through (E) network connection	COV	COV	–
Active demand limit	AO			Through (E) network connection	COV	COV	–
Active setpoint	AI			Through (E) network connection	5 min	15 min	–
Alarm state	AI			Through (E) network connection	COV	COV	–
EXV % open	AI			Through (E) network connection	5 min	15 min	–
Entering chilled water temperature	AI			Through (E) network connection	5 min	15 min	F

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Leaving chilled water temperature	AI			Through (E) network connection	5 min	15 min	F
Total capacity (%)	AI			Through (E) network connection	5 min	15 min	–
Saturated condensing temperature	AI			Through (E) network connection	5 min	15 min	F
Saturated suction temperature	AI			Through (E) network connection	5 min	15 min	F
Suction pressure A	AI			Through (E) network connection	5 min	15 min	F
Suction pressure B	AI			Through (E) network connection	5 min	15 min	F
Discharge pressure A	AI			Through (E) network connection	5 min	15 min	F
Discharge pressure B	AI			Through (E) network connection	5 min	15 min	F
Suction superheat temperature	AI			Through (E) network connection	5 min	15 min	F
Compressor A1 relay	DI			Through (E) network connection	COV	COV	–
Compressor A2 relay	DI			Through (E) network connection	COV	COV	–
Compressor B1 relay	DI			Through (E) network connection	COV	COV	–
Compressor B2 relay	DI			Through (E) network connection	COV	COV	–
Emergency stop	DI			Through (E) network connection	COV	COV	–
Alarm state	MSV			Through (E) network connection	COV	COV	–
Control mode	MSV			Through (E) network connection	COV	COV	–

4. Boilers

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Status/fault code 1-47	AI			Through (E) network connection	±1	±1	–
Unit Status code 0-5	AI			Through (E) network connection	±1	±1	–
HW supply temperature	AI			Through (E) network connection	1 min	10 min	F
HW return temperature	AI			Through (E) network connection	10 min	10 min	F

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Exhaust temperature	AI			Through (E) network connection	10 min	10 min	F
FFWD temperature	AI			Through (E) network connection	10 min	10 min	F
Firing rate %	AI			Through (E) network connection	1 min	10 min	F
O2 level	AI			Through (E) network connection	10 min	10 min	F
CO level	AI			Through (E) network connection	10 min	10 min	F
Flame strength %	AI			Through (E) network connection	10 min	10 min	F
Active HWST setpoint	AI			Through (E) network connection	1 min	10 min	F
HWST Setpoint command	AO			Through (E) network connection	±1°F	±1°F	–

5. Building Power Meter

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Real kW	AI			Through network. Alternate 6: Relocate device if required. See note below.	15 min	15 min	HH
Volts (each phase)	AI			Through network	±10%	±10%	HH
Power factor	AI			Through network	±10%	±10%	HH
Amps (each phase)	AI			Through network	–	–	HH
Note: Determine existing installation location. Base scope: Retain existing power meter network interface Alternate 6: If not on the main service to the building, re-install on the main service.							

C. Hardwired Points

1. VAV Box - Cooling only (existing ALC controls)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO			(E) connection to (E) modulating actuator	1 min	15 min	–
Local Override	DI		X*	(E) connection to (E) TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Supply Airflow	AI			Connection to (E) DPT-5 connected to box manufacturer supplied flow cross – see VAV schedule	1 min	15 min	HH (see §230000)
Zone Temperature Setpoint Adjustment	AI		X*	(E) connection to (E) TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI		X*	(E) connection to (E) TS-3x (see Paragraph 2.9E)	1 min	15 min	F
Note*: If the existing thermostat matches the type required in the VAV schedule, existing thermostat may be reused.							

2. VAV Box - Cooling only (existing pneumatic or Reliable controls)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO	X	X	Modulating actuator	1 min	15 min	–
Local Override	DI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–
Supply Airflow	AI	X	X	(N) DPT-5 connected to box manufacturer supplied flow cross	1 min	15 min	HH (see §230000)
Zone Temperature Setpoint Adjustment	AI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI	X	X	TS-3x (see Paragraph 2.9E)	1 min	15 min	F

3. VAV Box - Cooling only (new)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO	X	X	Modulating actuator	1 min	15 min	–
Local Override	DI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–
Supply Airflow	AI	X	X	DPT-5 connected to box manufacturer supplied flow cross	1 min	15 min	HH (see §230000)
Zone Temperature Setpoint Adjustment	AI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI	X	X	TS-3x (see Paragraph 2.9E)	1 min	15 min	F

4. VAV Box with reheat (existing ALC controls, existing zone controllers may be reused)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO			(E) connection to (E) Modulating actuator	1 min	15 min	–
HW valve signal	AO			Connect to 2-way valve (occasional 3-way valve) , modulating actuator – see VAV schedule and Alternate 5. Note: Some reheat coils are mounted upstream of VAV box	1 min.	15 min	–
Local Override	DI		X*	(E) connection to (E) TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–
Supply Airflow	AI			Connect to (E) DPT-5 connected to box manufacturer supplied flow cross – see VAV schedule	1 min	15 min	HH (see §230000)
Supply air temperature	AI			(E) connection to (E) temperature sensor	1 min	15 min	F
Zone Temperature Setpoint Adjustment	AI		X*	(E) connection to (E) TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI		X*	(E) connection to (E) TS-3x (see Paragraph 2.9E)	1 min	15 min	F
Zone CO_2 Concentration	AI		X*	(E) connection to (E) TS-3x (see Paragraph 2.9E)	5 min	15 min	F
Note*: If the existing thermostat matches the type required in the VAV schedule, existing thermostat may be reused.							

5. VAV Box with reheat (existing pneumatic or Reliable controls)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO	X	X	Modulating actuator	1 min	15 min	–
HW valve signal	AO	X	X* (see device column)	2-way valve (occasional 3-way valve), modulating actuator – see VAV schedule and Alternate 5. Note: Some reheat coils are mounted upstream of VAV box	1 min.	15 min	–
Local Override	DI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–
Supply Airflow	AI	X	X	DPT-5 connected to (E) box manufacturer supplied flow cross	1 min	15 min	HH (see §230000)
Supply air temperature	AI	X	X	TS-1A	1 min	15 min	F

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Zone Temperature Setpoint Adjustment	AI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI	X	X	TS-3x (see Paragraph 2.9E)	1 min	15 min	F
Zone CO_2 Concentration	AI	X	X	TS-3x (see Paragraph 2.9E)	5 min	15 min	F

6. VAV Box with reheat (new)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
VAV Box Damper Position	AO	X	X	Modulating actuator	1 min	15 min	–
HW valve signal	AO	X	X	2-way valve (occasional 3-way valve), modulating actuator – see VAV schedule and Alternate 5	1 min.	15 min	−
Local Override	DI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	COV	COV	–
Supply Airflow	AI	X	X	DPT-5 connected to box manufacturer supplied flow cross	1 min	15 min	HH (see §230000)
Supply air temperature	AI	X	X	TS-1A	1 min	15 min	F
Zone Temperature Setpoint Adjustment	AI	X	X	TS-3x – where applicable (see Paragraph 2.9E).	15 min	60 min	F
Zone Temperature	AI	X	X	TS-3x (see Paragraph 2.9E)	1 min	15 min	F
Zone CO_2 Concentration	AI	X	X	TS-3x (see Paragraph 2.9E)	5 min	15 min	F

7. Upstream Reheat Coils (HC-4 and HC-17)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
HW valve signal	AO	X	X	(N) 2-way valve, modulating actuator	1 min.	15 min	−
Supply air temperature	AI	X	X	TS-1A	1 min	15 min	F

8. VAV Air Handler with Return Fan

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Supply Fan Start/Stop	DO	X	X	Connect to VFD Run	COV	COV	−
Return Fan Start/Stop	DO	X	X	Connect to VFD Run	COV	COV	−
Supply fan high static alarm reset	DO	X	X	Dry contact to 120V or 24V control circuit −see control schematics for details	COV	COV	−

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Return fan high static alarm reset	DO	X	X	Dry contact to 120V or 24V control circuit −see control schematics for details	COV	COV	−
Exhaust Air Damper	AO	X	X	Modulating actuator	1 min	15 min	−
Outdoor Air Damper	DO	X	X	2-position actuator	COV	COV	−
Return Air Damper	AO	X	X	Modulating actuator	1 min	15 min	−
Supply Fan Speed	AO	X	X	Connect to VFD Speed	1 min	15 min	−
Return Fan Speed	AO	X	X	Connect to VFD Speed	1 min	15 min	−
Chilled Water Control Valve	AO	X	X	Modulating 2-way valve	1 min	15 min	−
Return Fan Static Pressure	AI	X	X	DPT-4A, 0 to 1 inch	1 min	15 min	F
Outdoor Air Flow	AI	X	X	AFMS-3 cfm output	1 min	15 min	F
Mixed Air Temperature	AI	X	X	TS-1B across filter bank	1 min	15 min	F
Filter Pressure Drop	AI	X	X	DPT-3A, 0 to 1 inch	−	60 min	F
Return Air Temperature	AI	X	X	TS-1A	1 min	15 min	F
Supply Air Temperature	AI	X	X	TS-1B	1 min	15 min	HH
Outdoor Air Temperature	AI	X	X	AFMS-3 temperature output	1 min	15 min	F
Duct Static Pressure	AI	X	X	DPT-3A, 0 to 2 inches.	1 min	15 min	F

9. Single Zone DX Packaged Units (AC-2-1 to AC-2-4)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Supply Fan Start/Stop	DO			(E) connection to (E) motor starter	COV	COV	−
DX Stage 1 Enable	DO			(E) connection to (E) contact on unit control panel	COV	COV	−
DX Stage 2 Enable	DO			(E) connection to (E) contact on unit control panel	COV	COV	−
Gas Heat Enable	DO			(E) connection to (E) contact on unit control panel	COV	COV	−
Economizer Dampers	AO			(E) connection to (E) to OA/RA/EA modulating actuators	1 min	15 min	−
Supply Fan Status	DI			(E) connection to (E) current switch	COV	COV	See 3.11F
Local Override	DI	X	X*	TS-3CC	COV	COV	–
Mixed Air Temperature	AI			(E) connection to (E) averaging sensor	1 min	15 min	F
Return Air Temperature	AI			(E) connection to (E) temperature sensor	1 min	15 min	F
Supply Air Temperature	AI			(E) connection to (E) temperature sensor	1 min	15 min	HH
Zone Temperature Setpoint Adjustment	AI	X*	X*	TS-3CC	15 min	60 min	F

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Zone Temperature	AI		X*	TS-3CC	1 min	15 min	F
Zone CO_2 Concentration (AC-2-2 and AC-2-4 only)	AI		X*	TS-3CC	5 min	15 min	F
Note*: If the existing thermostat matches the type required in the VAV schedule, existing thermostat may be reused.							

10. Hot Water Plant

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Boiler Enable	DO			(E)connection to (E) boiler enable contact	COV	COV	–
HWP-1 Start/Stop	DO			(E) connection to (E) motor starter	COV	COV	–
HWP-2 Start/Stop	DO			(E) connection to (E) motor starter	COV	COV	–
Alternate 3: HW Bypass Valve	AO	X	X	Modulating ball valve, 25 GPM at 2 psi. Coordinate location with Division 230000 Contractor	1 min.	5 min.	–
HWP-1 Status	DI			(E) connection to (E) current switch	COV	COV	–
HWP-2 Status	DI			(E) connection to (E) current switch	COV	COV	–
Primary Hot Water Supply Temperature	AI			(E) connection to (E) temperature sensor	1 min.	±2°F	HH
Primary Hot Water Return Temperature	AI			(E) connection to (E) temperature sensor	1 min.	±2°F	HH
Alternate 3: HW supply flow	AI	X	X	FM-2	5 min	15 min	F

11. Air-Cooled Chilled Water Plant

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Chiller Enable	DO			(E) connection to (E) contact on unit control panel	COV	COV	–
PCH-1 Start/Stop	DO			(E) connection to (E) VFD run	COV	COV	–
Alternate 1: PCH-1 Speed	AO	X		Connect to (E) VFD speed	1 min	5 min	–
Chilled Water Supply Temperature Setpoint	AO			(E) connection to (E) terminals on unit control panel	1 min	5 min	–

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
PCH-1 Amps	AI			(E) connection to (E) current transducer	1 min	15 min	F
Chilled Water Supply Temperature	AI			(E) connection to (E) temperature sensor	1 min	±2°F	HH
Chilled Water Return Temperature	AI			(E) connection to (E) temperature sensor	1 min	±2°F	HH
Alternate 1: Chilled Water Differential Pressure	AI	X	X	DPT-1 with 5-valve manifold, 0 to 20 psi, located at end of piping system	5 min	15 min	F

12. Constant Speed DX Fan-Coil

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Fan Start/Stop	DO			(E) connection to (E) motor starter	COV	COV	–
DX Enable	DO			(E) connection to (E) contact on unit control panel	COV	COV	–
Fan Amps	AI			(E) connection to (E) current transducer	1 min	15 min	F
Supply Air Temperature	AI			(E) connection to (E) temperature sensor	1 min	15 min	F
Zone Temperature	AI			(E) connection to (E) thermostat	1 min	15 min	F

13. Exhaust Fans (EF-1-1, Art Exhaust Fan, Kitchen Exhaust Fan)

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Fan Start/Stop	DO			(E) connection to (E) motor starter	COV	COV	–
Unit price 6: Fan Status (Art Exhaust Fan and Kitchen Exhaust Fan only)	DI	X	X	CS-1	COV	COV	See 3.11F
Fan Status (EF-1-1 only)	DI			(E) connection to (E) current switch	COV	COV	See 3.11F

14. Miscellaneous

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Building Pressure	AI	X	X	DPT-4, ±0.25, located on 2nd floor in thermostat cover for zone xx-xx	1 min	15 min	F

Description	Type	New Point	New Device	Device	Trend Logging		Calibration
					Commissioning	Continuous	
Outdoor Air Temperature	AI	X	X	TS-4, located on exterior of AHU-XX	1 min	15 min	HH
Alternate 2: Building Gas Flow	AI	X	X	FM-3A	1 min	10 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. Provide canning for openings in concrete walls and floors and other structural elements prior to their construction.

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

C. 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.

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

3.5 Cleaning

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

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

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

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

3.6 Controllers

A. General

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

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

   a. Global points such as outdoor air temperature

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

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

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

B. Controller Application Categories

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

Application Category	**Examples**	**Acceptable Controller**		
		ASC	**AAC**	**BC**
0	Monitoring of variables that are not used in a control loop, sequence logic, or safety, such as status of sump pumps or associated float switches, temperatures in monitored electrical rooms.	X	X	X
1	Miscellaneous heaters Constant speed exhaust fans and pumps	X	X	X
2	Fan Coil Units Terminal Units (such as VAV Boxes) Unitary AC and HP units	X		
3	"Slow" Lab Zone –Non-Hood Dominated	X (note 1)	X	X
4	Air Handling Units Central Hot Water Plant		X (note 1)	X

Application Category	Examples	Acceptable Controller		
		ASC	AAC	BC
	"Fast" Lab Zone –Hood Dominated Air-Cooled Chilled Water Plant			
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 that control equipment located above accessible ceilings shall be mounted in a NEMA 1, locking enclosure and shall be rated for plenum use if ceiling attic is used as a return air plenum.

    b. AACs/BCs that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the Contractor) or in a proximate mechanical/utility room in which case it shall be enclosed in a NEMA 1, locking enclosure.

3.7 Communication Devices

A. General

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

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

B. LANID and LAN Routers

1. Provide as required

2. Connect networks to both sides of device

3. Thoroughly test to ensure proper operation

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

C. Gateways and Routers to Equipment Controllers

1. See Paragraph 2.4C for network connection of gateways and routers.

2. Wire to networks on both sides of device.

3. Map across all monitoring and control points listed in Paragraph 2.12B.1.

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

5. Initiate trends of points as indication in Paragraph 2.12B.1.

D. External Communications

1. Reuse existing connection to District IT LAN (intranet). Contractor shall coordinate with the District's Representative to establish an IP address and communications parameters to assure proper operation. This connection shall also provide access to Internet through District's firewall to Internet Services Provider procured by District.

3.8 Control Air Tubing

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

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

C. Installation methods and materials

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.9 Control Power

A. Power wiring and wiring connections required for Work in this Section shall be provided under this Section. See Paragraph 1.2.

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

1. Where no power source is indicated on drawings, for bid purposes only, assume a dedicated circuit is available within an average of 20 feet of panel location. If this is not the case, request additional cost prior to submission of shop drawings or no additional costs will be reimbursed.

2. Coordinate with District’s Representative during shop drawing development for final connection location.

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 shall be powered by the highest level of reliability served.

D. Unless transformers are provided with equipment as specified in related Division 23 equipment Sections, Contractor shall provide transformers for all low voltage control devices including non-powered terminal units such as cooling-only VAV boxes and VAV boxes with hot water reheat. Transformer(s) shall be located in control panels in readily accessible locations such as Electrical Rooms.

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

3.10 Control and Communication Wiring

A. Control and Signal Wiring

1. Line Voltage Wiring

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

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

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

2. Low Voltage Wiring

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

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

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

a) Equipment rooms

b) Exposed to weather

c) Exposed to occupant view

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

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

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

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

a) Inside mechanical equipment enclosures and control panels

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

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

d) In shafts within reach of access panels throughout

e) Nonrated wall cavities

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

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

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

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

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

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

5. Use coded conductors throughout with different colored conductors.

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

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

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

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

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

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

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

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

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

15. Terminate all control or interlock wiring.

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

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

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

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

    a. Hot water pumps

20. Hardwire Interlocks

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

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

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

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

1) Duct smoke detector

2) High discharge static pressure

3) Low mixing plenum pressure

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

B. Communication Wiring

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

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

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

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

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

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

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

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

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

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

3.11 Sensors and Miscellaneous Field Devices

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

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

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

D. Temperature Sensors

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

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

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

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

3. Averaging sensors shall be installed in a serpentine manner vertically across duct. Each bend shall be supported with a capillary clip. Where located in front of filters (such as mixed air sensors), access for filter removal shall be maintained.

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

5. 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.

6. 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.

7. 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. Supply Duct Static 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 (high) signal of the building static pressure transmitter.

b) Open to a conditioned space inside the building

c) Open to the BAS panel in which the DPT is mounted provided the panel is inside the building envelope and not in an air plenum.

c. High-pressure port of the pressure sensor

1) Pipe to the duct using a static pressure tip located as indicated on Drawings; if no location is indicated, locate at end of duct riser or main as far out in the system as possible but upstream of all smoke and fire dampers.

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

2. Building Static 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 the ambient static pressure probe located on the outside and at high point of the building through a high-volume accumulator or otherwise protected from wind fluctuations.

c. High-pressure port of the pressure sensor

1) Pipe to either

a) Behind a BAS temperature sensor cover in an interior zone (provided sensor has openings to allow ambient air to freely flow through it)

b) Wall plate sensor

2) Do not locate near elevators, exterior doors, atria, or (for ceiling sensor applications) near diffusers.

3. Filter Differential Pressure

a. Install static-pressure tips upstream and downstream of filters with tips oriented in direction of flow.

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.

4. 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.

5. 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.

6. 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.

7. 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) where, 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 for Motor Status Monitoring: Adjust so that setpoint 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. Airflow Measuring Stations: Install per manufacturer's recommendations for unobstructed straight length of duct both upstream and downstream of sensor, except those installations specifically designed for installation in fan inlet. For installations in fan inlets, provide on both inlets of double inlet fans and provide inlet cone adapter as recommended by AFMS manufacturer.

H. 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 District'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 District 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 District. New categories and descriptors may be created with approval of the District.

b. Format:

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

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

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

Building	Category	System	Equipment Tag	Component	Property	Typical units
	HVAC	Airhandling Exhaust Heatplant Coolplant Misc		CWS CWR HWS HWR CHWS CHWR OA SA RA EA GAS FLUID	Voltage Current ValvePos DamperPos Temperature Humidity Pressure Flow Energy Speed Signal	Volts Amps %open %open °F %RH Psig, "H_2O Cfm, gpm Btu %, Hz %
	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 District 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 District 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 District.

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 controlling 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 1.8.)

b. At the completion of functional performance testing, and

c. At the end of the warranty period (see Warranty Maintenance, Paragraph 1.13).

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 District 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. Graphic displays shall show all relevant alarms when active. Graphical alarm representation shall be consistent across all BAS graphics.

5. 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.

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

7. 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 District does not guarantee the suitability of these drawings for the Contractor’s purpose.

8. 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 building electrical demand shown roughly on the map where the utilities connect to the site.

c. Building environmental index: Provide a building-level environmental index graphic, which displays the weighted building environmental index.

d. Electricity demand limiting

1) Demand limit. Include entries for sliding window interval and a table of On-Peak or Partial-Peak demand time periods 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.

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. Indicate thermostat location and room numbers as provided by the Onwer.. Display space temperature and associated effective heating and cooling setpoints.

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. Include status off all major building systems and access to 'global' building setpoints.

9. Each equipment floor/area plan: To scale, with links to graphics of all BAS controlled/monitored equipment. Indicate the physical location of all equipment with corresponding on/off status.

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

b. 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 Guideline 36) 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.

c. Each zone terminal:

1) Provide link to associated air handling unit where applicable and to floor plan where terminal is located.

2) Include supply air temperature from AHU serving terminal unit.

3) 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.

4) Include zone environmental index metric

d. Central plant equipment including chilled water system and hot water system: 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, etc. as valve positions change.

e. 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) 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); Fan start/stop command, speed, and status (fan-powered); 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).

3) Fan-coil units: operating mode; zone temperature; active heating setpoint; active cooling setpoint; supply air temperature; supply air temperature setpoint (where applicable); fan status.

4) AC units: 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.

f. 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.

g. 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 Paragraph 3.13C.18.d.1).

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

i. All other BAS controlled/monitored equipment.

j. On all system graphics, include a "note" block that allows users to enter comments relevant to system operation.

k. 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. 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 included as a part of Submittal Package 2.

B. Sequences are based on ASHRAE Guideline 36-2018 where available and applicable. Sequences that are taken verbatim from Guideline 36 (as permitted by ASHRAE) are shown in grey to ease reapplication of existing Guideline 36 logic from contractor's control program libraries.

C. General

1. Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent windup.

2. When a control loop is enabled or re-enabled, it and all its constituents (such as the proportional and integral terms) shall be set initially to a Neutral value.

3. 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.

4. 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.

    a. Outdoor air temperature sensors at air handler outdoor air intakes shall be considered valid only when the supply fan is proven on and unit is in Occupied Mode or in any other Mode with the economizer enabled.

    b. 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.

5. 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.

6. 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).

7. 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 following guidelines shall be followed:

    a. Use proportional only (P-only) loops for limiting loops (such as zone CO_2 control loops, etc.).

    b. Do not use the derivative term on any loops unless field tuning is not possible without it.

8. 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.

9. 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.

10. 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.

11. Alarms

    a. There shall be 4 levels of alarm

        1) Level 1: Life Safety Message

        2) Level 2: Critical Equipment Message

        3) Level 3: Urgent Message

        4) Level 4: Normal Message

    b. Maintenance Mode: Operators shall have the ability to put any device (e.g., AHU) in/out of maintenance mode.

        1) All alarms associated with a device in maintenance mode will be suppressed

            a) Exception: Life safety alarms shall not be suppressed.

        2) If a device is in maintenance mode, issue a daily level 3 alarm at a scheduled time, indicating the device is still in maintenance mode.

    c. Exit Hysteresis

        1) 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.

        2) Each analog alarm shall have an adjustable %-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.

    d. Latching –A latching alarm requires acknowledgement from the operators before it can return to normal even if the exit deadband has been met. A non-latching alarm does not require acknowledgement. Default latching status:

        1) Level 1 alarms: latching

        2) Level 2 alarms: latching

3) Level 3 alarms: non-latching

4) Level 4 alarms: non-latching

e. Post Exit Suppression period – To limit alarms, any alarm may have an adjustable suppression period such that, once the alarm is exited, its post-exist suppression timer is triggered, the alarm may not trigger again until the post-exit timer has expired. Default suppression periods:

1) Level 1 alarms: 0 minutes

2) Level 2 alarms: 5 minutes

3) Level 3 alarms: 24 hours

4) Level 4 alarms: 7 days

12. VFD Speed Points

a. The speed analog output 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.

b. 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 3.14E.7 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.

13. Trim & Respond (T&R) Setpoint Reset Logic

a. Trim & Respond setpoint reset logic and zone/system reset Requests where referenced in sequences shall be implemented as described below.

b. 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.

1) For each downstream zone or system, and for each type of setpoint reset Request listed for the zone/system, provide the following software points:

a) Importance-Multiplier (default = 1)

b) Request-Hours Accumulator. Provided SystemOK (see Paragraph 3.13C.16) 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.

c) System Run-Hours Total. This is the number of hours the zone/system has been operating in any Mode other than Unoccupied Mode.

d) 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.

e) The Request-Hours Accumulator and System Run-Hours Total are reset to zero as follows:

1. Reset automatically for an individual zone/system when the System Run-Hours Total exceeds 400 hours.

2. Reset manually by a global operator command. This command will simultaneously reset the Request-Hours point for all zones served by the system.

f) 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.

2) See zone and air handling system control sequences for logic to generate Requests.

3) 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 Trim & Respond logic.

c. 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.

Variable	Definition
Device	Associated device (e.g., fan, pump)
SP0	Initial setpoint
SPmin	Minimum setpoint
SP_{max}	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)

d. Trim & Respond logic shall reset setpoint within the range SPmin to SP_{max}. 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

14. Air Economizer High Limits

a. Economizer shall be disabled whenever the outdoor air conditions exceed the economizer high limit setpoint as specified by local code. 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 Paragraph 3.13L.7. Setpoints listed below are for current ASHRAE and California Energy Standards.

b. ASHRAE 90.1-2016:

Device Type	Allowed only in these ASHRAE Climate Zones	Required High Limit (Economizer Off When):
Fixed Dry Bulb	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	T_{OA} > 24°C (75°F)
	5a, 6a	T_{OA} > 21°C (70°F)
	1a, 2a, 3a, 4a	T_{OA} > 18°C (65°F)
Differential Dry Bulb	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$
Fixed Enthalpy + Fixed Dry bulb	All	h_{OA} > 66 kJ/kg (28 Btu/lb) or T_{OA} > 24°C (75°F)
Differential Enthalpy + Fixed Dry bulb	All	$h_{OA} > h_{RA}$ T_{OA} > 24°C (75°F)

c. Title 24-2016:

Device Type	California Climate Zones	Required High Limit (Economizer Off When):
Fixed Dry Bulb	1, 3, 5, 11-16	T_{OA} > 24°C (75°F)
	2, 4, 10	T_{OA} > 23°C (73°F)
	6, 8, 9	T_{OA} > 22°C (71°F)
	7	T_{OA} > 21°C (69°F)
Differential Dry Bulb	1, 3, 5, 11-16	$T_{OA} > T_{RA}$
	2, 4, 10	$T_{OA} > T_{RA}$ – 1°C (2°F)
	6, 8, 9	$T_{OA} > T_{RA}$ –2°C (4°F)
	7	$T_{OA} > T_{RA}$ – 3°C (6°F)
Fixed Enthalpy + Fixed Dry bulb	All	h_{OA} > 66 kJ/kg (28 Btu/lb) or T_{OA} > 24°C (75°F)

15. Damper/Valve Position

    a. Knowledge of damper and valve position are required for proper generation of Trim & Respond reset requests.

    b. The following are acceptable methods for determining position:

        1) Analog actuator. Position may be assumed to be equal to analog signal to actuator.

        2) Floating actuator. Provide position feedback analog input.

16. Hierarchical Alarm Suppression

    a. 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."

        1) A component is a "source" if it provides resources to a downstream component, such as a chiller providing chilled water to an AHU.

        2) A component is a "load" if it receives resources from an upstream component, such as an AHU that receives chilled water from a chiller.

        3) The same component may be both a load (receiving resources from an upstream source) and a source (providing resources to a downstream load).

        4) 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).

            a) 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.

b) For equipment with associated pumps (chillers, boilers, cooling towers):

1. If the pumps are in a one-to-one relationship with equipment they serve, the pumps shall be treated as part of the system to which they are associated (i.e., they are not considered loads) since a pump failure will necessarily disable its associated equipment.

2. 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).

b. For each system as defined above, there shall be a SystemOK flag, which is either true or false.

c. SystemOK shall be true when all of the following are true:

1) The system is proven on.

2) The system is achieving its temperature and/or pressure setpoint(s) for at least five minutes

3) The system is ready and able to serve its load

d. 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.

1) 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.

2) The operator shall have the ability to individually determine which component alarms may or may not inhibit SystemOK.

e. 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.

1) 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.

2) 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.

3) If SystemOK is false for an airside system (air handler, fan coil, VAV box, etc.), then all alarms from the loads shall be suppressed.

f. This hierarchical suppression shall cascade through multiple levels of load-source relationship, such that alarms at downstream loads shall also be suppressed.

g. The following types of alarms will never be suppressed by this logic:

1) Life/safety and Level 1 alarms

2) Failure-to-start alarms (i.e., equipment is commanded on, but status point shows equipment to be off)

3) Failure-to-stop/hand alarms (i.e., equipment is commanded off, but status point shows equipment to be on)

17. Time-Based Suppression

a. 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:

Time-based suppression is used to suppress reset requests and alarms after a change in setpoint. This includes automatic changes in setpoint, e.g., due to a change in window switch or occupancy sensor status, as well as changes made by occupants.

1) For thermal zone temperature alarms: 18 minutes per °C (10 minutes per °F) of difference, but no longer than 120 minutes

*For example, if setpoint changes from 20°C (68°F) to 21°C (70°F) and the zone temperature is 20.2°C (68.5°F) at the time of the change, inhibit alarm for 15 minutes (0.8°C * 18 minutes per °C, (1.5°F * 10 minutes/°F) after the change.*

2) For thermal zone temperature cooling requests: 9 minutes per °C (5 minutes per °F) of difference, but no longer than 30 minutes

3) For thermal zone temperature heating requests: 9 minutes per °C (5 minutes per °F) of difference, but no longer than 30 minutes

18. Equipment Staging and Rotation

a. Parallel devices shall be lead/standby rotated to maintain even wear.

b. Two runtime points shall be defined for each device:

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

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

c. Lead/standby devices:

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

d. Exceptions to Lead/standby rotation

1) 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 below.

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

1. Fans and Pumps

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

b) Upon identification of a fault condition:

1. For fans and pumps:

a. The next commanded OFF device in the staging order, Device "B", shall be commanded ON while alarming Device "A" remains commanded ON.

b. If Device 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 devices called for by the lead/lag logic have proven on.

c. When either the required number of devices proves on or all devices are commanded on, set alarming devices to the last positions in the lead/lag staging order sequenced reverse chronologically (i.e. the device that alarmed most recently is sent to last position).

d. Staging order of non-alarming devices shall follow the even wear logic. A device in alarm can only automatically move up in the staging order if another device goes into alarm.

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

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

a) Fans and Pumps

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

19. VAV Box Controllable Minimum

a. 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.

b. Option 1: If the VAV box controller can control to 0.004" per Paragraph 2.9F.5.c., the minimum setpoint *Vm* shall be determined from the table below if the VAV box manufacturer is listed:

Inlet	Titus	Krueger	Price	MetalAire High Gain	ETI
4	15	15	20	15	15
6	30	35	30	30	30
8	55	60	55	50	55
10	90	90	95	85	90
12	120	130	135	110	130
14	190	175	195	155	180
16	245	230	260	210	235
24x16	455	445	490	N/A	415

c. Option 2: The minimum setpoint Vm shall be determined as follows:

1) Determine the velocity pressure sensor reading VP_m in Pa (inches H_2O) that will give a reliable flow indication. If this information is not provided by the sensor manufacturer, determine the velocity pressure that will result in a digital reading from the transducer and A/D converter of 12 bits or counts (assuming a 10-bit A/D converter). This is considered sufficient resolution for stable control.

2) Determine the minimum velocity v_m for each VAV box size and model. If the VAV box manufacturer provides an amplification factor F for the flow pickup, calculate the minimum velocity v_m as

$$v_m = 4005\sqrt{\frac{VP_m}{F}}$$ IP

Where F is not known, in IP units it can be calculated from the measured airflow at 1 inch w.c. signal from the VP sensor

$$F = \left(\frac{4005A}{CFM_{@1"}} \right)^2$$ IP

where A is the nominal duct area (ft^2)

$$A = \pi \left(\frac{D}{24} \right)^2$$ IP

where D is the nominal duct diameter (inches).

3) Calculate the minimum airflow setpoint allowed by the controls (Vm) for each VAV box size as

$$Vm = v_m A$$

D. Electricity Demand Limiting

1. On home page, provide three manual software switches: Demand Limit Level 1 to 3. These can be manually set by operator to initiate demand limit sequences herein. (These switches may also in the future be tied to PG&E demand reduction contacts.)

E. Generic Ventilation Zones

1. This section applies to sub-zones of air handlings systems, including all VAV boxes and fan powered boxes.

2. Zone Minimum Outdoor Air and Minimum Airflow Setpoints

a. Vmin, zone occupied minimum airflow setpoint on plans (see VAV schedule)

b. Vocc-min, zone minimum outdoor airflow for occupants, per Title 24 prescribed airflow-per-occupant requirements see VAV schedule)

c. Varea-min, zone minimum outdoor airflow for building area, per Title 24 prescribed airflow-per-area requirements (see VAV schedule)

d. For compliance with California Title 24-2019, outdoor air setpoints shall be calculated as follows:

1) Determine the zone minimum outdoor air setpoints Zone-Abs-OA-min and Zone-Des-OA-min.

a) Zone-Abs-OA-min shall be reset based on the following conditions in order from higher to lower priority:

1. Zero if the zone has an occupancy sensor, is unpopulated, and is permitted to be in occupied-standby mode.

2. Varea-min if the zone has a CO_2 sensor

3. Zone-Des-OA-min otherwise

b) Zone-Des-OA-min is equal to, in order from highest to lowest priority:

1. Zero if the zone has an occupancy sensor, is unpopulated, and is permitted to be in occupied-standby mode.

2. The larger of Varea-min and Vocc-min otherwise

2) The occupied minimum airflow Vmin* shall be equal to Vmin except as noted below, in order from higher to lower priority:

a) If the zone has an occupancy sensor and is permitted to be in occupied-standby mode, Vmin* shall be equal to zero when the room is unpopulated.

b) If the zone has a CO_2 sensor

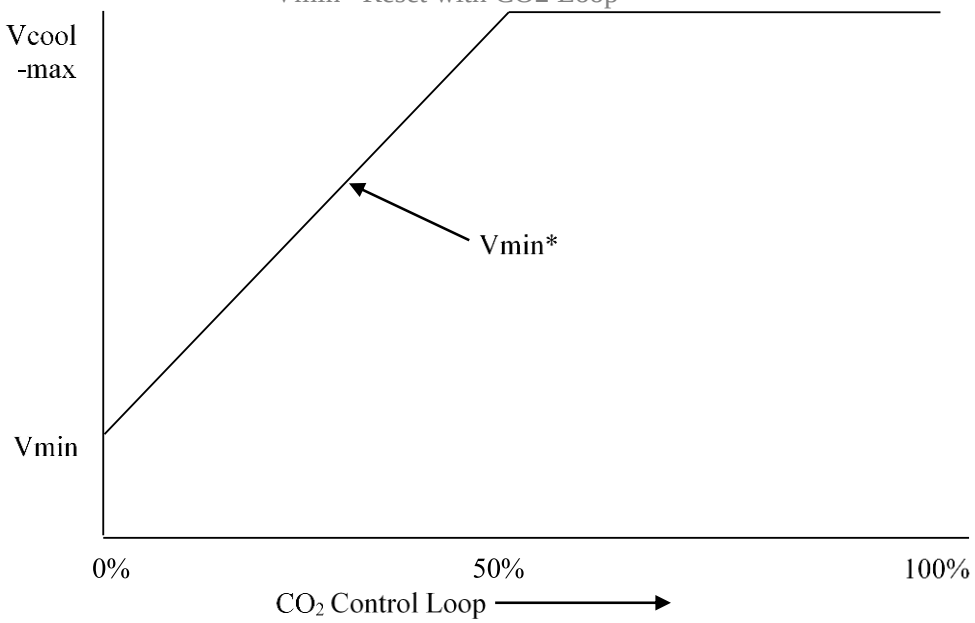
1. During Occupied Mode, a P-only loop shall maintain CO_2 concentration at setpoint of 1000 ppm; reset from 0% at (setpoint minus 200 PPM) to 100% at setpoint.

2. Loop is disabled and output set to zero when the zone is not in Occupied Mode.

3. For cooling-only VAV terminal units, reheat VAV terminal units, and constant volume series fan powered terminal units

a. The CO_2 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 below. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

Vmin* Reset with CO2 Loop



3. Time-Averaged Ventilation (TAV)

ASHRAE Standard 62.1 and 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.

a. When the active airflow setpoint (Vspt) is non-zero and is less than the lowest possible airflow setpoint allowed by the controls (Vm), the airflow setpoint shall be pulse width modulated as follows:

1) The TAV ratio shall be determined as: TAV_{ratio} = Vspt/Vm

2) The total cycle time (TCT) shall be 15 minutes (adjustable)

3) 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:

a) 1.5 minutes or

b) TCT multiplied by TAV_{ratio}

4) 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 re-enabling the control loop.

5) During TAV mode, each cycle shall consist of an open and closed period which alternate until Vspt is greater than Vm.

6) 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

b. When in TAV mode, the active airflow setpoint, Vspt, shall be overridden to Vspt*.

F. Generic Thermal Zones

1. This section applies to all single zone systems (e.g. fan-coils) and sub-zones of air handling systems, including VAV boxes.

2. Setpoints

a. Default zone temperature setpoints

Zone type	Occupied		Unoccupied	
	Heat	Cool	Heat	Cool
VAV exterior	70ºF	75ºF	60ºF	90ºF
VAV interior	70ºF	73ºF	60ºF	90ºF
Electrical and mechanical	60ºF	85ºF	60ºF	85ºF
IDF/MDF	60ºF	78ºF	60ºF	78ºF

b. Each zone shall have separate occupied and unoccupied heating and cooling setpoints.

c. The active setpoints shall be determined by the Operating Mode of the Zone Group [see 3.13G.6].

1) The setpoints shall be the occupied setpoints during Occupied Mode, Warm up Mode, and Cool-down Mode.

2) The setpoints shall be the unoccupied setpoints during Unoccupied Mode, Setback Mode, and Setup Mode.

d. The software shall prevent

1) 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)).

2) The unoccupied heating setpoint from exceeding the occupied heating setpoint; and

3) The unoccupied cooling setpoint from being less than the occupied cooling setpoint.

e. Where the zone has a local setpoint adjustment knob/button

1) 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.

2) The adjustment shall be capable of being limited in software.

a) As a default, the active occupied cooling setpoint shall be limited between 22°C (72°F) and 27°C (80°F).

b) As a default, the active occupied heating setpoint shall be limited between 18°C (65°F) and 22°C (72°F).

3) The active heating and cooling setpoints shall be independently adjustable, respecting the limits and anti-overlap logic described above. If zone thermostat provides only a single setpoint adjustment, then the adjustment shall move both the active heating and cooling setpoints upwards or downwards by the same amount, within the limits described above.

4) The adjustment shall only affect occupied setpoints in Occupied Mode, Warm-up Mode, and Cool-down Mode and shall have no impact on setpoints in all other modes.

5) At the onset of demand limiting, the local setpoint adjustment value shall be frozen. Further adjustment of the setpoint by local controls shall be suspended for the duration of the demand limit event.

f. Cooling Demand Limit Setpoint 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.

1) At Demand Limit Level 1, increase setpoint by 0.5°C (1°F).

2) At Demand Limit Level 2, increase setpoint by 1°C (2°F).

3) At Demand Limit Level 3, increase setpoint by 2°C (4°F).

g. Heating Demand Limit Setpoint 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.

1) At Demand Limit Level 1, decrease setpoint by 0.5°C (1°F).

2) At Demand Limit Level 2, decrease setpoint by 1°C (2°F).

3) At Demand Limit Level 3, decrease setpoint by 2°C (4°F).

h. Occupancy sensors. For zones that have an occupancy switch

1) 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).

2) When the switch indicates that the space has been populated for one minute continuously, the active heating and cooling setpoints shall be restored to their previous values.

i. Hierarchy of Setpoint Adjustments: The following adjustment restrictions shall prevail in order from highest to lowest priority:

1) Setpoint overlap restriction (3.13F.2.d.1))

2) Absolute limits on local setpoint adjustment (3.13F.2.e.1))

3) Demand limit

a) Occupancy sensors: Change of setpoint by occupancy sensor is added to change of setpoint by any demand limits in effect.

b) Local setpoint 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.

4) Scheduled setpoints based on Zone Group mode

3. Local override: When thermostat override buttons are depressed, the call for Occupied Mode operation shall be sent up to the Zone Group control for 60 minutes.

4. Control Loops

a. Two separate control loops shall operate to maintain space temperature at setpoint, the Cooling Loop and the Heating Loop. Where multiple VAVs serve a single zone, a common set of heating and cooling setpoints, a single common Cooling Loop and single common Heating Loop shall be used.

1) The Heating Loop shall be enabled whenever the space temperature is below the current zone heating setpoint 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.

2) The Cooling Loop shall be enabled whenever the space temperature is above the current zone cooling setpoint temperature, and disabled when space temperature is below the current zone cooling 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 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).

c. 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).

d. 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.

e. See other sections for how the outputs from these loops are used.

5. Zone State

a. Heating: when the output of the space heating control loop is nonzero and the output of the cooling loop is equal to zero.

b. Cooling: when the output of the space cooling control loop is nonzero and the output of the heating loop is equal to zero.

c. Deadband: when not in either Heating or Cooling.

6. Zone Alarms

a. Zone temperature alarms

1) High temperature alarm

a) If the zone is 2°C (3°F) above cooling setpoint for 10 minutes, generate Level 3 alarm.

b) If the zone is 3°C (5°F) above cooling setpoint for 10 minutes, generate Level 2 alarm.

2) Low temperature alarm

a) If the zone is 2°C (3°F) below heating setpoint for 10 minutes, generate Level 3 alarm.

b) If the zone is 3°C (5°F) below heating setpoint for 10 minutes, generate Level 2 alarm.

3) Suppress zone temperature alarms as follows:

a) After zone setpoint is changed per 3.13C.17.

b) While Zone Group is in Warm-up or Cool-down Modes.

b. For zones with CO_2 sensors:

1) CO_2 sensors: 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.

G. Zone Groups

1. Each system shall be broken into separate Zone Groups composed of a collection of one or more zones served by a single air handler.

2. Each Zone Group shall be capable of having separate occupancy schedules and Operating Modes from other Zone Groups.

3. All zones in each Zone Group shall be in the same Zone Group Operating Mode as defined in Paragraph 3.13G.6. 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.

4. A Zone Group may be in only one mode at any given time.

5. 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.

6. Zone Group Operating Modes: Each Zone Group shall have the following modes:

   a. Occupied Mode: A Zone Group is in the Occupied Mode when any of the following is true:

      1) The time of day is between the Zone Group's scheduled occupied start and stop times.

      2) The schedules have been overridden by the Occupant Override System.

      3) Any zone local override timer (initiated by local override button) is nonzero.

   b. Warm-up Mode: For each zone, the BAS shall calculate the required warm up time based on the zone's occupied heating setpoint, the current zone temperature, the outdoor air temperature, and a mass/capacity factor for each zone. Zones where the window switch indicates that a window is open shall be ignored. The mass factor shall be manually adjusted or 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. Warm-up Mode shall start based on the zone with the longest calculated warm up time requirement, but no earlier than 3 hours before the start of the scheduled occupied period, and shall end at the scheduled Occupied start hour.

   c. Cool-Down Mode: For each zone, the BAS shall calculate the required cool down time based on the zone's occupied cooling setpoint, the current zone temperature, the outdoor air temperature, and a mass/capacity factor for each zone. Zones where the window switch indicates that a window is open shall be ignored. The mass factor shall be manually adjusted or 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. Cool-down Mode shall start based on the zone with the longest calculated cool-down time requirement, but no earlier than 3 hours before the start of the scheduled occupied period, and shall end at the scheduled Occupied start hour.

   d. Setback Mode: During Unoccupied Mode, if any 5 zones (or all zones, if fewer than 5) in the Zone Group fall below their unoccupied heating setpoints or if the average zone temperature of the Zone Group falls below the average unoccupied heating setpoint, the Zone Group shall enter Setback Mode until all spaces in the Zone Group are 1°C (2°F) above their unoccupied setpoints.

   e. Freeze Protection Setback Mode: During Unoccupied Mode, if any single zone falls below 4°C (40°F), the Zone Group shall enter Setback Mode until all zones are above 7°C (45°F), and a Level 3 alarm shall be set.

   f. Setup Mode: During Unoccupied Mode, if any 5 zones (or all zones, if fewer than 5) in the Zone rise above their unoccupied cooling setpoints or if the average zone temperature of the Zone Group rises above the average unoccupied cooling setpoint, the Zone Group shall enter Setup Mode until all spaces in the Zone Group are 1°C (2°F) below their unoccupied setpoints. Zones where the window switch indicates that a window is open shall be ignored.

   g. Unoccupied Mode: When the Zone Group is not in any other mode.

7. Unless otherwise specified by District, the following Zone Groups shall be created. Confirm schedules and zone assignments with the District prior to programming.

Zone Group Name	AH Tag	Terminal Unit Tags	Default Schedule
AHU-1-1	AHU-1-1	VX-11101 to VX-11109	See Applied Arts Building Class Schedules in RFQP.
AHU-1-2	AHU-1-2	VX-12101 to VX-12111	See Applied Arts Building Class Schedules in RFQP
AHU-1-3	AHU-1-3	VX-13101 to VX-13110	See Applied Arts Building Class Schedules in RFQP
AHU-2-1	AHU-2-1	VX-21201 to VX-21209	See Applied Arts Building Class Schedules in RFQP
AHU-2-2	AHU-2-2	VX-22201 to VX-22206	See Applied Arts Building Class Schedules in RFQP
AHU-2-3	AHU-2-3	VX-23201 to VX-23210	See Applied Arts Building Class Schedules in RFQP
AHU-2-4	AHU-2-4	VR-24201 to VR-24205	See Applied Arts Building Class Schedules in RFQP

H. VAV Terminal Unit, Cooling Only

1. See Generic Thermal Zones (3.13F) for setpoints, loops, control modes, alarms, etc.

2. See Generic Ventilation Zones (3.13E) for calculation of zone minimum outdoor airflow.

3. Parameters

   a. Design Information

      1) Vcool-max, zone maximum cooling airflow setpoint on VAV schedule

      2) Vmin, zone occupied minimum airflow setpoint on VAV schedule

      3) Vocc-min, zone minimum outdoor airflow for occupants, per Title 24 prescribed airflow-per-occupant requirements, see VAV schedule

      4) Varea-min, zone minimum outdoor airflow for building area, per Title 24 prescribed airflow-per-area requirements, see VAV schedule

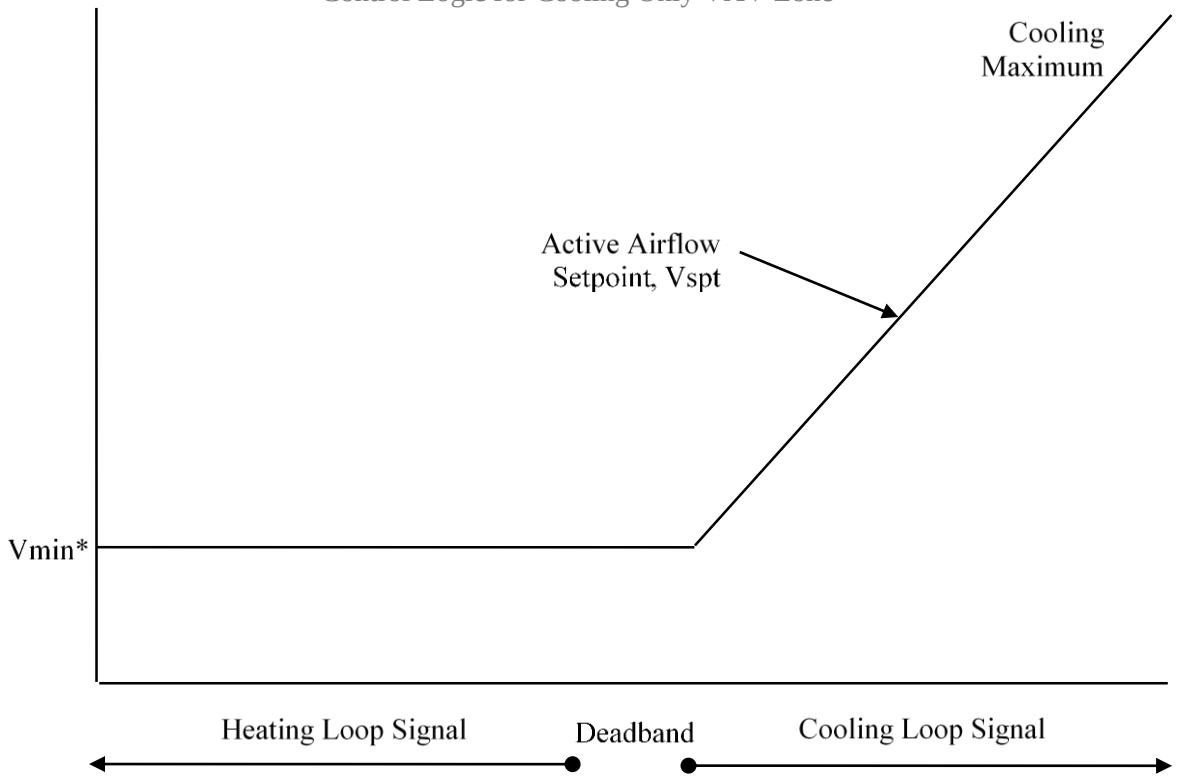
      5) Occupied-standby mode: Disallowed. Include occupied-standby logic for future use.

4. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vmin*	0	0	0	0	0

5. Control logic is depicted schematically in the below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

Control Logic for Cooling Only VAV Zone



   a. When the Zone State is Cooling, the Cooling Loop output shall be mapped to the active airflow setpoint from the minimum to the cooling maximum airflow setpoints.

      1) If supply air temperature from the air handler is greater than room temperature, cooling supply airflow setpoint shall be no higher than the minimum.

   b. When the Zone State is Deadband or Heating, the active airflow setpoint shall be the minimum airflow setpoint.

6. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

7. Alarms

   a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 4 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 3 alarm.

3) If a zone has an Importance-Multiplier of 0 [see 3.13C.13.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. 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.

c. 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.

8. 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 damper full closed/open.

e. Reset request-hours accumulator point to zero (provide one point for each reset type listed below).

9. System Requests

a. Cooling SAT Reset Requests

1) If the zone temperature exceeds the zone's cooling setpoint by 3°C (5°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 3 Requests,

2) Else if the zone temperature exceeds the zone's cooling setpoint by 2°C (3°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 2 Requests,

3) Else if the Cooling Loop is greater than 95%, send 1 Request until the Cooling Loop is less than 85%,

4) Else if the Cooling Loop is less than 95%, send 0 Requests

b. Static Pressure Reset Requests

1) 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,

2) 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,

3) Else if the damper position is greater than 95%, send 1 Request until the damper position is less than 85%,

4) Else if the damper position is less than 95%, send 0 Requests.

I. VAV Terminal Unit, Cooling Only with Upstream Heating Coil (VC-2-06, VC-2-07, VC-2-08, VC-2-09 and HC-4)

1. See Generic Thermal Zones (3.13F) for setpoints, loops, control modes, alarms, etc.

2. See Generic Ventilation Zones (3.13E) for calculation of zone minimum outdoor airflow.

3. Parameters

a. Design Information (see VAV Box schedule to be created by Design/Build Mechanical Contractor):

1) Vcool-max, zone maximum cooling airflow setpoint on VAV schedule

2) Vmin, zone occupied minimum airflow setpoint on VAV schedule

3) Vheat-max, zone maximum heating airflow setpoint on VAV schedule

4) Vocc-min, zone minimum outdoor airflow for occupants, per Title 24 prescribed airflow-per-occupant requirements, see VAV schedule

5) Varea-min, zone minimum outdoor airflow for building area, per Title 24 prescribed airflow-per-area requirements, see VAV schedule

6) Occupied-standby mode: Disallowed. Include occupied-standby logic for future use.

b. Set the following:

1) Zone maximum discharge air temperature above heating setpoint (MaxΔT) = 25°F

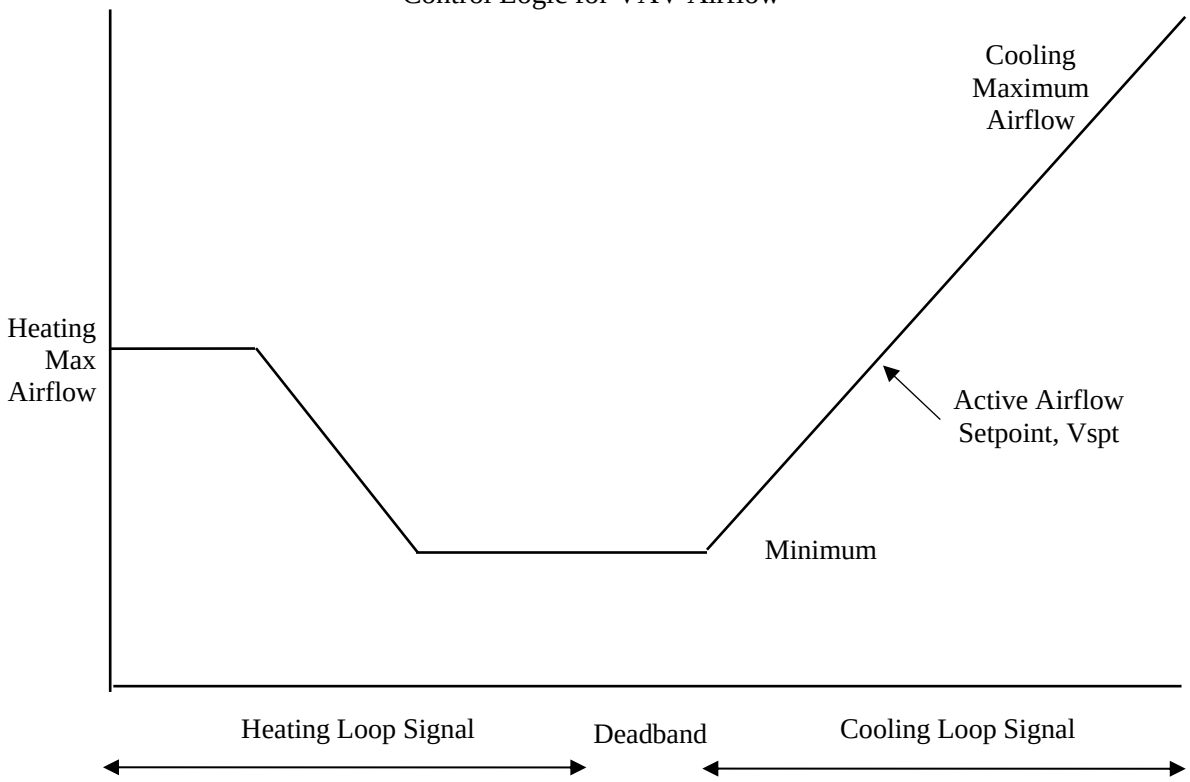
4. Active maximum and minimum setpoints in each zone shall vary depending on the mode and sub-mode of the System that the zone is served by and whether or not the zone is the current Control Zone:

Setpoint	Occupied cooling submode	Occupied heating submode	Occupied deadband submode	Cool-down or Setup	Warm-up or Setback	Unoccupied
Cooling maximum	Vcool-max	Vmin*	Vcool-max	Vcool-max	0	0
Minimum	Vmin*	Vmin*	Vmin*	0	0	0

Setpoint	Occupied cooling submode	Occupied heating submode	Occupied deadband submode	Cool-down or Setup	Warm-up or Setback	Unoccupied
Heating maximum	Vheat-max	Vheat-max	Vmin*	0	Vcool-max	0

5. Control logic is depicted schematically in the figure below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

Control Logic for VAV Airflow



a. When the Zone State is Cooling, the Cooling Loop output shall be mapped to the airflow setpoint from the cooling minimum to the cooling maximum airflow setpoints.

1) If supply air temperature from the upstream heating coil is greater than room temperature, cooling supply airflow setpoint shall be no higher than the minimum.

b. When the Zone State is Deadband, the active airflow setpoint shall be the minimum airflow setpoint.

c. When the zone state is heating, the heating loop shall maintain space temperature at the heating set point as follows:

1) From 33%-66%, if the DAT from the upstream heating coil is greater than the room temperature plus 5ºF, the Heating Loop output shall reset the zone airflow setpoint from the minimum airflow endpoint to the maximum heating airflow endpoint.

6. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

7. System Heating/Cooling SubMode

    a. When AHU supply fan is proven on, SubMode shall be one of three modes as described below: Heating, Cooling, or Deadband. When fan is proven off, SubMode shall be Deadband.

        1) Definitions

            a) AveCool = sum of cooling loop outputs of all zones served by this upstream heating coil divided by the number of zones

            b) AveHeat = sum of the absolute value of heating loop outputs of all zones served by this upstream heating coil divided by the number of zones

        2) SubMode determination

            a) SubMode shall be set to Cooling if AveCool > 10% and AveCool > AveHeat

            b) SubMode shall be set to Heating if AveHeat > 10% and AveHeat > AveCool

        3) Exception to prevent extreme temperatures. The above SubMode determination rules shall be overridden as follows

            a) If in Heating and any zone has Cooling Loop = 100 and temperature is above setpoint + 2°F for more than 5 minutes, switch to Cooling

            b) If in Cooling and any zone has Heating Loop = 100 and temperature is below setpoint + 2°F for more than 5 minutes, switch to Heating

        4) If SubMode is neither Cooling nor Heating, it shall be set to Deadband.

    b. Once the unit is in SubMode Heating or Cooling, it shall stay in that SubMode for at least 10 minutes.

8. Heating Coil (HC-4)

    a. The zone with the highest Heating Loop output is the Control Zone when the system is in the Heating SubMode. Once a zone is set to the Control Zone, it shall remain so for a minimum of 15 minutes (adj.)

    b. The Control Zone Heating Loop output shall be mapped to reset the discharge air temperature setpoint as follows:

        1) From 0% to 33%, discharge air temperature shall be reset from the AHU discharge air temperature setpoint from the current AHU SAT setpoint to a maximum of MaxΔT above space temperature setpoint.

        2) From 66-100%, the Heating Loop output shall reset the discharge temperature from MaxΔT above space temperature setpoint to 115°F

c. The heating coil control loop shall be enabled when the SubMode is Heating and SubMode has been out of Cooling Mode for more than 5 minutes. The heating coil control loop shall be disabled with output set to zero otherwise.

d. When enabled, the heating coil shall be modulated to maintain the discharge temperature at setpoint.

1) When the airflow setpoint is pulse width modulated per 3.13E.3, the heating coil and PID loop shall be disabled with output set to 0 when all associated VAVs are in the closed period.

e. In Occupied Mode, the heating coil shall be modulated to maintain a discharge air temperature no lower than 50°F.

9. Alarms

a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 4 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 3 alarm.

3) If a zone has an Importance-Multiplier of 0 [see 3.13C.13.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Low discharge air temperature

1) If heating hot water plant is proven on and the discharge air temperature is 8°C (15°F) less than setpoint for 10 minutes, generate a Level 4 alarm.

2) If heating hot water plant is proven on and the discharge air temperature is 17°C (30°F) less than setpoint for 10 minutes, generate a Level 3 alarm.

3) If a zone has an Importance-Multiplier of 0 [see 3.13C.13.b.1)a)] for its Hot Water reset Trim & Respond control loop, low discharge air temperature alarms shall be suppressed for that zone.

c. 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.

d. 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.

e. Leaking valve. If the valve position is 0% for 15 minutes, discharge air temperature is above AHU SAT by 3°C (5°F), and the fan serving the zone is proven on, generate a Level 4 alarm.

10. 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.

    g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below).

11. System Requests

    a. Cooling SAT Reset Requests

        1) If the zone temperature exceeds the zone's cooling setpoint by 3°C (5°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 3 Requests,

        2) Else if the zone temperature exceeds the zone's cooling setpoint by 2°C (3°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 2 Requests,

        3) Else if the Cooling Loop is greater than 95%, send 1 Request until the Cooling Loop is less than 85%,

        4) Else if the Cooling Loop is less than 95%, send 0 Requests

    b. Static Pressure Reset Requests

        1) 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,

        2) 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,

        3) Else if the damper position is greater than 95%, send 1 Request until the damper position is less than 85%,

        4) Else if the damper position is less than 95%, send 0 Requests

    c. If there is a hot water coil, Hot Water Reset Requests

1) If the discharge air temperature is 17°C (30°F) less than setpoint for 5 minutes, send 3 Requests,

2) Else if the discharge air temperature is 8°C (15°F) less than setpoint for 5 minutes, send 2 Requests,

3) Else if HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 85%,

4) Else if the HW valve position is less than 95%, send 0 Requests

d. If there is a hot water coil and a 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:

1) If the HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 10%

2) Else if the HW valve position is less than 95%, send 0 Requests.

J. VAV Terminal Unit with Reheat

1. See Generic Thermal Zones (3.13F) for setpoints, loops, control modes, alarms, etc.

2. See Generic Ventilation Zones (3.13E) for calculation of zone minimum outdoor airflow.

3. Parameters

a. Design Information (see VAV Box schedule to be created by Design/Build Mechanical Contractor):

1) Vcool-max, zone maximum cooling airflow setpoint on VAV schedule

2) Vmin, zone occupied minimum airflow setpoint on VAV schedule

3) Vheat-max, zone maximum heating airflow setpoint on VAV schedule

4) Vocc-min, zone minimum outdoor airflow for occupants, per Title 24 prescribed airflow-per-occupant requirements, see VAV schedule

5) Varea-min, zone minimum outdoor airflow for building area, per Title 24 prescribed airflow-per-area requirements, see VAV schedule

6) Occupied-standby mode: Disallowed. Include occupied-standby logic for future use.

b. Set the following:

1) Zone maximum discharge air temperature above heating setpoint (MaxΔT) = 25°F

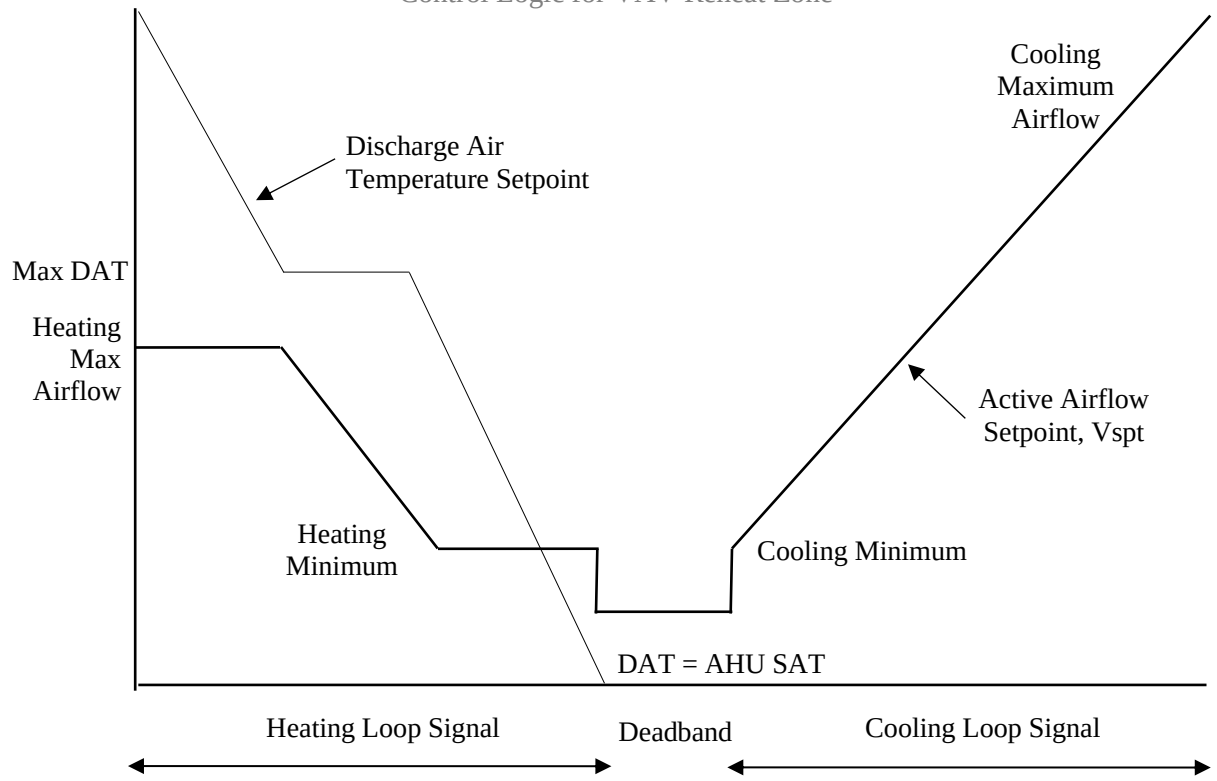
2) The heating minimum airflow setpoint (Vheat-min) = 0

4. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	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

5. Control logic is depicted schematically in the figure below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

Control Logic for VAV Reheat Zone



a. When the Zone State is Cooling, the Cooling Loop output shall be mapped to the airflow setpoint from the cooling minimum to the cooling maximum airflow setpoints. Heating coil is disabled unless the discharge air temperature is below the minimum setpoint [see 3.13J.5.d below].

1) If supply air temperature from the air handler is greater than room temperature, cooling supply airflow setpoint shall be no higher than the minimum.

b. When the Zone State is Deadband, the active airflow setpoint shall be the minimum airflow setpoint. Heating coil is disabled unless the discharge air temperature is below the minimum setpoint [see 3.13J.5.d below].

c. When the zone state is heating, the heating loop shall maintain space temperature at the heating set point as follows:

1) From 0% to 33%, the heating-loop output shall reset the discharge air temperature (DAT) set point from the current AHU SAT setpoint to a maximum of MaxΔT above space temperature setpoint. The airflow setpoint shall be the heating minimum endpoint.

2) From 33%-66%, if the DAT is greater than the room temperature plus 5ºF, the Heating Loop output shall reset the zone airflow setpoint from the minimum airflow endpoint to the maximum heating airflow endpoint.

3) From 66-100%, the Heating Loop output shall reset the discharge temperature from current DAT setpoint (item a) above to 115°F. The airflow setpoint shall be the heating maximum endpoint.

4) 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).

a) When the airflow setpoint is pulse width modulated per 3.13E.3, the heating coil and PID loop shall be disabled with output set to 0 during closed periods.

d. In Occupied Mode, the heating coil shall be modulated to maintain a discharge air temperature no lower than 10°C (50°F).

6. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

7. Alarms

a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 4 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes while setpoint is greater than zero, generate a Level 3 alarm.

3) If a zone has an Importance-Multiplier of 0 [see 3.13C.13.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Low discharge air temperature

1) If heating hot water plant is proven on and the discharge air temperature is 8°C (15°F) less than setpoint for 10 minutes, generate a Level 4 alarm.

2) If heating hot water plant is proven on and the discharge air temperature is 17°C (30°F) less than setpoint for 10 minutes, generate a Level 3 alarm.

3) If a zone has an Importance-Multiplier of 0 [see 3.13C.13.b.1)a)] for its Hot Water reset Trim & Respond control loop, low discharge air temperature alarms shall be suppressed for that zone.

c. 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.

d. 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.

e. Leaking valve. If the valve position is 0% for 15 minutes, discharge air temperature is above AHU SAT by 3°C (5°F), and the fan serving the zone is proven on, generate a Level 4 alarm.

8. 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.

g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below).

9. System Requests

a. Cooling SAT Reset Requests

1) If the zone temperature exceeds the zone's cooling setpoint by 3°C (5°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 3 Requests,

2) Else if the zone temperature exceeds the zone's cooling setpoint by 2°C (3°F) for 2 minutes and after suppression period due to setpoint change per 3.13C.17, send 2 Requests,

3) Else if the Cooling Loop is greater than 95%, send 1 Request until the Cooling Loop is less than 85%,

4) Else if the Cooling Loop is less than 95%, send 0 Requests

b. Static Pressure Reset Requests

1) 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,

2) 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,

3) Else if the damper position is greater than 95%, send 1 Request until the damper position is less than 85%,

4) Else if the damper position is less than 95%, send 0 Requests

c. If there is a hot water coil, Hot Water Reset Requests

1) If the discharge air temperature is 17°C (30°F) less than setpoint for 5 minutes, send 3 Requests,

2) Else if the discharge air temperature is 8°C (15°F) less than setpoint for 5 minutes, send 2 Requests,

3) Else if HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 85%,

4) Else if the HW valve position is less than 95%, send 0 Requests

d. If there is a hot water coil and a 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:

1) If the HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 10%

2) Else if the HW valve position is less than 95%, send 0 Requests.

K. Air Handling Unit System Modes:

1. 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).

1) Occupied Mode

2) Cool-down Mode

3) Setup Mode

4) Warm-up Mode

5) Setback Mode

6) Freeze Protection Setback Mode

7) Unoccupied Mode

L. Multiple Zone VAV Air Handling Unit

1. Parameters

a. Design Information:

1) Temperature Setpoints

a) Min_ClgSAT, lowest cooling supply air temperature setpoint: 55°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: 65°F.

2) Ventilation Setpoints

a) AbsMinOA: the design outdoor airflow rate when all zones with CO2 sensors or occupancy sensors are unpopulated: per AHU schedule on plans (TBD)

b) DesMinOA: the design minimum outdoor airflow with areas served by the system are occupied at their design population: per AHU schedule on plans (TBD)

3) Economizer High Limit

a) California Title 24 Economizer High Limit

1. California Climate Zone: 3

2. Differential Dry Bulb + Fixed Dry Bulb

4) Filter High-Limit Differential Pressure at Design Airflow, DP100: 1”, final TBD based on filter selection.

b. TAB Information

1) Duct design maximum static pressure, Max_DSP, to be determined per TAB procedures in Section 230000.

2) Return fan discharge static pressure setpoints (for Return Fan Direct Building Pressure Control – see 3.13L.8)

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 inches) to ensure outdoor air is not drawn backwards thru the relief damper.

b) RFDSPmax: That required to exhaust enough air to maintain building static pressure at setpoint 12 Pa (0.05 inches) when the supply air fan is at design airflow and on 100% outdoor air.

3) Minimum Fan Speed: Per Paragraph 3.14E.7

2. Supply Fan Control

a. Supply Fan Start/Stop

1) Supply fan shall run when system is in the Cool-down Mode, Setup Mode, or Occupied Mode.

2) If there are any VAV-reheat boxes on perimeter zones, supply fan shall also run when system is in Setback Mode or Warm-up Mode (i.e., all Modes except Unoccupied).

3) Totalize current airflow rate from VAV boxes to a software point, Vps.

VAV box airflow rates are summed to get overall supply air rate without the need for an airflow measuring station at the air handler discharge. This is used for ventilation rate calculations and may also be used for display and diagnostics.

b. Static Pressure Setpoint Reset

1) Static pressure setpoint: Setpoint shall be reset using Trim & Respond logic [see 3.13C.13] using the following parameters:

Variable	Value
Device	Supply Fan
SP0	120 Pa. (0.5 inches)
SPmin	25 Pa. (0.1 inches)
SP_{max}	Max_DSP (See 3.13L.1.b.1))
Td	10 minutes
T	2 minutes
I	2
R	Zone Static Pressure Reset Requests
SPtrim	-12 Pa (-0.05 inches)
SPres	15 Pa (+0.06 inches)
SPres-max	32 Pa (+0.13 inches)

The trim & respond reset parameters above are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

c. Static Pressure Control

1) Supply fan speed is controlled to maintain duct static pressure at setpoint when the fan is proven on. Where the Zone Groups served by the system are small, provide multiple sets of gains that are used in the control loop as a function of a load indicator (such as supply fan airflow rate, the area of the Zone Groups that are occupied, etc.).

High pressure trips may occur if all VAV boxes are closed (as in Unoccupied Mode) or if fire/smoke dampers are closed (in some FSD designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors). Multiple sets of gains are used to provide control loop stability as system characteristics change.

3. Supply Air Temperature Control

a. Control loop is enabled when the supply air fan is proven on, and disabled and output set to Deadband (no heating, minimum economizer) otherwise.

b. Supply Air Temperature Setpoint

The default range of outdoor air temperatures [21°C (70°F) – 16°C (60°F)] used to reset the Occupied Mode SAT setpoint was chosen to maximize economizer hours. It may be preferable to use a lower range of OATs [e.g., 18°C (65°F) – 13°C (55°F)] to minimize fan energy if:

- *There is a 24/7 chiller plant that is running anyway*
- *Reheat is minimized, as in a VAV dual-fan, dual-duct system*
- *The climate severely limits the number of available economizer hours*

If using this logic, the engineer should oversize interior zones and rooms with high cooling loads (design them to be satisfied by the warmest SAT) so these zones don't drive the T&R block to the minimum SAT setpoint.

1) See 3.13L.1.a.1) for Min_ClgSAT, Max_ClgSAT, OAT_Min, and OAT_Max setpoints.

2) 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.

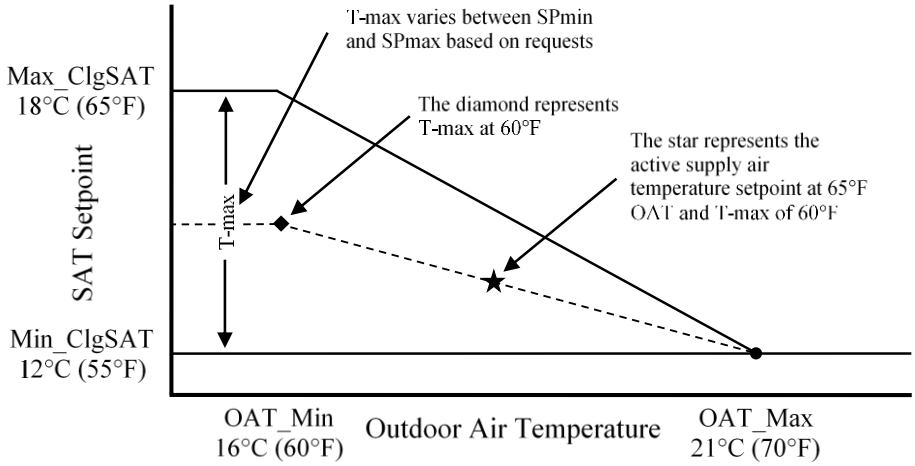
a) T-max shall be reset using Trim & Respond logic [see 3.13C.13] between Min_ClgSAT and Max_ClgSAT. The following parameters are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase:

Variable	Value
Device	Supply Fan

Variable	Value
SP0	SP_{max}
SPmin	Min_ClgSAT
SP_{max}	Max_ClgSAT
Td	10 minutes
T	2 minutes
I	2
R	Zone Cooling SAT Requests
SPtrim	+0.1°C (+0.2°F)
SPres	-0.2°C (-0.3°F)
SPres-max	-0.6°C (-1.0°F)

The net result of this SAT reset strategy is depicted in the chart below for Min_ClgSAT = 12°C (55°F), Max_ClgSAT = 18°C (65°F), OAT_Max=21°C (70°F), and OAT_Min = 16°C (60°F):

Figure 5.16.2.2. Example Supply Air Temperature Reset Diagram



The trim & respond reset parameters above are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

3) During Cool-Down Mode: Setpoint shall be Min_ClgSAT.

4) During Warm-up and Setback Modes: Setpoint shall be 35°C (95°F).

Raising the SAT setpoint in warm-up will effectively lock out the economizer and cooling coil, which is desirable for warm-up even if there is no heating coil at the AHU to meet the higher SAT.
This does not apply in the case of a DFDD AHU, or if all the zones are equipped with fan-powered boxes such that the AHU is off in warm-up and setback.

4. Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to sequence the outdoor air damper, return air damper, and cooling coil as shown in the diagram below.

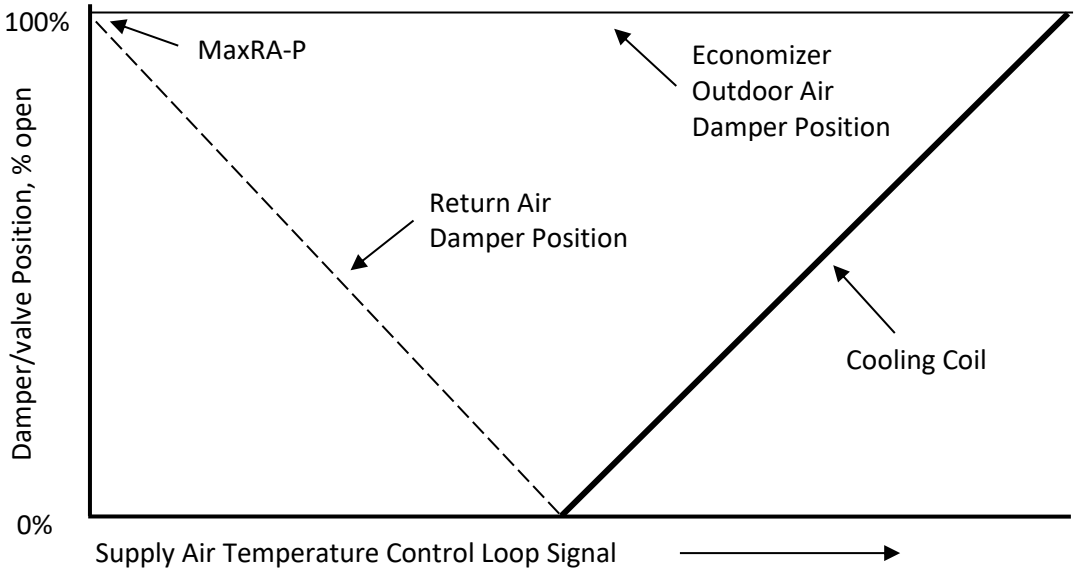
a. For units with a single common minimum outdoor air and economizer damper, return air damper maximum position MaxRA-P is modulated to control minimum outdoor air volume (see Section 3.13L.6.b **Error! Reference source not found.**).

b. The points of transition along the x-axis shown and described below are representative. Separate gains shall be provided for each section of the control map (heating coil, economizer, cooling coil), that are determined by the Contractor to provide stable control. Alternatively, Contractor shall adjust the precise value of the x-axis thresholds shown in the figure to provide stable control. Damper control depends on the type of building pressure control system:

The engineer should indicate which of the following three diagrams apply and delete the others.

1) Return Fan Control with Direct Building Pressure Controls:

Figure 5.16.2.3-3. SAT Loop Mapping with Return Fan Control with Direct Building Pressure Controls



For air handling units with return fans, the outdoor air damper remains fully open whenever the AHU is on while the return air damper modulates to maintain supply air temperature and minimum outdoor airflow at setpoint. For return fan systems using airflow tracking building pressure control logic, the relief/exhaust damper inversely tracks the return air damper. Outdoor air dampers on air handlers with return fans have no impact on the outdoor air flowrate into the mixing plenum. Instead, the return fan and return damper controls dictate outdoor air flow. See ASHRAE Guideline 16.

5. Minimum Outdoor Airflow Setpoints

a. Outdoor airflow setpoint, for California Title 24 ventilation:

1) See 3.13E.2.d for zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.

2) See for setpoints AbsMinOA and DesMinOA:

3) Effective outdoor air absolute minimum and design minimum setpoints are recalculated continuously based on the Mode of the zones being served.

a) 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.

b) 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.

6. Minimum Outdoor Air Control with a single common damper for minimum outdoor air and economizer functions, and airflow measurement

a. Outdoor airflow setpoint, for California Title 24 ventilation:

1) See 3.13L.5.a.3) for calculation of current setpoints, AbsMinOA* and DesMinOA*.

2) See zone CO_2 control logic under terminal unit sequences.

3) The minimum outdoor air setpoint MinOAsp shall be reset based on the highest zone CO_2 control loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

b. Minimum Outdoor Air Control Loop

1) Minimum outdoor air control loop is enabled when the supply fan is proven on and the AHU is in Occupied Mode and disabled and output set to zero otherwise.

2) The outdoor airflow rate shall be maintained at the minimum outdoor air setpoint MinOAsp by a reverse-acting control loop whose output is mapped to return air damper maximum position, MaxRA-P.

7. Economizer High Limit Lockout

a. The normal sequencing of the economizer dampers (above) shall be disabled in accordance with 3.13C.14.

b. When economizer is enabled, MaxRA-P = 100%.

c. Once the economizer is disabled, it shall not be re-enabled within 10 minutes, and vice versa.

d. When the economizer is disabled:

1) Return air damper shall be fully opened

2) Wait 3 minutes, then release return air damper for minimum outdoor air control.

The return air damper is at first opened to avoid drawing the mixing plenum too negative.

The three-minute delay is because the minimum OA damper may be pressure controlled. In that case, delay allows time for the plenum pressure to stabilize so that the return damper loop does not become unstable chasing a fluctuating pressure reading.

8. Return Fan Control – Direct Building Pressure

    a. Return fan operates whenever associated supply fan is proven on and shall be off otherwise.

    b. Return fans shall be controlled to maintain return fan discharge static pressure at setpoint (see below).

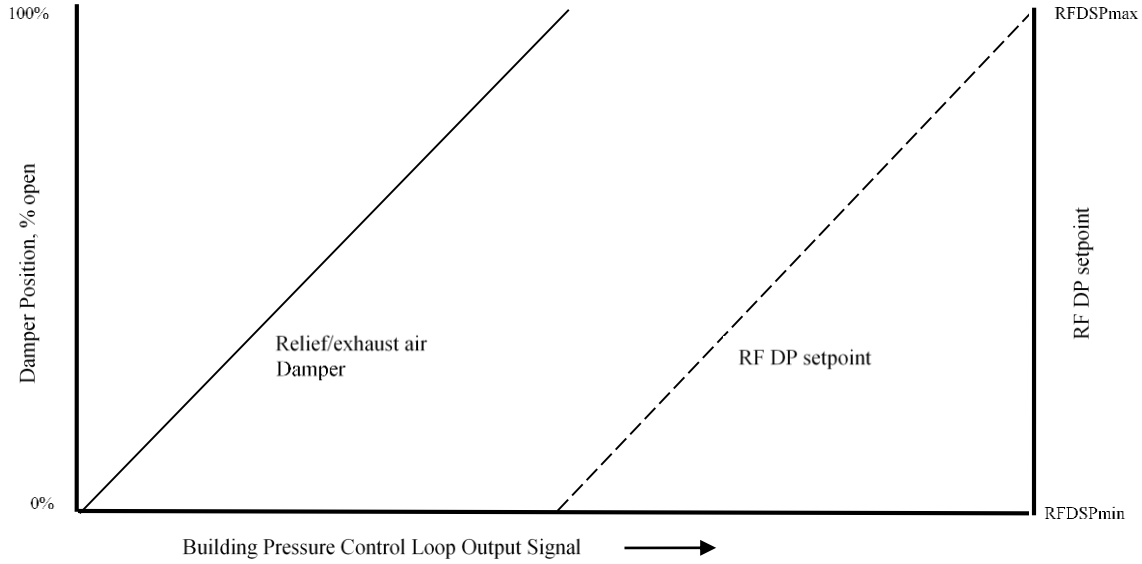
    c. Exhaust dampers shall only be enabled when the associated supply and return fans are proven on and the minimum outdoor air damper is open. The exhaust dampers shall be closed when disabled.

    d. Building static pressure shall be time averaged with a sliding 5-minute window (to dampen fluctuations). The averaged value shall be that displayed and 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.

    e. When exhaust dampers are enabled, a control loop shall modulate exhaust dampers in sequence with the return fan static pressure setpoint as shown in the figure below to maintain the building pressure at a setpoint of 12 Pa (0.05 inches).

Figure 5.16.10.5. Exhaust Damper Position & Return Fan DP Reset



1) From 0% - 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.

2) From 51% - 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 3.13L.1.b.2) for RFDSPmin and RFDSPmax.

9. Freeze Protection

a. If supply air temperature drops below 3.3°C (38F) for 15 minutes or below 1°C (34°F) for 5 minutes, shut down supply and return fan(s), close outdoor air damper, open the cooling coil valve to 100%, and energize the chilled water pump system. Set a Level 2 alarm indicating the unit is shut down by freeze protection.

1) If a freeze protection shutdown is triggered by a low air temperature sensor reading, it shall remain in effect until it is reset by a software switch from the operator's workstation. (If a freeze stat with a physical reset switch is used instead, there shall be no software reset switch.)

10. Alarms

a. Maintenance interval alarm when fan has operated for more than 1,500 hours: Level 4. Reset interval count when alarm is acknowledged.

b. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

1) Commanded on, status off: Level 2

2) Commanded off, status on: Level 4

c. Filter pressure drop exceeds the larger of the alarm limit or 12.5 Pa (0.05 in. of water) for 10 minutes when airflow (expressed as a percentage of design airflow) exceeds 20%: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

$$DP_x = DP_{100}(x)^{1.4}$$

where DP100 is the high limit pressure drop at design airflow (determine limit from filter manufacturer) and DPx is the high limit at the current airflow rate x (expressed as a fraction). For instance, the setpoint at 50% of design airflow would be $(.5)^{1.4}$ or 38% of the design high limit pressure drop.

d. High building pressure [more than 25 Pa (0.10")] for 5 minutes: Level 3

e. Low building pressure (less than 0 Pa (0.0"), i.e., negative) for 5 minutes: Level 4

11. Automatic Fault Detection and Diagnostics

The Automatic Fault Detection and Diagnostics (AFDD) routines for AHUs continually assesses AHU performance by comparing the values of BAS inputs and outputs to a subset of potential fault conditions. The subset of potential fault conditions that is assessed at any point depends on the Operating State of the AHU, as determined by the position of the cooling and heating valves and the economizer damper. Time delays are applied to the evaluation and reporting of fault conditions, to suppress false alarms. Fault conditions that pass these filters are reported to the building operator along with a series of possible causes.
These equations assume that the air handler is equipped with hydronic heating and cooling coils, as well as a fully integrated economizer. If any of these components are not present, the associated tests, and variables should be omitted from the programming.
Note that these alarms rely on reasonably accurate measurement of mixed air temperature. A MAT sensor is required for many of these alarms to work, and an averaging sensor is strongly recommended for best accuracy.

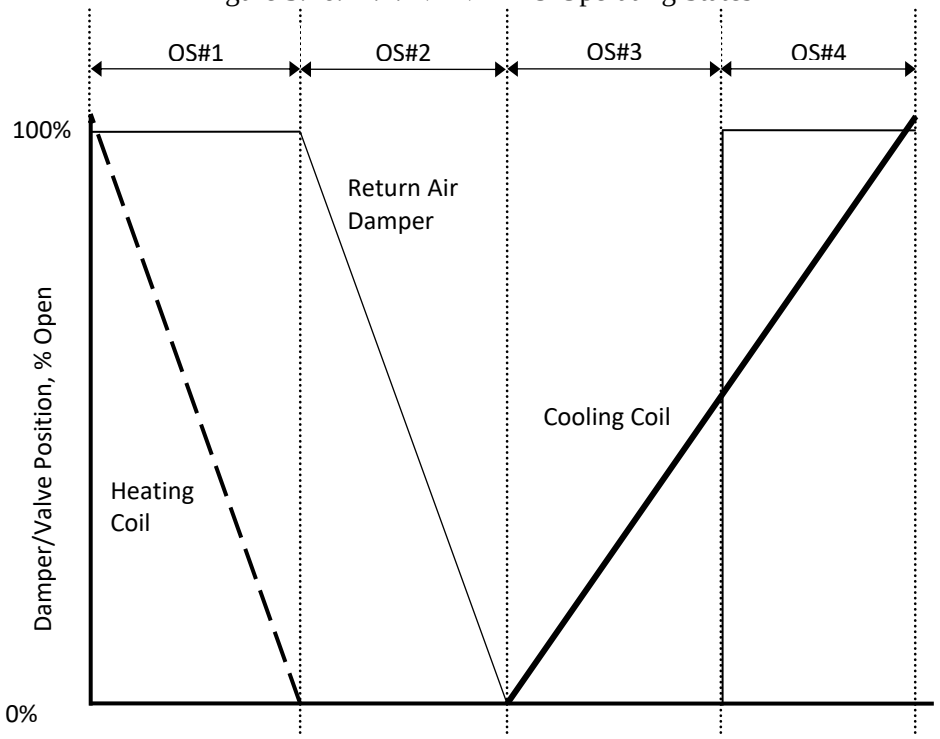
a. AFDD conditions are evaluated continuously and separately for each operating air handling unit.

b. The Operating State (OS) of each AHU shall be defined by the commanded positions of the heating coil control valve, cooling coil control valve, and economizer damper in accordance with the following table and corresponding graphic.

The Operating State is distinct from and should not be confused with the Zone Status (Cooling, Heating, Deadband) or Zone Group Mode (Occupied, Warm-up, etc.).
OS#1 – OS#4 represent normal operation during which a fault may nevertheless occur, if so determined by the fault condition tests in section e below. By contrast, OS#5 may represent an abnormal or incorrect condition (such as simultaneous heating and cooling) arising from a controller failure or programming error, but it may also occur normally, e.g., when dehumidification is active or during warm-up.

Operating State	Cooling Valve Position	Return Air Damper Position
#1: Heating	Not used	
#2: Free Cooling, Modulating OA	= 0	0% < X < MaxRA-P
#3: Mechanical + Economizer Cooling	> 0	= 0%
#4: Mechanical Cooling, Minimum OA	> 0	= MaxRA-P
#5: Unknown or Dehumidification	No other OS applies	

Figure 5.16.14.2. VAV AHU Operating States



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

For the AFDD routines to be effective, an averaging sensor is recommended for supply air temperature. An averaging sensor is essential for mixed air temperature, as the environment of the mixing box will be subject to non-uniform and fluctuating air temperatures. It is recommended that the OAT sensor be located at the AHU, so that it accurately represents the temperature of the incoming air.

1) SAT = Supply air temperature
2) MAT = Mixed air temperature
3) RAT = Return air temperature
4) OAT = Outdoor air temperature
5) DSP = Duct static pressure
6) SATSP = supply air temperature setpoint
7) DSPSP = duct static pressure setpoint
8) CC = cooling coil valve position command; $0\% \leq CC \leq 100\%$
9) FS = fan speed command; $0\% \leq FS \leq 100\%$

10) CCET = cooling coil entering temperature; depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.

11) CCLT = cooling coil leaving temperature; depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.

d. The following values must be continuously calculated by the AFDD routines for each AHU:

1) 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

a) SAT_{AVG} = rolling average of supply air temperature

b) MAT_{AVG} = rolling average of mixed air temperature

c) RAT_{AVG} = rolling average of return air temperature

d) OAT_{AVG} = rolling average of outdoor air temperature

e) DSP_{AVG} = rolling average of duct static pressure

f) $CCET_{AVG}$ = rolling average of cooling coil entering temperature

g) $CCLT_{AVG}$ = rolling average of cooling coil leaving temperature

2) %OA = actual outdoor air fraction as a percentage = $\frac{\text{MAT - RAT}}{\text{OAT - RAT}}$ or per airflow measurement station if available.

3) $\%OA_{MIN}$ = Active minimum OA setpoint (MinOAsp) divided by actual total airflow (from sum of VAV box flows, or by airflow measurement station) as a percentage.

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

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

Default values are derived from NISTIR 7365 (Jeffrey Schein, October 2006) and have been validated in field trials. They are expected to be appropriate for most circumstances, but individual installations may benefit from tuning to improve sensitivity and reduce false alarms. The default values have been intentionally biased towards minimizing false alarms, if necessary at the expense of missing real alarms. This avoids excessive false alarms that will erode user confidence and responsiveness. However, if the goal is to achieve the best possible energy performance and system operation, these values should be adjusted based on field measurement and operational experience.
Values for physical factors such as fan heat, duct heat gain, and sensor error can be measured in the field or derived from trend logs. Likewise, the occupancy delay and switch delays can be refined by observing in trend data the time required to achieve quasi steady state operation.

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

Variable Name	Description	Default Value
ΔT_{SF}	Temperature rise across supply fan	1°C (2°F)
ΔT_{MIN}	Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)	6°C (10° F)
ε_{SAT}	Temperature error threshold for SAT sensor	1°C (2°F)
ε_{RAT}	Temperature error threshold for RAT sensor	1°C (2°F)
ε_{MAT}	Temperature error threshold for MAT sensor	3°C (5°F)
ε_{OAT}	Temperature error threshold for OAT sensor	1°C (2°F) if local sensor @ unit. 3°C (5°F) if global sensor.
ε_{F}	Airflow error threshold	30%
ε_{VFDSPD}	VFD speed error threshold	5%
ε_{DSP}	Duct static pressure error threshold	25 Pa (0.1")
ε_{CCET}	Cooling coil entering temperature sensor error. Equal to ε_{MAT} or dedicated sensor error	Varies, see Description
ε_{CCLT}	Cooling coil leaving temperature sensor error. Equal to ε_{SAT} or dedicated sensor error	
ΔOS_{MAX}	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend Fault Condition evaluation after a change in Mode	30
AlarmDelay	Time in minutes to that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

The purpose of ΔT_{MIN} is to ensure that the mixing box/economizer damper tests are meaningful. These tests are based on the relationship between supply, return, and outdoor air. If RAT ≈ MAT, these tests will not be accurate and will produce false alarms.
The purpose of TestModeDelay is to ensure that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in 3.13L.11.l.

f. 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 AHU.

These equations assume that the SAT sensor is located downstream of the supply fan, and the RAT sensor is located downstream of the return fan. If actual sensor locations differ from these assumptions, it may be necessary to add or delete fan heat correction factors.
To detect the required economizer faults in Title 24 section 120.2(i)7, use Fault Conditions #2, 3, and 5-13 at a minimum. Other Title 24 AFDD requirements, including acceptance tests, are not met through these fault conditions.

FC#1	**Equation**	$DSP < DSPSP - \varepsilon_{DSP}$ and $VFDSPD \geq 99\% - \varepsilon_{VFDSPD}$	**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	**Equation**	$MAT_{AVG} + \varepsilon_{MAT} < \min[(RAT_{AVG} - \varepsilon_{RAT}), (OAT_{AVG} - \varepsilon_{OAT})]$	**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	**Equation**	$MAT_{AVG} - \varepsilon_{MAT} > \max[(RAT_{AVG} + \varepsilon_{RAT}), (OAT_{AVG} + \varepsilon_{OAT})]$	**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**	$\Delta OS > \Delta OS_{MAX}$	**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	**Equation**	$SAT_{AVG} + \varepsilon_{SAT} \leq MAT_{AVG} - \varepsilon_{MAT} + \Delta T_{SF}$	**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**	$\lvert RAT_{AVG} - OAT_{AVG} \rvert \geq \Delta T_{MIN}$ and $\lvert \%OA - \%OA_{MIN} \rvert > \varepsilon_F$	**Applies to OS #1, #4**
	Description	OA fraction is too low or too high; should equal $\%OA_{MIN}$	
	Possible Diagnosis	RAT sensor error MAT sensor error OAT sensor error Leaking or stuck economizer damper or actuator	
FC#8	**Equation**	$\lvert SAT_{AVG} - \Delta T_{SF} - MAT_{AVG} \rvert > \sqrt{\varepsilon_{SAT}^2 + \varepsilon_{MAT}^2}$	**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**	$OAT_{AVG} - \varepsilon_{OAT} > SATSP - \Delta T_{SF} + \varepsilon_{SAT}$	**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	**Equation**	$\lvert MAT_{AVG} - OAT_{AVG} \rvert > \sqrt{\varepsilon_{MAT}^2 + \varepsilon_{OAT}^2}$	**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**	$OAT_{AVG} + \varepsilon_{OAT} < SATSP - \Delta T_{SF} - \varepsilon_{SAT}$	**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	**Equation**	$SAT_{AVG} - \varepsilon_{SAT} - \Delta T_{SF} \geq MAT_{AVG} + \varepsilon_{MAT}$	**Applies to OS #3, #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**	$SAT_{AVG} > SATSP + \varepsilon_{SAT}$ and $CC \geq 99\%$	**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**	$CCET_{AVG} - CCLT_{AVG} \geq \sqrt{\varepsilon_{CCET}{}^2 + \varepsilon_{CCLT}{}^2} + \Delta T_{SF}{}^*$ *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	

g. A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the Operating State of the AHU:

1) In OS #1 (Heating), the following Fault Conditions shall be evaluated:

a) FC#1: Duct static pressure is too low with fan at full speed

b) FC#2: MAT too low; should be between RAT and OAT

c) FC#3: MAT too high; should be between RAT and OAT

d) FC#4: Too many changes in Operating State

e) FC#5: SAT too low; should be higher than MAT

f) FC#6: OA fraction is too low or too high; should equal %OAMIN

g) FC#14: Temperature drop across inactive cooling coil

2) In OS#2 (Modulating Economizer), the following Fault Conditions shall be evaluated:

a) FC#1: Duct static pressure is too low with fan at full speed

b) FC#2: MAT too low; should be between RAT and OAT

c) FC#3: MAT too high; should be between RAT and OAT

d) FC#4: Too many changes in Operating State

e) FC#8: SAT and MAT should be approximately equal

f) FC#9: OAT is too high for free cooling without mechanical cooling

g) FC#14: Temperature drop across inactive cooling coil

3) In OS#3 (Mechanical + 100% Economizer Cooling), the following Fault Conditions shall be evaluated:

a) FC#1: Duct static pressure is too low with fan at full speed

b) FC#2: MAT too low; should be between RAT and OAT

c) FC#3: MAT too high; should be between RAT and OAT

d) FC#4: Too many changes in Operating State

e) FC#10: OAT and MAT should be approximately equal

f) FC#11: OAT too low for 100% OA

g) FC#12: SAT too high; should be less than MAT

h) FC#13: SAT too high in full cooling

4) In OS#4 (Mechanical Cooling, Min OA), the following Fault Conditions shall be evaluated:

a) FC#1: Duct static pressure is too low with fan at full speed

b) FC#2: MAT too low; should be between RAT and OAT

c) FC#3: MAT too high; should be between RAT and OAT

d) FC#4: Too many changes in Operating State

e) FC#6: OA fraction is too low or too high; should equal %OAMIN

f) FC#12: SAT too high; should be less than MAT

g) FC#13: SAT too high in full cooling

5) In OS#5 (Other), the following Fault Conditions shall be evaluated:

a) FC#1: Duct static pressure is too low with fan at full speed

b) FC#2: MAT too low; should be between RAT and OAT

c) FC#3: MAT too high; should be between RAT and OAT

d) FC#4: Too many changes in Operating State

h. For each air handler, the operator shall be able to suppress the alarm for any Fault Condition.

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

1) When AHU is not operating.

2) For a period of ModeDelay minutes following a change in Mode (e.g., from Warm up to Occupied) of any Zone Group served by the AHU.

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

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

l. 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.

m. 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 3.13L.11.f.

12. Testing/Commissioning Overrides: Provide software switches that interlock to a chilled water and hot water plant level to

a. Force chilled water valve full open

b. Force chilled water valve full closed

13. Plant Requests

a. Chilled Water Reset Requests

1) If the supply air temperature exceeds the supply air temperature setpoint by 3°C (5°F) for 2 minutes, send 3 Requests,

2) Else if the supply air temperature exceeds the supply air temperature setpoint by 2°C (3°F) for 2 minutes, send 2 Requests,

3) Else if the CHW valve position is greater than 95%, send 1 Request until the CHW valve position is less than 85%,

4) Else if the CHW valve position is less than 95%, send 0 Requests

b. Chiller Plant Requests. Send the chiller plant that serves the system a Chiller Plant Request as follows:

1) If the CHW valve position is greater than 95%, send 1 Request until the CHW valve position is less than 10%

2) Else if the CHW valve position is less than 95%, send 0 Requests.

c. Hot Water Reset Requests

1) If the supply air temperature is 17°C (30°F) less than setpoint for 5 minutes, send 3 Requests,

2) Else if the supply air temperature is 8°C (15°F) less than setpoint for 5 minutes, send 2 Requests,

3) Else if HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 85%,

4) Else if the HW valve position is less than 95%, send 0 Requests

d. Heating Hot Water Plant Requests. Send the heating hot water plant that serves the AHU a Heating Hot Water Plant Request as follows:

1) If the HW valve position is greater than 95%, send 1 Request until the HW valve position is less than 10%

2) Else if the HW valve position is less than 95%, send 0 Requests.

M. Constant Volume DX Fan Coil Units

1. Existing sequences to remain.

N. Single Zone DX Packaged Units

1. Existing sequences to remain.

O. Chilled Water Plant (see Alternate 4)

1. Parameters

a. Design Information

1) CHWSTmin: 44°F

2) CH-LOT: 60°F

3) GPM_D: 287 GPM

b. TAB Information

1) Alternate 1: CHW-DPmax, the maximum chilled water differential pressure setpoint, in psi. To be determined per TAB procedures in Section 230000.

2) Alternate 1: Minimum Pump Speed: Per Paragraph 3.14E.7

2. Plant Enable/Disable

a. 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).

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

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

2) OAT>CH-LOT, and

3) The chiller plant enable schedule is active.

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

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

2) OAT<CH-LOT – 1°F, or

3) The chiller plant enable schedule is inactive.

Chiller Plant Requests are generated by coil control valves per Guideline 36 sequences. See Guideline 36. If the plant serves critical valves whose positions are not known to the plant controller, e.g. pneumatic controls, the Chiller Plant Request variable can be set to 1 manually by the operator such that the plant is enabled strictly based on OAT lockout and schedule per subsequent logic.

Importance multipliers (IM) shall be added to Chiller Plant Requests in Guideline 36 to ensure that critical coils can independently cause the plant to start. For example, setting the importance multiplier of a large air handler's Chiller Plant Requests to 4 will cause 4 requests so that air handler alone can start the plant even if I=4. Unimportant coils can be assigned an IM of zero so that they cannot cause the plant to start. Small coils can be assigned IM values less than one so that several are required to be active before the plant will start.

d. When the plant is enabled:

1) Enable secondary CHW pump per 3.13O.5.

2) Once the pump is proven on, enable the lead chiller.

e. When the plant is disabled:

1) Shut off the enabled chiller.

2) Disable the operating secondary CHW pump per 3.13O.5.

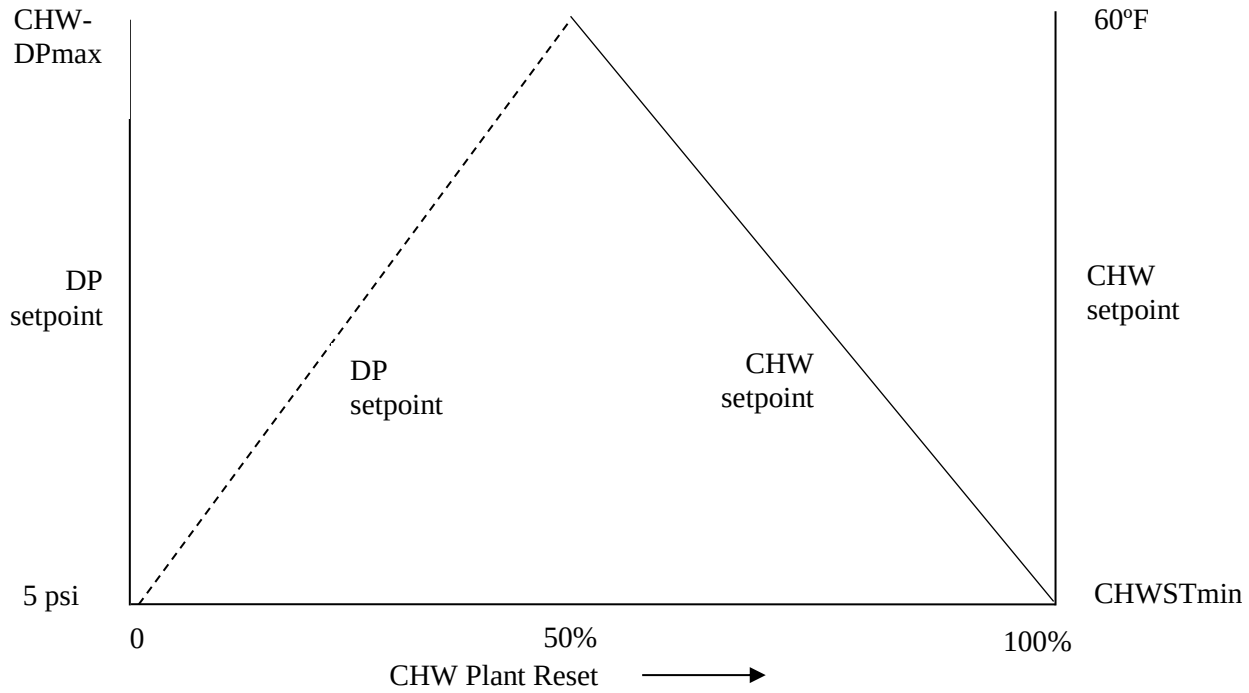
3. Base scope: Chilled Water Supply Temperature Reset

a. Chilled water supply temperature setpoint CHWSTsp shall be reset using Trim & Respond logic with the following parameters:

Variable	Value
Device	Secondary CHW Pump
SP_0	CHWSTmin
SP_{min}	CHWSTmin
SP_{max}	60°F
T_d	15 minutes
T	5 minutes
I	2
R	Cooling CHWST Reset Requests
SP_{trim}	+2°F
SP_{res}	-3°F
$SP_{res-max}$	-7°F

4. Alternate 1: Chilled Water Plant Reset

a. Differential Pressure Controlled Loops: Chilled water supply temperature setpoint CHWSTsp and pump differential pressure setpoint CHW-DPsp shall be reset based on the current value of the logic variable called “CHW Plant Reset” as shown below and described subsequently.



This logic first resets differential pressure setpoint to maximum before resetting chilled water supply temperature setpoint down towards design. Parametric plant analysis in a variety of climate zones shows that the pump energy penalty incurred with this approach is more than offset by chiller energy savings resulting from keeping the chilled water supply temperature setpoint as high as possible.

1) CHW Plant Reset shall be reset using Trim & Respond logic with the following parameters:

Variable	Value
Device	Secondary CHW Pump
SP_0	100%
SP_{min}	0%
SP_{max}	100%
T_d	15 minutes
T	5 minutes
I	2
R	Cooling CHWST Reset Requests
SP_{trim}	-2%
SP_{res}	+3%
$SP_{res-max}$	+7%

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.

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

5. Primary Chilled Water Pumps

   a. Primary chilled water pump is controlled directly by the internal chiller controls.

6. Secondary Chilled Water Pumps

   a. Enable the secondary CHW pump when plant is enabled and any load served by the pump(s) is generating a Chiller Plant Request. Disable the lead pump otherwise.

      1) Alternate 1: When the secondary CHW pump is proven on, pump speed will be controlled by a reverse acting PID loop maintaining the differential pressure signal at a setpoint CHW-DPsp determined by the reset scheme described herein. 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%.

7. Performance Monitoring

   a. 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.

   b. Device Load. Calculate load for each operating chiller using flowrate through the device, GPM_D; chilled water return temperature entering the device, $CHWRT_D$; and chilled water supply temperature leaving the device, $CHWST_D$. Inputs to the below equation shall be determined per the following rules.

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

      1) For constant flow primary loops where neither flowrate through the chillers nor flowrate through the primary loop is measured, GPM_D shall be assumed equal to the design flowrate through the chiller.

      2) $CHWRT_D$ shall be the return temperature entering the device 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) $CHWST_D$ shall be a hardwired temperature sensor at the outlet of the device 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.

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

8. Alarms

a. 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.

b. 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.

c. Chiller alarm: level 2

d. Pump alarm is indicated by the status input being different from the output command for 15 seconds.

1) Commanded on, status off: Level 2. Do not evaluate alarm until the device has been commanded on for 15 seconds.

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

e. Sensor Failure:

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

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

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

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

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

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

9. 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.

a. AFDD conditions are evaluated continuously for the plant.

b. 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#2 represent normal operating states during which a fault may nevertheless occur, if so determined by the fault condition tests below.

Operating State	PCHWP Status	SCHWP Status
#1: Disabled	Off	Off
#2: Chiller Enabled	On	On

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

1) Alternate 1: DP = Chilled water loop differential pressure (each loop, where applicable)

2) Alternate 1: DPSP = Chilled water loop differential pressure setpoint (each loop, where applicable)

3) $Status_{PCHWP}$ = Lead primary chilled water pump status

4) $Status_{SCHWP}$ = Lead secondary chilled water pump status

5) CHWST = Common chilled water supply temperature leaving the chillers

6) CHWSTSP = Chilled water supply temperature setpoint

7) CHWRT = Common chilled water return temperature entering the chillers

8) $CHWST_{CH\text{-}x}$ = CH-x chilled water supply temperature (each chiller)

9) $CHWRT_{CH\text{-}x}$ = CH-x chilled water return temperature (each chiller)

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

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

1) 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

a) $CHWST_{AVG}$ = rolling average of the common chilled water supply temperature

b) $CHWRT_{AVG}$ = rolling average of the common chilled water return temperature

c) $CHWST_{CH\text{-}x,\ AVG}$ = rolling average of CH-x chilled water supply temperature

d) $CHWRT_{CH\text{-}x,\ AVG}$ = rolling average of CH-x chilled water return temperature

e) Alternate 1: DP_{AVG} = rolling average of loop differential pressure (each loop, where applicable)

f) RefrigEvapTempCH-x, AVG = rolling average of CH-x refrigerant evaporating temperature

2) CHW-FlowCH-X

a) For plants with dedicated primary chilled water pumps: 1 if $Status_{PCHWP}$ = On, 0 if $Status_{PCHWP}$ = Off.

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

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

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

e. 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
ε_{CHWT}	Temperature error threshold for chilled water temperature sensors	2°F

Variable Name	Description	Default Value
Alternate 1: ε_{DP}	Differential pressure error threshold for DP sensor	2 psi
Alternate 1: ε_{VFDSPD}	VFD speed error threshold	5%
$Approach_{EVAP}$	Evaporator approach threshold	3°F
$CHStarts_{MAX}$	Maximum number of chiller starts during the previous 60 minutes (moving window)	2
ΔOS_{MAX}	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	2
$\Delta Stage_{MAX}$	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 3.13L.11.l.

f. 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#1 (Alternate 1)	**Equation**	$DP_{AVG} > \varepsilon_{DSP}$ <u>and</u> $Status_{CHWP}$ = Off	**Applies to OS #1**
	Description	Differential pressure is too high with the chilled water pumps off	
	Possible Diagnosis	DP sensor error	

FC#4 (Alternate 1)	**Equation**	$DP_{AVG} < DPSP - \varepsilon_{DP}$ and $Speed_{CHWP} \geq 99\% - \varepsilon_{VFDSPD}$	**Applies to OS #2**
	Description	Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.	
	Possible Diagnosis	Problem with VFD Mechanical problem with pump(s) Pump(s) are undersized Differential pressure setpoint is too high CHWST is too high Primary flow is higher than the design evaporator flow of the operating chillers	
FC#6	**Equation**	$CHWST_{AVG} - \varepsilon_{CHWT} \geq CHWSTSP$	**Applies to OS #2**
	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#9	**Equation**	$Approach_{EVAP} \geq CHWST_{CH\text{-}x,\ AVG} - RefrigEvapTemp_{CH\text{-}x,\ AVG}$	**Applies to OS #2**
	Description	Evaporator approach is too high	
	Possible Diagnosis	Possible evaporator fouling or blocked evaporator tubes Low refrigeration charge Contaminated refrigeration charge	

FC#10	**Equation**	$\lvert CHWST_{CH\text{-}X} - CHWST_{AVG} \rvert > \varepsilon_{CHWT}$ and $\sum CHW\text{-}Flow_{CH\text{-}X} = 1$	**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**	$\lvert CHWRT_{CH\text{-}X} - CHWRT_{AVG} \rvert > \varepsilon_{CHWT}$ and $\sum CHW\text{-}Flow_{CH\text{-}X} = 1$	**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#18	**Equation**	$\Delta OS > \Delta OS_{MAX}$	**Applies to OS #1 – #2**
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#19	**Equation**	$\Delta StartsCH\text{-}x > \Delta CHStart_{MAX}$	**Applies to OS #2**
	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**	$\Delta Stage > \Delta Stage_{MAX}$	**Applies to OS #1 – #2**
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

g. A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the Operating State of the plant:

1) In OS #1 (Disabled), the following Fault Conditions shall be evaluated:

a) FC#1: Differential pressure is too high with the chilled water pumps off

b) FC#18: Too many changes in operating state

c) FC#20: Too many stage changes

2) In OS#2 (One chiller enabled without WSE), the following Fault Conditions shall be evaluated:

a) FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.

b) FC#6: Chilled water supply temperature is too high

c) FC#9: Evaporator approach is too high

d) FC#10: A chilled water supply temperature sensor is out of calibration

e) FC#11: A chilled water return temperature sensor is out of calibration

f) FC#18: Too many changes in Operating State

g) FC#19: Too many chiller starts

h) FC#20: Too many stage changes

3) In OS#3 (More than one chiller enabled), the following Fault Conditions shall be evaluated:

a) FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.

b) FC#6: Chilled water supply temperature is too high

c) FC#9: Evaporator approach is too high

d) FC#18: Too many changes in Operating State

e) FC#19: Too many chiller starts

f) FC#20: Too many stage changes

4) In OS#4 (Waterside Economizer-only), the following Fault Conditions shall be evaluated:

a) FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.

b) FC#6: Chilled water supply temperature is too high

c) FC#18: Too many changes in Operating State

d) FC#20: Too many stage changes

5) In OS#5 (Integrated waterside economizer), the following Fault Conditions shall be evaluated:

a) FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.

b) FC#6: Chilled water supply temperature is too high

c) FC#9: Evaporator approach is too high

d) FC#10: A chilled water supply temperature sensor is out of calibration

e) FC#11: A chilled water return temperature sensor is out of calibration

f) FC#18: Too many changes in Operating State

g) FC#19: Too many chiller starts

h) FC#20: Too many stage changes

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

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

1) When no pumps are operating.

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

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

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

l. 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.

m. 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 3.13L.11.f.

P. Hot Water Plant (see Alternates 3 and 4)

1. Design Parameters

a. HWSTmax: 180°F

b. HW-LOT: 75°F

c. HW-MinFlowSp, the design minimum boiler water flowrate as recommended by the manufacturer, 25 gpm.

2. Plant Enable/Disable

a. 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).

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

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

2) OAT<HW-LOT, and

3) The Boiler plant enable schedule is active.

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

1) Number of Heating Hot-Water Plant Requests ≤ I for 3 minutes, or

2) OAT>HW-LOT + 1°F, or

3) The Boiler plant enable schedule is inactive.

d. When the plant is enabled:

1) Stage on lead primary HW pump per 4.

2) Once the lead pump has proven on, enable the lead boiler.

e. When the plant is disabled:

1) Shut off the enabled boiler(s).

2) Disable the operating primary HW pump per 3.13P.4.

3. Hot Water Supply Temperature Reset

a. Plant hot water supply temperature setpoint shall be reset using Trim & Respond logic (see Guideline 36) with the following parameters:

Variable	**Value**
Device	Any HW Pump Distribution Loop
SP_0	SP_{max}
SP_{min}	90ºF
SP_{max}	HWSTmax
T_d	10 minutes
T	5 minutes
I	2
R	Hot-Water Reset Requests
SP_{trim}	-2ºF
SP_{res}	+3ºF
$SP_{res-max}$	+7ºF

4. Hot Water Pump

a. Enable the hot water pump when plant is enabled. Disable the hot water pump when the boiler is disabled and the boiler has been proven off for 3 minutes.

5. Minimum Flow Bypass Valve

a. Boiler minimum flow setpoint shall equal HW-MinFlowSP.

b. A reverse acting PID loop shall maintain minimum flow as measured by the hot water flow meter at setpoint. Reset valve position from 0% open at 0% loop output to 100% open at 100% loop output.

c. When any HW pump is proven on, the bypass valve control loop shall be enabled. The valve shall be opened otherwise. When enabled, the bypass valve minimum flow PID loop shall be biased 100% (valve 100% open).

6. Boiler efficiency shall be calculated for the boiler from the following:

a. Convert measured gas usage to Btu/h by a user adjustable conversion factor (default value = 1000 Btu/h per ft^3 of gas; actual value set by user from utility bill).

b. Calculate load from flow and temperature difference (HWS temperature minus HWR temperature).

$$Q = 490GPM(T_{HWS} - T_{HWR})$$

c. Thermal efficiency is equal to measured load divided by measured gas consumption.

d. Summary Data. For the boiler, statistics shall be calculated and displayed on associated graphic for runtime, peak load, energy use, average actual efficiency, and average load (flow rate, MBH, etc.), all summarized on an instantaneous (displaying real-time data), year-to-date, and last year basis.

7. Alarms

a. 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.

b. 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.

c. Boiler alarm: Level 2

d. 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

e. Pump alarm is indicated by the status input being different from the output command for 15 seconds.

1) Commanded on, status off: Level 2. Do not evaluate alarm until the device has been commanded on for 15 seconds.

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

f. Sensor Failure:

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

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

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

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

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

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

8. Automatic Fault Detection and Diagnostics

a. AFDD conditions are evaluated continuously for the plant.

b. 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.

Operating State	Primary HW Pump Status
#1: Disabled	Off
#2: Boiler enabled	On

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

1) HW-MinFlowSP = Effective minimum hot water flow setpoint, HW-MinFlowX

2) $Status_{PHWP}$ = Lead primary hot water pump status

3) HWST = Common hot water supply temperature

4) HWSTSP = Hot water supply temperature setpoint

5) HWRT = Average boiler entering water temperature (each loop)

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

1) 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

a) $HWST_{AVG}$ = rolling average of the common hot water supply temperature (each primary loop, where applicable)

b) $HWRT_{AVG}$ = rolling average of the average boiler entering water return temperature.

c) $HWRT_{B-1}$ = rolling average of B-1 hot water return temperature (each boiler)

2) $HWFlow_{B-1}$

a) 1 if $Status_{PHWP}$ = on, 0 if $Status_{PHWP}$ = off

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

4) $\Delta Stage$ = number of hot water plant stage changes during the previous 60 minutes (moving window)

5) $Starts_{B-1}$ = number of B-1 starts in the last 60 mins

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

Variable Name	Description	Default Value
ε_{HWT}	Temperature error threshold for hot water temperature sensors	5°F
CondTemp	Boiler condensing temperature threshold	135°F
$BStarts_{MAX}$	Maximum number of boiler starts during the previous 60 minutes (moving window)	2
ΔOS_{MAX}	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	2
$\Delta Stage_{MAX}$	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

9. 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#6	**Equation**	$HWST_{AVG} + \varepsilon_{HWT} < HWSTSP$	
	Description	Hot water supply temperature is too low.	

	Possible Diagnosis	Mechanical problem with boilers imary flow is higher than the design flow of the operating boilers eviation between the internal boiler hot water supply temperature sensor and the plant hot water supply temperature is too high (i.e. boiler sensor is out of calibration).	**Applies to OS #2**
FC#8	**Equation**	$HWRT_{AVG} - \varepsilon_{HWT} > CondTemp$	**Applies to OS #2**
	Description	ot water return temperature is too high for condensing to occur.	
	Possible Diagnosis	Hot water supply temperature setpoint is too high. ot water load is too low. High bypass flow is raising the entering water temperature. ot water coils are not designed for condensing at current loads.	
FC#10	**Equation**	$HWST_{B-1} - HWST_{AVG} > \varepsilon_{HWT}$	**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**	$HWRT_{B-1} - HWRT_{AVG} > \varepsilon_{HWT}$	**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**	$\Delta OS > \Delta OS_{MAX}$	**Applies to OS #1**
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#13	**Equation**	$\Delta Starts_{B-1} > \Delta BStart_{MAX}$	**Applies to OS #2**
	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**	$\Delta Stage > \Delta Stage_{MAX}$	**Applies to OS #1 – #2**
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

10. A subset of all potential fault conditions is evaluated by the AFDD routines.The set of applicable fault conditions depends on the Operating State of the plant:
    a. In OS #1 (Disabled), the following Fault Conditions shall be evaluated:
        1) FC#10: Too many changes in operating state
        2) FC#12: Too many stage changes
    b. In OS#2 (One boiler enabled), the following Fault Conditions shall be evaluated:
        1) FC#6: Hot water supply temperature is too low
        2) FC#8: Hot water return temperature is too high for condensing to occur
        3) FC#10: Deviation between the active boiler hot water supply temperature and the common hot water supply temperature is too high.
        4) FC#11: Deviation between the active boiler hot water return temperature and the common boiler entering water temperature is too high.
        5) FC#12: Too many changes in Operating State
        6) FC#13: Too many boiler starts
        7) FC#14: Too many stage changes
11. For each boiler, the operator shall be able to suppress the alarm for any Fault Condition.
12. 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.
13. Fault Conditions that are not applicable to the current Operating State shall not be evaluated.
14. A Fault Condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.
15. 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.
16. 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 3.13P.9.

Q. General Exhaust Fans

1. Exhaust fans shall operate when any of the associated system supply fans is proven on and any associated Zone Group is in the occupied mode.

2. Alarms

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

    b. Fan alarm is indicated by the status input being different from the output command for 15 seconds.

        1) Commanded on, status off: Level 2. Do not evaluate alarm until the device has been commanded on for 15 seconds.

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

R. Miscellaneous Alarms

1. 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

2. Equipment alarm (for equipment with alarm contacts such as VFDs, AC units): Level 2

3. Failure or disconnection of a sensor as indicated by signal widely out of range: Level 2.

4. Panel or LAN failure: Level 2

5. 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).

3.14 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 (Functional Testing) and receive approval.

10. Perform BAS Pre-functional Tests (start up, calibration and tuning) and submit completed Pre-functional Test Forms for approval.

11. Field test application programs prior to functional testing.

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

13. Prepare and initiate commissioning Trend Logs.

14. Perform and record functional tests and submit Functional Test Report for approval.

    a. Some tests may not be possible due to weather conditions. These tests may be deferred to post-occupancy period.

15. Assist in TAB tests and determining setpoints as specified in Section 230000 Heating, Ventilating and Air Conditioning.

16. Assist in Title 24 Acceptance Testing as specified in Section 230000 Heating, Ventilating and Air Conditioning.

17. Submit Package 4 (Training Materials) and receive approval.

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

19. Perform Demonstration Tests to Commissioning Provider and District's Representatives and submit Demonstration Test Report.

20. Receive acceptance of Demonstration Tests.

21. Train District personnel on BAS operation and maintenance.

22. Substantial Completion

23. Submit Package 5 (Post-Construction Trend Logs) in format specified for review and approval.

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

25. Complete all items in Completion Requirements per Paragraph 1.9.

26. Provide administration level password access to the District.

27. Final Acceptance

28. Begin Warranty Period.

29. Prepare and initiate post-occupancy Trend Logs.

30. Update all software as specified.

31. End of Warranty Period

B. Test Documentation

1. Pre-functional Tests

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 forms for approval in Submittal Package 3.

e. Complete work, document results on forms, and submit for approval as Pre-Functional Test Report.

2. Functional Tests

a. District'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.

c. Adapt forms from District's Representative into electronic format. 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 forms for approval in Submittal Package 3.

e. Complete work, document results on forms, and submit for approval as Functional Test Report.

C. Assist Commissioning Provider/Coordinator.

D. Coordinate with Work specified in Section 230000 Heating, Ventilating and Air Conditioning Commissioning.

E. 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. 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.

3. 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).

4. 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.

5. 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.

6. 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. Coordinate with the District to test fire and life safety systems alarm contacts.

   d. 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.

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

7. 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.

8. 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

9. 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.

10. 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.

F. Testing, Adjusting, and Balancing (TAB) Coordination

1. Coordinate with Work performed under Section 230000 Heating, Ventilating and Air Conditioing. Some balancing procedures require the BAS to be operational and require Contractor time and assistance.

2. Calibration Software

a. Software shall be provided free of charge on at least a temporary basis to allow calibration of terminal box airflow controls and other Work specified under Section 230000 Heating, Ventilating and Air Conditioning.

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 specified under Section 230000 Heating, Ventilating and Air Conditioning.

c. Provide sufficient training to those performing Work specified under Section 230000 Heating, Ventilating and Air Conditioning 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 3.14B.1 before assisting in setpoint determination.

b. Coordinate with Work performed under Section 230000 Heating, Ventilating and Air Conditioning to determine fan and pump differential pressure setpoints, outdoor air damper minimum positions and DP setpoints, etc. as indicated in Section 230000 Heating, Ventilating and Air Conditioning.

G. Functional Tests

1. Test schedule shall be coordinated with the Commissioning Provider, Commissioning Coordinator, and District's Representative.

2. Functional tests may be witnessed by District's Representative at the District'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 shall be submitted to the District for review and approval.

H. 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 2 working days.

2. Schedule the demonstration with the Commissioning Provider and District'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 District's Representative at the District's option.

6. Contractor shall conduct tests as directed by and in the presence of the Commissioning Provider and complete test forms. Completed forms shall be submitted as the Demonstration Test Report to the Commissioning Provider after tests are complete.

7. Demonstration Tests shall be successfully completed and approved prior to Substantial Completion.

I. 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 District'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 by 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.

   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 District in an electronic format agreed to by the District and Contractor (such as flash drive or via direct access to the CSS via the internet).

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.

J. Remedial Work

1. Repair or replace defective Work, as directed by District's Representative in writing, at no additional cost to the District.

2. Restore or replace damaged Work due to tests as directed by District's Representative in writing, at no additional cost to the District.

3. Restore or replace damaged Work of others, due to tests, as directed by District's Representative in writing, at no additional cost to the District.

4. Remedial Work identified by site reviews, review of submittals, demonstration test, trend reviews, etc. shall be performed to the satisfaction of the District's Representative, at no additional cost to the District.

5. Contractor shall compensate District'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 District.

3.15 TRAINING

A. Coordinate schedule and materials with Commissioning Authority.

B. Interim Training

1. Provide minimal training so the operating staff can respond to occupant needs and other operating requirements during start-up and commissioning phase.

C. Formal Training

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

2. ALC Training

    a. It may be assumed that District building engineers have been previously trained on the existing ALC system.

    b. Include training on ALC system operations only for new features installed at CSS/OWS as a part of this project.

3. Jobsite Training

    a. Include 24 hours total of on-site training to assist personnel in becoming familiar with job-specific issues, systems, control sequences, etc.

    b. Training sessions shall be video recorded with copy provided to the District

4. Training may be in non-contiguous days at the request of the District.

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

END OF SECTION 250000

C-1168 AA BUILDING MECHANICAL SYSTEMS UPGRADE - ENERGY CONSERVATION PROJECT

Taylor Engineering

1080 Marina Village Parkway, Suite 501
Alameda, CA 94501-6427
Phone: (510) 749-9135

ISSUES / REVISIONS

No.	Description	Date
0	BID SET	6/30/2020

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

Drawn by RK

Scale

FIRST FLOOR HVAC ZONING PLAN

M-101

6/30/2020 9:46:20 AM

C-1168 AA BUILDING MECHANICAL SYSTEMS UPGRADE - ENERGY CONSERVATION PROJECT

Taylor Engineering
1080 Marina Village Parkway, Suite 501
Alameda, CA 94501-6427
Phone: (510) 749-9135

ISSUES / REVISIONS

No.	Description	Date
0	BID SET	6/30/2020

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

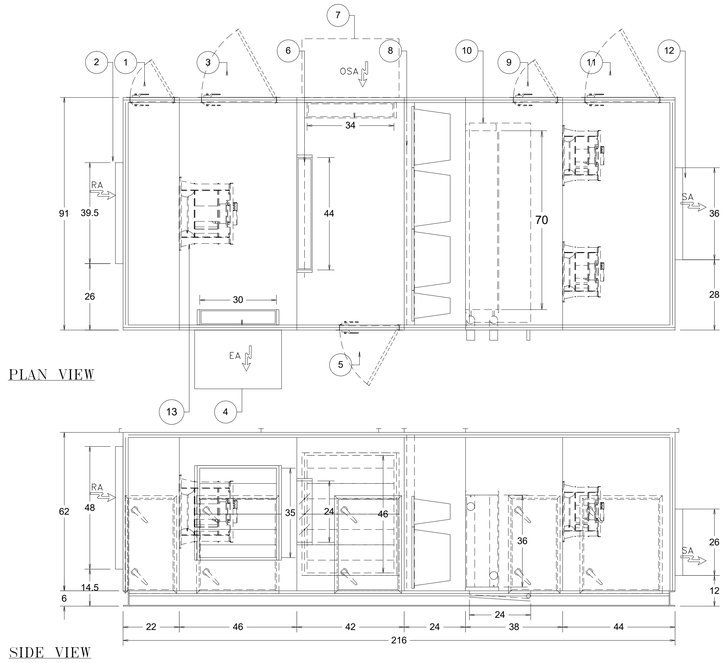
Drawn by RK

Scale

SECOND FLOOR HVAC ZONING PLAN

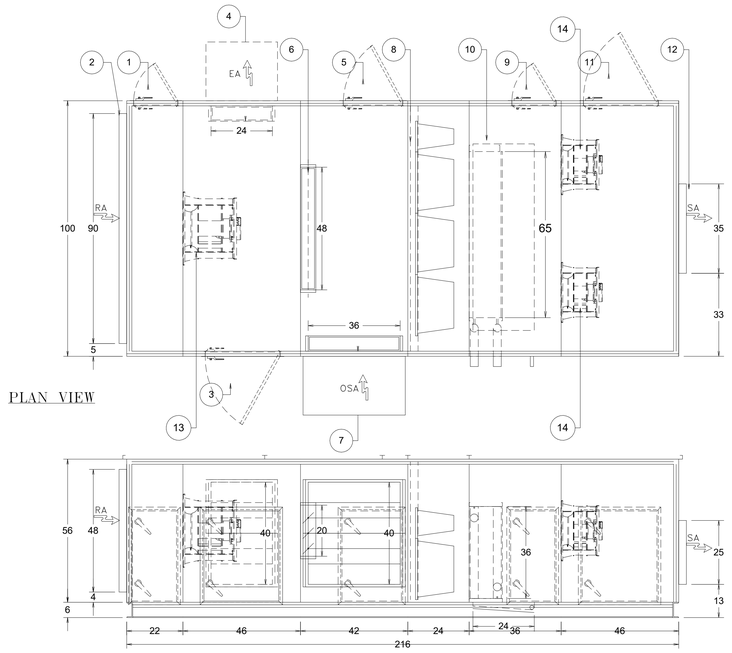
M-102

6/30/2020 9:46:45 AM



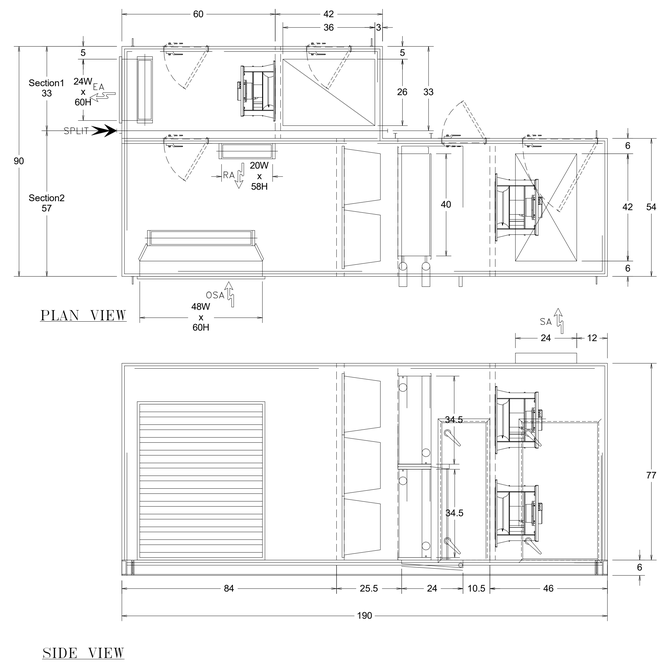
1 18Wx36H Access Door
2 39.5Wx48H Plain Opening
3 30Wx36H Access Door w/ Window
4 (1) 30Wx35H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 44Wx24H Damper
7 (1) 34Wx46H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 70Wx 36H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 36Wx26H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

2 AHU 1-2



1 18Wx36H Access Door
2 90Wx48H Plain Opening
3 30Wx36H Access Door w/ Window
4 (1) 24Wx40H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 48Wx20H Damper
7 (1) 36Wx40H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 65Wx 36H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 35Wx25H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

3 AHU 1-3



1 AHU 1-1

C-1168 AA BUILDING MECHANICAL SYSTEMS UPGRADE - ENERGY CONSERVATION PROJECT

Taylor Engineering

1080 Marina Village Parkway, Suite 501
Alameda, CA 94501-6427
Phone: (510) 749-9135

ISSUES / REVISIONS

No.	Description	Date
0	BID SET	6/30/2020

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

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Scale

AHU DETAILS

M-501

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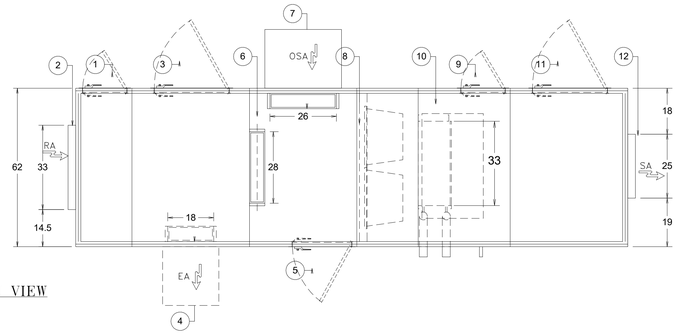
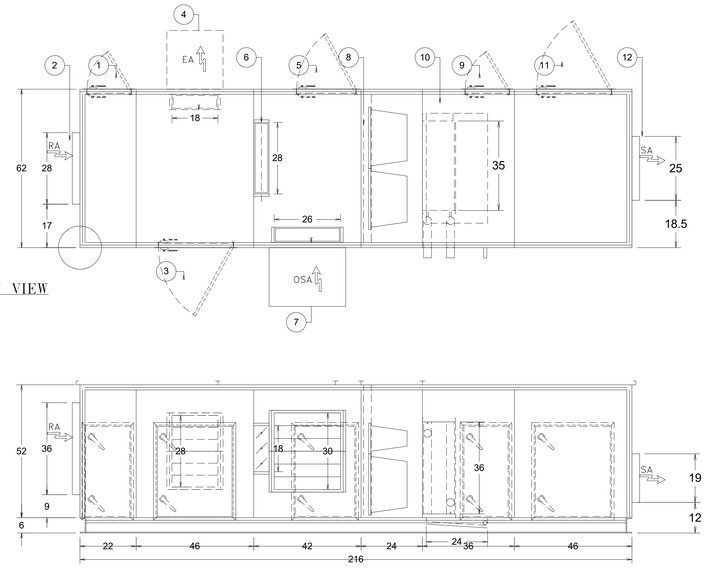


1 18Wx36H Access Door
2 33Wx36H Plain Opening
3 30Wx36H Access Door w/ Window
4 (1) 18Wx28H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 28Wx18H Damper
7 (1) 26Wx30H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 33Wx 36H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 25Wx19H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

PLAN VIEW

SIDE VIEW

4 AHU 2-4

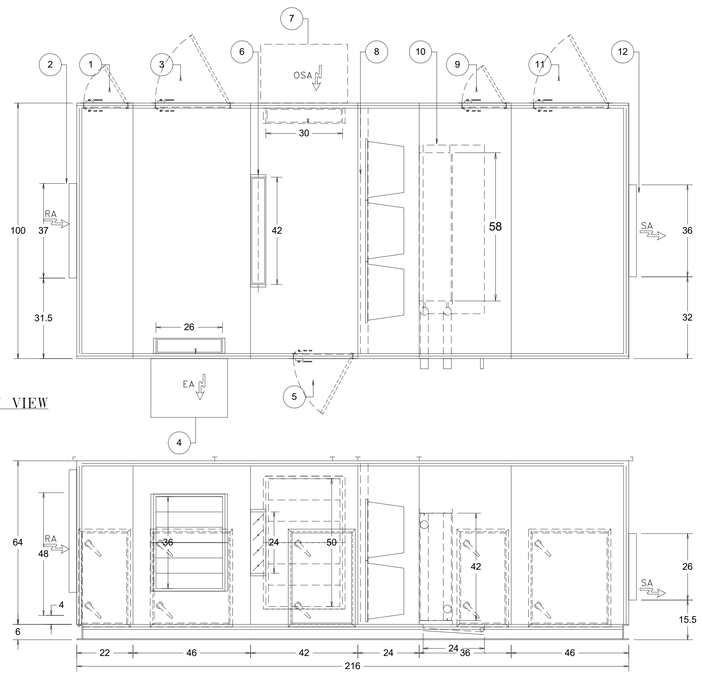


1 18Wx36H Access Door
2 85Wx48H Plain Opening
3 30Wx38H Access Door w/ Window
4 (1) 30Wx38H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 48Wx24H Damper
7 (1) 34Wx40H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 65Wx 42H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 34Wx30H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

PLAN VIEW

SIDE VIEW

2 AHU 2-2

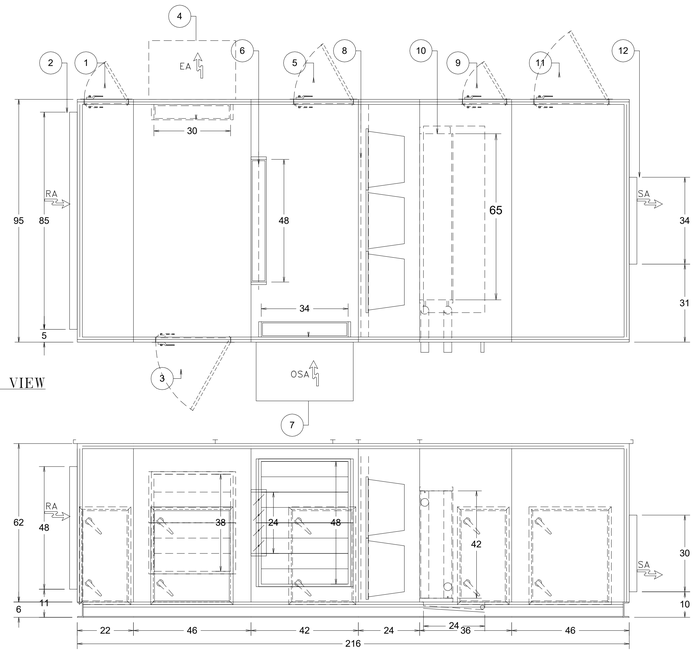


1 18Wx36H Access Door
2 37Wx48H Plain Opening
3 30Wx36H Access Door w/ Window
4 (1) 26Wx36H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 44Wx24H Damper
7 (1) 30Wx50H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 65Wx 42H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 36Wx26H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

PLAN VIEW

SIDE VIEW

3 AHU 2-3



1 18Wx36H Access Door
2 85Wx48H Plain Opening
3 30Wx38H Access Door w/ Window
4 (1) 30Wx38H Damper w/Rainhood
5 24Wx36H Access Door
6 (1) 48Wx24H Damper
7 (1) 34Wx40H Damper w/Rainhood
8 0In. Prefilter w/ 15In. Final Filters
9 18Wx36H Access Door
10 (1) 65Wx 42H Cooling Coil(s)
11 30Wx36H Access Door w/ Window
12 34Wx30H Plain Opening
13 Return Fan & Motor Assy
14 Supply Fan & Motor Assy

PLAN VIEW

SIDE VIEW

1 AHU 2-1

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ISSUES / REVISIONS

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AHU DETAILS

M-502

6/30/2020 9:46:12 AM

AIR TERMINAL UNITS

(E) TAG	TAG (TAB)	(N) TAG	SYSTEM	LOCATION	SPACES SERVED	SPACE TYPE	UPSTREAM HEATING COIL	2-WAY OR 3-WAY VALVE	VALVE TYPE	VCOOL-MAX	VHEAT-MAX	VMIN	VAREA-MIN	VOCC-MIN	T'STAT TYPE	MEASURE 3	MEASURE 4	MEASURE 5	MEASURE 8	MEASURE 9	MEASURE 11	MEASURE 12
?	VR-1-01	VR-11101	AHU-1-1	FIRST FLOOR	103, 103A	OFFICE	-	2-WAY	(N) BALL	2200	1100	95	140	95	TS-3CC				X			
?	VR-1-02	VR-11102	AHU-1-1	FIRST FLOOR	109	CLASSROOM	-	2-WAY	(N) BALL	790	395	260	125	305	TS-3CC				X			
IB-?	VC-1-03	VC-11103	AHU-1-1	FIRST FLOOR	109, 109B	CLASSROOM, OFFICE	-	-	-	625	-	0	0	0	TS-3C	X						
IB-?	VC-1-04	VR-11104	AHU-1-1	FIRST FLOOR	111	OFFICE	-	2-WAY	(N) BALL	600	300	60	60	40	TS-3C	X						
IB-1	VR-1-05	VR-11105	AHU-1-1	FIRST FLOOR	113	OFFICE	-	2-WAY	(N) BALL	1100	550	80	120	80	TS-3CC	X						
IB-2	VC-1-06	VR-11106	AHU-1-1	FIRST FLOOR	113A, 113B, 113C, 147	OFFICE, ARCHIVES	-	2-WAY	(N) BALL	1225	615	85	85	55	TS-3C	X						
IB-1A	VR-1-07	VR-11107	AHU-1-1	FIRST FLOOR	117B, 117D	CUSTODIAL STORAGE	-	3-WAY	(N) BALL	1975	990	0	0	0	TC-3C	X						
IB-1B	VC-1-08	VR-11108	AHU-1-1	FIRST FLOOR	117, 117A, 117B, 117H	STOR., CONF., OFFICE	-	2-WAY	(N) BALL	1650	825	150	150	100	TS-3C	X						
-	-	VR-11109	AHU-1-1	FIRST FLOOR	111A	OFFICE	-	2-WAY	(N) BALL	220	110	35	35	20	TS-3C					X		
IB-?	VC-1-01	VC-12101	AHU-1-2	FIRST FLOOR	110, 148	CORRIDOR	-	-	-	635	-	90	90	45	TS-3A	X						
IB-3A	VR-1-02	VR-12102	AHU-1-2	FIRST FLOOR	140	CLASSROOM	-	3-WAY	(N) BALL	950	475	105	105	510	TS-3CC	X						
IB-3	VR-1-03	VR-12103	AHU-1-2	FIRST FLOOR	137	CLASSROOM	-	3-WAY	(N) BALL	1805	905	105	105	510	TS-3CC	X						
IB-?	VR-1-04	VR-12104	AHU-1-2	FIRST FLOOR	135, 135B	CLASSROOM	-	3-WAY	(N) BALL	1230	615	130	130	635	TS-3CC	X						
IB-?	VR-1-05	VR-12105	AHU-1-2	FIRST FLOOR	133	CLASSROOM	-	3-WAY	(N) BALL	1300	650	175	175	850	TS-3CC	X						
IB-4	VC-1-06	VR-12106	AHU-1-2	FIRST FLOOR	131	CLASSROOM	-	3-WAY	(N) BALL	800	400	135	135	660	TS-3CC	X						
IB-?	VR-1-07	VR-12107	AHU-1-2	FIRST FLOOR	108	HALLWAY, STORAGE	-	3-WAY	(N) BALL	600	300	80	80	40	TS-3A	X						
IB-?	VR-1-08	VR-12108	AHU-1-2	FIRST FLOOR	132, 134, 136	OFFICE	-	3-WAY	(N) BALL	375	190	40	40	25	TS-3C	X						
IB-?	VR-1-09	VR-12109	AHU-1-2	FIRST FLOOR	124, 126, 128	OFFICE	-	3-WAY	(N) BALL	495	250	40	40	25	TS-3C	X						
IB-?	VR-1-10	VR-12110	AHU-1-2	FIRST FLOOR	104, 106, 121, 123, 125, 127	OFFICE, CORRIDOR	-	3-WAY	(N) BALL	1095	550	115	115	75	TS-3C	X						
IB-?	VR-1-11	VR-12111	AHU-1-2	FIRST FLOOR	118, 120	OFFICE	-	2-WAY	(N) BALL	250	125	25	25	15	TS-3C	X						
IB-?	VC-1-01	VC-13101	AHU-1-3	FIRST FLOOR	150, 102	CORRIDOR	-	-	-	750	-	145	145	70	TS-3A	X						
IB-?	VR-1-02	VR-13102	AHU-1-3	FIRST FLOOR	143	CLASSROOM	-	3-WAY	(N) BALL	1800	900	160	160	780	TS-3CC	X						
IB-?	VR-1-03	VR-13103	AHU-1-3	FIRST FLOOR	142	CLASSROOM	-	2-WAY	(N) BALL	1800	900	165	165	815	TS-3CC	X						
IB-?	VR-1-04	VR-13104	AHU-1-3	FIRST FLOOR	145	CLASSROOM	-	3-WAY	(N) BALL	1800	900	165	165	815	TS-3CC	X						
IB-?	VR-1-05	VR-13105	AHU-1-3	FIRST FLOOR	102, 146	OFFICE	-	2-WAY	(N) BALL	1200	600	135	135	85	TS-3C	X						
IB-?	VC-1-06	VR-13106	AHU-1-3	FIRST FLOOR	105, 107, 104	OFFICE	-	2-WAY	(N) BALL	700	350	140	140	95	TS-3C	X						
IB-?	VC-1-08	VC-13107	AHU-1-3	FIRST FLOOR	104	CORRIDOR	-	2-WAY	(N) BALL	300	-	40	40	20	TS-3A	X						
IB-?	VR-1-07	VR-13108	AHU-1-3	FIRST FLOOR	116	OFFICE, STORAGE, CUST.	-	2-WAY	(N) BALL	480	240	45	45	30	TS-3C	X						
-	-	VR-13109	AHU-1-3	FIRST FLOOR	103B	OFFICE	-	2-WAY	(N) BALL	120	60	20	20	10	TS-3C					X		
-	-	VR-13110	AHU-1-3	FIRST FLOOR	105, 107, 109A	OFFICE		2-WAY	(N) BALL	300	150	45	45		TS-3C					X		
VAV-?	VC-2-01	VC-21201	AHU-2-1	SECOND FLOOR	215	JOURNALISM LAB, LIGHT RM	-	2-WAY	(N) BALL	1255	-	0	0	0	TS-3C				X			
VAV-?	VC-2-02	VR-21202	AHU-2-1	SECOND FLOOR	215, 215C	JOURNALISM LAB, LIGHT RM	-	2-WAY	(N) BALL	1400	700	665	270	665	TS-3C				X			
VAV-E(2)	VC-2-03	VR-21203	AHU-2-1	SECOND FLOOR	210, 210K, 210J, 208, 209	OFFICE	-	2-WAY	(N) BALL	2530	1265	290	290	190	TS-3C				X			
VAV-4	VC-2-04	VR-21204	AHU-2-1	SECOND FLOOR	210F, 210G, 210H	OFFICE	-	3-WAY	(N) BALL	750	375	80	80	50	TS-3C				X			
VAV-3	VC-2-05	VR-21205	AHU-2-1	SECOND FLOOR	211	CLASSROOM, READING, TESTING	-	2-WAY	(N) BALL	1200	600	125	125	600	TS-3CC				X			
VAV-2	VC-2-06	VC-21206	AHU-2-1	SECOND FLOOR	210D, 210E	OFFICE	HC-4	-	-	570	285	40	40	25	TS-3C							
VAV-1	VC-2-07	VC-21207	AHU-2-1	SECOND FLOOR	210A, 210B, 210C, 210L	OFFICE, TUTORING	HC-4	-	-	1000	500	65	65	45	TS-3C							
VAV-?	VC-2-08	VC-21208	AHU-2-1	SECOND FLOOR	215D, 215E	JOURNALISM LAB, OFFICE	HC-4	-	-	950	475	250	105	250	TS-3C	X			X			
VAV-?	VC-2-09	VC-21209	AHU-2-1	SECOND FLOOR	215A, 215B	EDITORS, OFFICE	HC-4	-	-	670	335	60	60	40	TS-3C				X			
VAV-?	VC-2-01	VR-22201	AHU-2-2	SECOND FLOOR	216	CONFERENCE	-	2-WAY	(N) BALL	450	225	45	45	215	TS-3CC				X			
VAV-?	VC-2-02	VC-22202	AHU-2-2	SECOND FLOOR	295	CORRIDOR	-	-	-	450	-	40	40	20	TS-3A				X			
VAV-?	VC-2-03	VR-22203	AHU-2-2	SECOND FLOOR	217, 217A	OFFICE	-	-	-	500	250	55	55	35	TS-3C				X			
VAV-?	VC-2-04	VR-22204	AHU-2-2	SECOND FLOOR	295, 218, 220, 216A	OFFICE, CORRIDOR	-	2-WAY	(N) BALL	470	235	80	80	45	TS-3C				X		X	
VAV-?	VC-2-05	VR-22205	AHU-2-2	SECOND FLOOR	219A, 219B, 219C, 219D, 219E	CLASSROOM, OFFICE, STOR.	-	-	-	2250	1125	255	255	1270	TS-3CC				X			
VAV-?	VC-2-06	VR-22206	AHU-2-2	SECOND FLOOR	294, 224, 226, 228	OFFICE	-	2-WAY	(N) BALL	665	335	100	100	65	TS-3C				X			
VAV-2C	VC-2-01	VR-23201	AHU-2-3	SECOND FLOOR	201B	CLASSROOM, LOBBY	HC-17	3-WAY	(N) BALL	925	465	65	65	320	TS-3CC				X			
VAV-2B	VC-2-02	VR-23202	AHU-2-3	SECOND FLOOR	201C	READING/STUDY	HC-17	3-WAY	(N) BALL	350	175	20	25	20	TS-3CC			X				X
VAV-2A	VC-2-03	VR-23203	AHU-2-3	SECOND FLOOR	201A	CLASSROOM	HC-17	3-WAY	(N) BALL	900	450	65	65	315	TS-3CC				X			
VAV-?	VC-2-04	VR-23204	AHU-2-3	SECOND FLOOR	291, 297	CORRIDOR, OFFICE	-	3-WAY	(N) BALL	650	325	125	125	80	TS-3A				X			
VAV-2E	VC-2-05	VR-23205	AHU-2-3	SECOND FLOOR	212, 206	EXAM LAB, CLASSROOM	-	2-WAY	(N) BALL	1930	965	280	280	695	TS-3CC				X			
VAV-?	VC-2-06	VC-23206	AHU-2-3	SECOND FLOOR	296, 212A, 212B	CORRIDOR, STORAGE	-	-	-	1145	-	435	175	435	TS-3A				X			
VAV-203	VR-2-07	VR-23207	AHU-2-3	SECOND FLOOR	203	CLASSROOM	-	2-WAY	(E) BALL	1400	700	105	105	525	TS-3CC	X						
VAV-204	VR-2-08	VR-23208	AHU-2-3	SECOND FLOOR	204	OFFICE	-	2-WAY	(E) BALL	500	250	65	65	40	TS-3C	X						
V-6	VR-2-09	VR-23209	AHU-2-3	SECOND FLOOR	205	CLASSROOM	-	2-WAY	(N) BALL	905	455	80	80	380	TS-3CC				X			
V-5	VR-2-10	VR-23210	AHU-2-3	SECOND FLOOR	207	CLASSROOM	-	2-WAY	(N) BALL	510	255	80	80	385	TS-3CC				X			
VAV-?	VC-2-01	VR-24201	AHU-2-4	SECOND FLOOR	232, 234, 236, 206A, 293	OFFICE, CORRIDOR, STOR.	-	3-WAY	(N) BALL	915	460	110	110	70	TS-3C				X			
VAV-2D	VR-2-02	VR-24202	AHU-2-4	SECOND FLOOR	237A, 237B	OFFICE	-	2-WAY	(N) BALL	615	310	40	40	25	TS-3C			X				
VAV-239F	VR-2-03	VR-24203	AHU-2-4	SECOND FLOOR	239F, 239G	SIM LAB, CONTROL ROOM	-	2-WAY	(E) BALL	700	350	130	55	130	TS-3C			X				
VAV-239E	VR-2-04	VR-24204	AHU-2-4	SECOND FLOOR	239E	SIM LAB	-	2-WAY	(E) BALL	400	200	75	35	75	TS-3C			X				
VAV-239D	VR-2-05	VR-24205	AHU-2-4	SECOND FLOOR	239D	CLASSROOM	-	2-WAY	(E) BALL	1775	890	115	115	570	TS-3CC			X				

LIST OF MEASURES	
MEASURE 1	ROOFTOP AHU UPGRADE
MEASURE 2	AHU-1-1 REPLACEMENT
MEASURE 3	REPLACE EXISTING INDUCTION BOXES WITH VAV BOXES
MEASURE 4	FOR EXISTING VAV REHEAT BOXES AND UPSTREAM HEATING COILS WITH PNEUMATIC ACTUATORS, REPLACE CONTROL VALVES AND REMOVE STRAINERS
MEASURE 5	REMOVE STRAINER BASKET FROM EXISTING VAV BOXES WITH ELECTRIC ACTUATOR
MEASURE 6	REMOVE COMPRESSED AIR SYSTEM
MEASURE 7	CONFIGURE EXISTING BOILER MIXING VALVE TO BE FIXED IN THE NORMALLY CLOSED (100% OPEN TO BOILER, 0% BYPASS) POSITION. REMOVE MIXING VALVE PNEUMATIC ACTUATOR.
MEASURE 8	REPLACE EXISTING VAV BOXES WITH NEW VAV BOXES
MEASURE 9	INSTALL NEW VAV BOXES
MEASURE 10	DRAIN, CUT AND CAP HOT AND CHILLED WATER PIPING ASSOCIATED WITH HOT WATER PUMP PHY-1 AND CHILLED WATER PUMP CHP-2
MEASURE 11	ADD SUPPLY DIFFUSER AND RETURN GRILLE TO OFFICE 216A
MEASURE 12	ABANDON HC-17 SERVING ROOMS 201A, 201B AND 201C IN-PLACE. MANUALLY CLOSE SUPPLY AND RETURN ISOLATION VALVES AND DRAIN COIL
MEASURE 13	CONTROL SYSTEM UPGRADE

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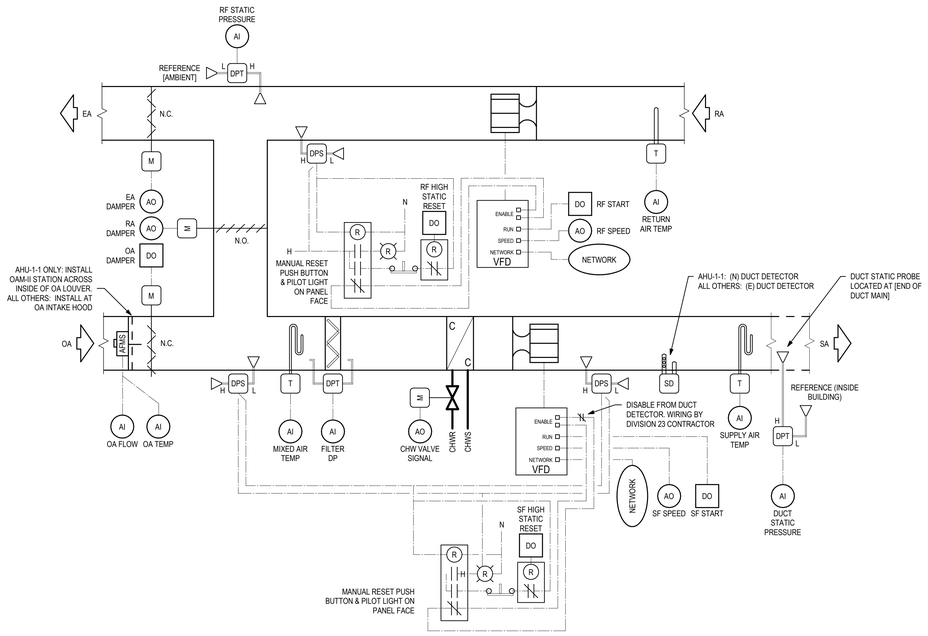
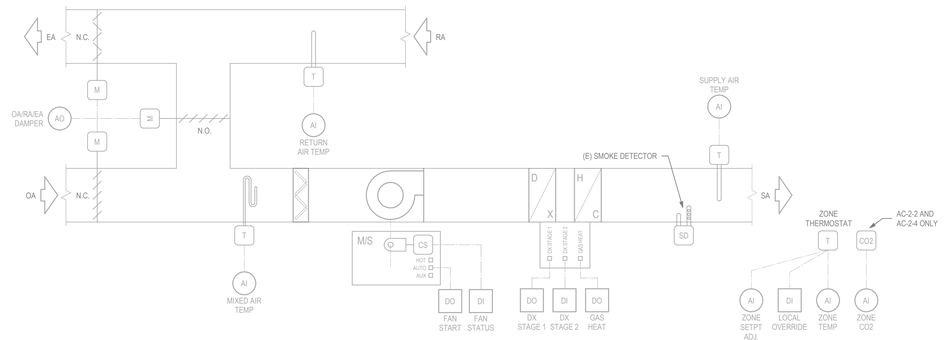
HVAC SCHEDULES

M-601

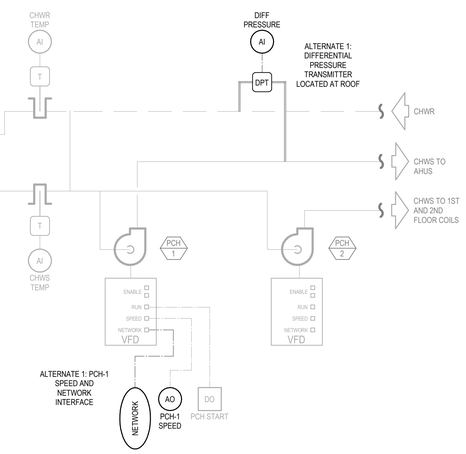
6/30/2020 9:46:54 AM



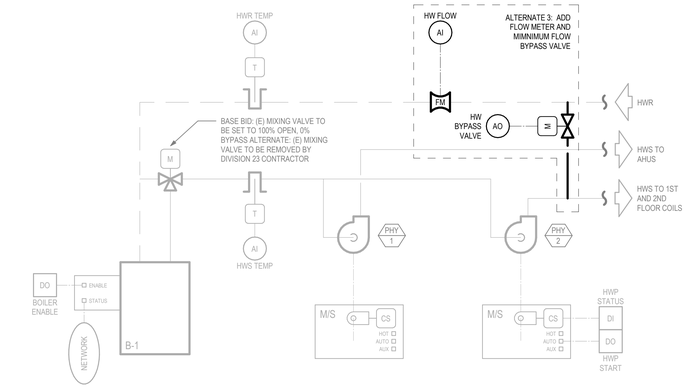
1 MULTIPLE ZONE VAV AIR HANDLING UNIT (AHU-1-1,1-2, 1-3, 2-1, 2-2, 2-3 AND 2-4)



2 SINGLE ZONE DX PACKAGED UNITS (ACU-2-1, 2-2, 2-3 AND 2-4)



3 DX FAN COIL UNIT (FCU-1 AND FCU-3)



4 HOT WATER SYSTEM

5 CHILLED WATER SYSTEM

CONTROLS

GENERAL

- SA — SUPPLY AIR
- OA — OUTSIDE AIR
- RA — RETURN AIR
- EA — EXHAUST AIR

EQUIPMENT

- 2-WAY VALVE
- 3-WAY VALVE
- SD — SMOKE DETECTOR
- FAN-PROP
- CENTRIFUGAL HOUSED FAN
- FAN-PLUG
- FAN ARRAY
- PUMP
- INLINE PUMP
- FURNACE
- FILTER
- AIR FLOW STATION
- C / C — COIL
- OPPOSED BLADE DAMPER
- PARALLEL BLADE DAMPER
- BAROMETRIC DAMPER
- VAV DAMPER
- ENABLE, RUN, SPEED, NETWORK, VFD — VARIABLE SPEED DRIVE
- ENABLE, STATUS, SETPOINT — CONTROLLER
- M/S, HOT, AUTO, AUX — MOTOR STARTER

CONTROLS

EQUIPMENT (CONT'D)

- CONTACT (BOXED)
- CONTACT (UNBOXED)
- R — RELAY (1 CONTACT)
- R — RELAY (2 CONTACTS)
- SWITCH
- ACCUVALVE
- HX — HEAT EXCHANGER
- R — LIGHT

SENSORS

- STATIC PRESSURE TIP
- AFS FAN
- SENSOR WELL
- T — TEMPERATURE SENSOR & SENSOR WELL
- RH, T — HUMIDITY SENSOR (RH) OR TEMPERATURE SENSOR (T)
- T — AVERAGING TEMPERATURE SENSOR
- M — MODULATING ACTUATOR
- M2 — 2-POSITION ACTUATOR

DIGITAL POINT

- DO — HARDWIRED DIGITAL OUTPUT (DO) OR DIGITAL INPUT (DI)

ANALOG POINT

- AO — HARDWIRED ANALOG OUTPUT (AO) OR ANALOG INPUT (AI)
- NETWORK — NETWORK CONNECTION BETWEEN CONTROLLER AND DEVICE
- FLOW CROSS
- FM — FLOW METER
- CS — CURRENT SWITCH

COLOR LEGEND

- NEW EQUIPMENT/DEVICES
- EXISTING EQUIPMENT/DEVICES

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0	BID SET	6/30/2020

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

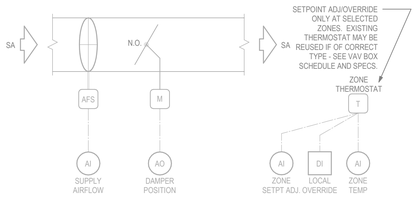
Drawn by RK

Scale

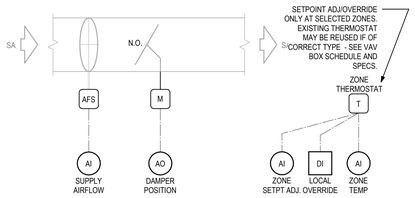
HVAC CONTROLS DRAWINGS

MC-601

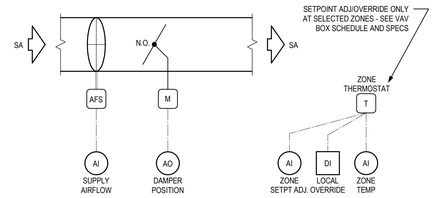
6/30/2020 9:45:55 AM



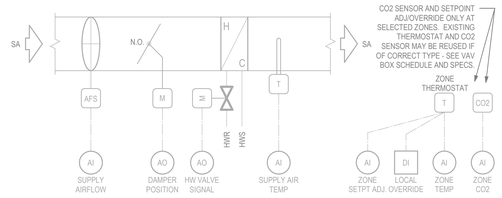
1 EXISTING ALC COOLING-ONLY VAVS



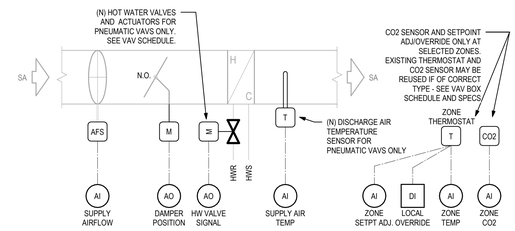
2 EXISTING PNEUMATIC AND RELIABLE CONTROLS COOLING-ONLY VAVS



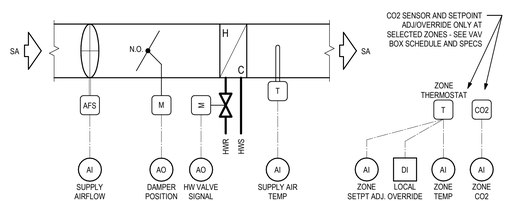
3 NEW COOLING-ONLY VAVS



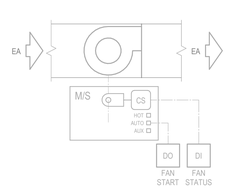
4 EXISTING ALC REHEAT VAV



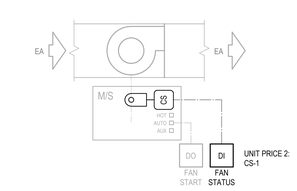
5 EXISTING PNEUMATIC AND RELIABLE CONTROLS REHEAT VAVS



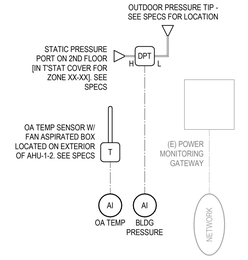
6 NEW REHEAT VAVS



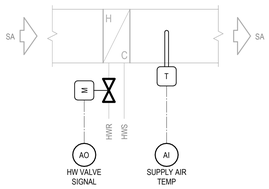
7 GENERAL EXHAUST FAN (EF-1-1)



8 GENERAL EXHAUST FANS (TYP. OF KITCHEN AND ART)



9 MISCELLANEOUS POINTS



10 UPSTREAM REHEAT COIL (HC-4)

C-1168 AA BUILDING MECHANICAL SYSTEMS UPGRADE - ENERGY CONSERVATION PROJECT

Taylor Engineering

1080 Marina Village Parkway, Suite 501
Alameda, CA 94501-6427
Phone: (510) 749-9135

ISSUES / REVISIONS

No.	Description	Date
0	BID SET	6/30/2020

CONTRA COSTA COMMUNITY COLLEGE DISTRICT

Drawn by RK

Scale

HVAC CONTROLS DRAWINGS

MC-602

6/30/2020 9:46:01 AM