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SPECIFICATION PACKAGE

SAN MATEO COUNTY HOSPITAL CONTROLS UPGRADES

FACILITY 10810

APRIL 29, 2016

SUBMITTED BY:

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BASIC MECHANICAL REQUIREMENTS

PART 1 - GENERAL

1.01 RELATED SECTIONS

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1.02 REQUIREMENTS OF REGULATORY AGENCIES:

A. Provide work and materials in full accordance with the latest rules and regulations of the following:

California Code of Regulations - Title 17
California Code of Regulations - Title 24 - Parts 2, 3, 4, 5, and 7
California Code of Regulations - Title 22 - Chapter 7
National Electric Code – 2013 State of California Amendments
National Fire Protection Association
CAL-OSHA
CAL OSHA Title 29 - Cal OSHA Title 8 or CA Labor Code
Occupational Safety and Health Administration
State Fire Marshal, Title 19 CRC
California Building Code, 2013 Edition
National Fire Code, 2013
California Mechanical Code, 2013 Edition
California Plumbing Code - 2013 Edition
AWWA 9th Edition
SMACNA Guidelines and Specifications
Other applicable state laws

B. Nothing in Drawings or specifications shall be construed to permit work not conforming to these codes.

C. Conform to State of California Energy Conservation Standards for all systems, equipment, and construction.

D. When contract documents differ from governing codes, furnish and install larger size or higher standards called for without extra charge.

E. No material installed as part of this Work shall contain asbestos in any form.

1.03 QUALITY ASSURANCE:

A. Plumbers' Qualifications:

1. Plumbing: Certification of Journey level Plumbers, or equal.

a. Show current certifications upon request.

b. Certification shall be copied and kept on file by Contractor for duration of the job and provided to Owner's Representative to be kept on file by Owner's Plant Operations and Maintenance Plumbing Supervisor.

1.04 FEES, PERMITS, AND UTILITY SERVICES:

A. Obtain and pay for all permits and service required in installation of this work; arrange for required inspections and secure approvals from authorities having jurisdiction.

B. Arrange for utility connections and pay charges incurred, including excess service charges, if any.

1.05 SITE EXAMINATION:

A. Examine site, verify dimensions and locations against Drawings, and inform self of conditions under which work is to be done before submitting proposal. No allowance will be made for extra expense on account of error.

B. Information shown relative to existing services is based upon available records and data but is approximate only. Make minor deviations found necessary to conform with actual locations and conditions without extra cost. Verify location and elevation of utilities prior to commencement of excavation for new piping or its installation.

C. Exercise extreme care in excavating near existing utilities to avoid any damage thereto. Contractor is responsible for any damage caused by Contractor's operations.

D. All material and equipment removed from site as part of this project is the property of the Owner unless specifically designated otherwise and shall be delivered to a location at the Owner as directed by the Owner's Representative.

1.06 PLACEMENT OF EQUIPMENT AND WORK:

A. The placement of equipment and mechanical work in the locations and spaces shown on the Drawings is the Contractor's responsibility.

B. Move equipment and/or work into spaces through openings provided or located in the spaces during construction, as required.

C. Do disassembling and reassembling of equipment or other work necessary to accomplish this requirement without extra cost to the Owner.

1.07 MATERIAL LIST AND SUBSTITUTIONS:

A. Prior to commencement of work, submit to Owner's Representative a complete list of equipment and materials to be furnished, including all substitutions as required per specification Section 01340.

B. Partial or incomplete lists of material will not be considered.

C. Only one request for substitution will be considered on each item of material or equipment. No substitutions will be considered thereafter.

D. Quantities are the Contractor's responsibility and will not be reviewed.

E. Contractor shall certify that Contractor has examined all submittal data and that the equipment submitted for review meets or exceeds the requirements of the Drawings and specifications. Submittals without the required certification will not be reviewed.

F. If Contractor desires to make a substitution, Contractor shall submit complete information or catalog data to show equality of equipment or material offered to that specified. No substitutions will be allowed unless requested and reviewed in writing. The Owner's Representative shall review and take appropriate action on shop Drawings, product data, samples, and other submittals required by the contract documents. Such review shall be only for general conformance with the design concept and general compliance with the information given in the contract documents. It shall not include review of quantities, dimensions, weights or gauges, fabrication processes, construction methods, coordination with the work of other trades, or construction safety precautions, all of which are the sole responsibility of the Contractor. Review of a specific item shall not indicate acceptance of an assembly of which the item is a component. The Owner's Representative shall not be required to review and shall not be responsible for any deviations from the contract documents not clearly noted by the Contractor, nor shall the Owner's Representative be required to review partial submissions or those for which submissions for correlated items have not been received. Owner's Representative reserves right to require originally specified item.

G. Installation of reviewed substitution is Contractor's responsibility. Any changes required for installation of reviewed substituted equipment must be made without additional cost. Review by the Owner's Representative of the substituted equipment and/or dimensional Drawings does not waive these requirements.

H. Submit to Owner's Representative for review, within reasonable time after award of contract and in ample time to avoid delay of construction, shop Drawings or submittals on all items of equipment and materials covered in list mentioned above. Provide submittals in seven (7) copies and in a complete package. Partial submittals will not be considered.

I. No item submitted on by the Contractor shall be of a lesser quality in materials or performance than what is in the project specifications. If the cost of the submitted item is less than the specified item then the Owner is due a credit for the total difference in cost.

1.08 MAINTENANCE AND OPERATING INSTRUCTIONS:

A. Furnish Owner's Representative with two complete sets of typewritten operating and maintenance instructions, descriptive literature, catalog cuts, and diagrams covering all items of operation and maintenance for each and every mechanical system and piece of equipment furnished under these specifications.

B. Contractor must start compiling the above data (including obtaining operating and maintenance instruction data and catalog cuts and diagrams from the manufacturer of the reviewed equipment) immediately upon review of Contractor's list of materials, so as not to delay the final installation of the work.

C. Bind and index each set in a durable, hardboard binder. Final observation will not be made until booklets are submitted and have been reviewed by the Owner's Representative.

D. Incorporate complete operating instructions including starting, stopping, and description of emergency manual operation methods for the following:

Heating Systems
Ventilating Systems
Cogen System
Plumbing Systems
Piping Systems
Temperature Control Diagrams
Test Data and Air Balancing Reports
Provide charts and diagrams as required.
Provide operating manual for all equipment listed in individual sections of the specification.

E. Provide maintenance instructions for each item of individual equipment covering pertinent maintenance data, such as lubricants to be used, frequency of lubrication, inspections required, adjustments, belt and pulley sizes, etc.

F. Provide parts bulletins containing manufacturer's bulletins with part numbers, instructions, etc. for each item of equipment. Strip bulletins so that useless bulk is avoided.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT:

A. Mention herein or on Drawings requires that Contractor provide each item listed of quality noted or equal. All material shall be new, full weight, standard in all respects, and in first-class condition. Provide materials of the same brand or manufacture throughout for each class of material or equipment wherever possible. Materials shall be tested within the Continental United States by independent, nationally

recognized testing agency and shall be listed in accordance with testing agency requirements.

B. The grade or quality of materials desired is indicated by the trade names or catalog numbers stated herein.

C. Dimensions, sizes, and capacities shown are a minimum and shall not be changed without permission of the Owner's Representative.

D. Conform to the State Energy Conservation Standards for all material and equipment.

2.02 MATERIALS FURNISHED:

A. Identify all materials and equipment by manufacturer's name and model number. Remove unidentified materials and equipment from site.

B. Equipment specified by manufacturer's number shall include all accessories, controls, etc. listed in catalog as standard with equipment. Furnish optional or additional accessories as specified.

C. Equipment or material damaged during transportation, installation, or operation is considered as totally damaged. Replace with new equipment. Variance from this permitted only with written consent of the Owner's Representative.

D. Welding materials and labor shall conform to ASME Code and applicable state labor regulations.

PART 3 - EXECUTION

3.01 DRAWINGS AND COORDINATION:

A. General arrangement and location of piping, ductwork, equipment, etc. are shown on Drawings or herein specified. Carefully examine other work that may conflict with this work. Install this work in harmony with other crafts and at proper time to avoid delay of work.

B. In advance of construction, work out minor changes and relocations to suit actual conditions and work of other trades to avoid conflict therewith. This shall not be cause for additional cost.

C. Verify all measurements at the building and be responsible for the correctness of same. No extra compensation will be allowed on account of differences between actual dimensions and those indicated on the Drawings.

D. In addition, obtain all necessary information from the other trades regarding centers of partitions, walls, location of plumbing mains, fire sprinkler mains, and electrical conduits, ducts, pipes, etc. in order that pipes, equipment, and ductwork may be placed in their correct positions.

E. Execute any work or apparatus shown on the Drawings and not mentioned in the specifications, or vice versa, the same as if specifically mentioned by both. Omission from Drawings or specifications of any minor details of construction, installation, materials, or essential specialties does not relieve Contractor from furnishing same in place complete.

F. Furnish and install any incidental work not shown or specified which can reasonably be inferred as part of the work and necessary to provide a complete and workable system.

G. Furnish materials and work at proper time to avoid delay of the work.

3.02 ACCESS:

A. Continuously check Drawings for clearance and accessibility of equipment specified herein to be placed. No allowance of any kind will be made for negligence on part of Contractor to foresee means of installing equipment into proper position.

3.03 CLOSING IN OF UNINSPECTED WORK:

A. Do not allow or cause work installed to be covered up or enclosed before it has been inspected and tested. Should work be enclosed or covered up before it has been inspected and tested, uncover work at own expense. After it has been inspected and tested, make repairs necessary to restore work of other Contractors to condition in which it was found at time of cutting.

3.04 PROJECT MODIFICATIONS:

A. During the progress of construction, if such conditions arise that require revisions, modifications, or relocations to any mechanical equipment or materials incorporated in this project, such alterations shall be immediately called to the attention of the Owner's Representative. Contractor shall then prepare necessary Drawings showing proposed changes. Submit proposed changes for review by the Owner's Representative prior to actual revision work in the field.

B. Two sets of Drawings showing all revisions shall be immediately presented to Owner's Representative for Owner records. Maintain additional copies on the project as necessary to comply with "RECORD DRAWINGS" requirement of the General Requirements.

C. Incorporate all revisions into Record Drawings.

3.05 FORMING, CUTTING AND PATCHING:

A. Coordinate as necessary to provide any special forming, recesses, chases, etc., and provide wood blocking, backing, and grounds as necessary for proper installation of mechanical work.

B. If Contractor fails to coordinate at proper time or fails to locate items properly, resulting in extra work, then Contractor is responsible.

C. Contractor is responsible for proper placement of pipe sleeves, hangers, inserts, and supports for work.

3.06 EXISTING SERVICES:

A. Provide and install all required connections to existing systems as required by the drawings and specifications.

B. Integrate existing systems with all new work to provide a complete working system.

C. Provide minimum seven (7) working days (coordinate with Division 1, Section 1040 - Coordination, for consistency) to Owner's Representative of service interruptions. All service interruptions shall be kept to the minimum possible time. When requested by Owner's Representative, service interruptions shall occur outside of normal working hours. In addition, refer to Section 01045 for all interruptions to existing facilities.

3.07 GUARANTEE:

A. Be responsible for work done and material installed under these plans and specifications. Repair or replace, as may be necessary, any defective work, material, or part which may show itself within one year of filing of Notice of Completion and be responsible for damage to other materials, furnishing, equipment, or premises caused by such defects during this period, if in the opinion of the Owner's Representative said defect is due to imperfection of material or workmanship. Provide all such work and materials at no cost to Owner.

B. Be responsible for damage to any part of premises during guarantee period caused by leaks or breaks in work furnished and/or installed under this section.

C. Replace refrigerant, lubricants, or gasses lost as result of defects, breaks, or leaks in work.

3.09 RECORD DRAWINGS:

A. Upon completion of work covered by this contract, furnish Owner's Representative with a marked up set of contract documents in red ink showing all changes to the project within building and installed under this contract which are not in accord with these Drawings for the work. Diazo sepia transparencies will not be acceptable.

B. In addition, furnish one tracing showing all outside utility connections, piping, etc. installed under this contract. Locate and dimension all work with reference to permanent landmarks.

C. Match all symbols and designations used in contract Drawings when preparing "Record" Drawings.

D. Indicate clearly and correctly all work installed differently from that shown, and maintain records up to date as work progresses. Include invert elevations of pipes below grade of floor, the floor lines, plugged wyes, tees, caps, exact locations and sizing of piping, location of valves, and the like. Dimension locations from structural points.

E. Properly identify all stubs for future connections as to locations and use by setting of concrete marker at finished grade in manner suitable to Owner's Representative.

3.10 PROJECT COMPLETION TESTS AND START-UP:

A. Upon completion of the mechanical work, or at such time prior to completion as may be determined by the Owner's Representative, operate and test all mechanical equipment and systems for a period of at least five consecutive 24-hour days to demonstrate the satisfactory overall operation of the building or project as a complete unit. Include operation of heating and air conditioning equipment and systems for a period of not less than five 24-hour days at not less than 90 percent of full specified heating and cooling capacities in tests. Commence tests after preliminary balancing and adjustments to equipment has been checked. Immediately before starting tests, install air filters and lubricate all running equipment. Notify the Owner's Representative at least seven calendar days in advance of starting the above tests.

B. Provide training and orientation of Owner's operating staff in proper care and operation of equipment, systems and controls to Owner's Representative's satisfaction.

C. Neatly tabulate and deliver to the Owner's Representative complete operational data. Air flows, room temperatures, fan speeds, motor currents, plenum and duct static pressures, and other data will be supplied by air balance contractor.

D. During test period, make final adjustments and balancing of equipment, systems, controls, and circuits so that all are placed in first-class operating condition.

E. Mark final positions of balancing valves after balancing is complete.

F. All areas of building shall receive proper flow of hot and chilled water to assure adequate and uniform temperatures throughout.

G. Final observation will not be made until all of the above have been completed and balance report has been submitted and reviewed.

3.11 POST-CONTRACT COMPLETION TESTS:

A. If the required full-load operation conditions cannot be obtained at the time of the Project Completion Tests due to outdoor seasonal temperatures, return to the job site when requested by the Owner's Representative and complete proper loading of equipment and systems as required. Changing of any air filters will not be required under these tests. Contractor will be allowed seven calendar days after notification to begin tests.

3.12 PRE-SEASON START UP:

A. When requested by the Owner within one year of the filing of Notice of Completion, and when full-load tests required under Project Completion Tests and Post Contract Completion Tests have not been performed, start up any equipment or systems required for heating or cooling season operation by the Owner when such equipment and systems have remained shut down immediately after the Project Completion Tests. Make proper assurance that all equipment and systems are operating properly before being turned over for the first operational use of the Owner within one year of filing of Notice of Completion. The changing of any air filters will not be required under these start-up requirements. The Contractor will be allowed seven calendar days after notification, to begin test.

END OF SECTION

SECTION 23 09 00

BUILDING AUTOMATION CONTROL SYSTEM (BACS)

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK:

A. Refer to Basic Mechanical Requirements Section, for general mechanical requirements.

B. Refer to Mechanical Division for installation of instrument wells, valve bodies, dampers, etc. in mechanical systems.

C. Provide the following electrical work as work of this Section, complying with requirements of Electrical Division, and as outlined below:

1. All control wiring between field-installed controls, indicating devices, and unit control panels.

2. Interlock wiring between electrically interlocked devices, sensors, and between a hand or auto position of motor starters as indicated.

3. Wiring associated with indicating and alarm panels (remote alarm panels) and connections to their associated field devices.

4. Contractor shall provide and extend low voltage power source wiring required for operation of control devices provided.

5. Wiring for fully complete and functional controls system and as specified.

1.02 CONTRACTOR PROPOSALS

A. Contractor shall visit site prior to bid. Ascertain and check all conditions and take all measurements that may affect the work. 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.

B. By submitting a proposal, contractor guarantees that their proposal is in full compliance with these specifications and is complete and turnkey, except where specific exceptions are provided herein or clearly noted in the contractor's proposal.

C. Include any charges, including overtime wages, required to perform work within scheduling criteria and use-of-premises restrictions.

D. Bid proposals shall include:

1. Completed bid forms

2. Schematic diagram for the EMCS system architecture

3. Proposed construction schedule

4. Any clarifications and exceptions to these specifications. Do not exclude work that is required.

1.03 ALTERNATES & UNIT PRICING

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. Provide CopperCube Trend Log Archiver for trend storage backup

B. 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 may be used to add or deduct items from scope during the period of the contract and assume that options are accepted prior to installation.

1. See Bid Form.

1.04 REUSE OF EXISTING SYSTEMS AND EQUIPMENT

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

B. Patch and paint at demo’d wall sensors visible to occupants.

C. Wiring

1. All existing control conduit may be reused.

2. All existing control wiring may be reused.

3. Where wiring is allowed to be reused, its integrity and suitability to the new application is the responsibility of the Contractor. Wiring shall be properly identified and tested. The cost to replace/repair defective wiring is outside the scope of this proposal.

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

D. Pneumatic Controls

1. Demolish all pneumatic actuators that have not already been replaced and replace with electric.

2. Pneumatic tubing for DP sensors and switches may be reused.

E. Dampers

1. Reuse existing dampers, except where otherwise noted.

F. Valves

1. Existing butterfly control valve bodies may be reused.

2. Existing globe or ball valves with pneumatic actuators shall be fully replaced, except where otherwise noted.

3. New control valves and actuators, except where otherwise noted.

G. Temperature Sensors

1. Reuse existing temperature sensors unless specifically called out to be new in the Control Points lists.

H. Other Sensors

1. Reuse existing sensors unless specifically called out to be new in Control Points lists.

2. Existing static pressure tips may be used provided their location is found and noted on shop drawings.

I. Local Control Panels and cabinets

1. The Contractor may reuse any existing local control panels to locate new equipment.

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

3. All unused panels shall be removed.

J. Starters and variable speed drives

1. Reuse existing starters and variable speed drives; repair of same is not part of this project.

K. Safeties and Fire Alarm Controls

1. Existing safeties in control circuits (duct smoke detectors, life safety system interlocks) are not to be bypassed and are to remain functional at all times during and after construction.

2. The fire alarm system and EMCS are integrated. All existing functionality is to be retained and shall be included in shop drawings.

L. Instrumentation. Existing pressure gauges and thermometers on pumps, boilers, etc. are to remain as-is; repair or calibration of same are not part of this project.

1.05 SUBMITTALS: IN ACCORDANCE WITH DIVISION 1

A. Product Data: Submit manufacturer's specifications for each control device furnished, including installation instructions and start-up instructions. Submit integrated wiring and electrical diagram to show complete system operation.

B. All submittals must be received and approved by the Owner prior to the ordering and installation of any equipment by the Contractor.

1. Provide the Owner with a Building Controls submittal with the following:

- System Hardware
- System Architecture
- Programming and Graphics
- Complete System Wiring Schematic
- Cloud Based Energy Dashboard
- Post-Construction Trend Logs

2. Submittal format: Provide in both paper and electronic format

C. Submit shop drawings showing construction and mounting details for review prior to construction. In addition, submit the following for review prior to panel and/or system fabrication and installation:

1. Field wiring diagrams showing wiring external to panel.

2. Panel internal wiring diagrams also showing panel terminal connections for external wiring, properly coordinated and keyed to external wiring diagram.

3. Designation of all switches, pilot lights, etc. and layout of instruments, switches, and nameplates of panel.

1.06 COORDINATION:

A. Automatic temperature control systems work shall be accomplished as outlined below:

1. Control Valves furnished under this section shall be installed as specified in Mechanical Division.

2. Control Dampers are provided under the applicable Mechanical Division air distribution or air handling equipment section.

3. Water Pressure Taps, Thermal Wells, Flow Switches, Flow Meters, that will have wet surfaces furnished under this Section shall be installed as specified in Mechanical Division.

4. Controlled Equipment Power Wiring shall be furnished and installed under Electrical Division. Where control involves 120V control devices controlling 120V equipment, the Division 16 Electrical Contractor shall extend power wiring to the equipment and shall extend it from the equipment to the control device.

1.07 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.

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 Owner's 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 communications 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

a. Control Systems Server (CSS). This shall be a server upon which the systems configuration and programming databases are maintained and serves as web server for operator interface. It shall hold the backup files of the information downloaded into the individual controllers and as such support uploading and downloading that information directly to or from the controllers. It shall also act as a control information server to non-control system based programs. It shall allow secure multiple-access to the control information. It shall also store trend data uploaded from controllers.

b. The Operator Workstations and Portable Operator Terminals shall provide for overall system supervision, graphical user interface, management report generation, and alarm annunciation.

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

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

5. Gateways

a. 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 3.06H.) 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.

1.08 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 Owner and if all completion requirements have been fulfilled, the Owner 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 Owner 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 Owner. Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.

E. 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 Owner during this period.

PART 2 - PRODUCTS

2.01 GENERAL

A. Manufacturer: The Building Automation Control System shall be Johnson Controls, Inc. using either the Metasys or the Facility Explorer (FX) product lines.

B. All components used shall be serviceable, repairable, and replaceable by qualified temperature control technicians using non-proprietary parts, tools, and instruments.

2.02 CONTROLLERS

A. General

1. Point information from any controller (including BCs, AACs, and ASCs) and from any gateway shall be capable of being used in a control sequence in any other panel. The use of OWS or CSS to serve as a communications server between control panels and gateways is not acceptable.

2. For all controllers, operating configuration and software shall be retained in the event of a power outage without requiring a download from upper level controllers by one or a combination of the following:

a. Volatile RAM shall have a replaceable battery backup using a lithium battery with a rated service life of 10,000 hours continuous and a rated shelf life of at least 7 years.

b. Volatile RAM shall have an automatically rechargeable battery backup using a lithium battery with a rated service life of 50 hours continuous and a rated shelf life of at least 10 years.

c. EEPROM, EPROM, or NVROM non-volatile memory.

3. Controllers shall allow independent operation regardless of the status of the other controllers or OWS or CSS. BCs, AACs, and ASCs shall perform all specified control sequences independent of operator interface devices and servers, i.e. all programming shall reside in BCs, AACs, and ASCs.

4. Each controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall.

a. Assume a predetermined failure mode.

b. Generate an alarm notification to the master controller, Operator Workstation, or both.

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

6. Programmability: All controllers, including BCs, AACs, and ASCs, shall be fully user programmable. Configurable pre-programmed logic shall not be acceptable in any controller. (This is required due to non-standard control sequences at AHUs and VAV terminal units.)

B. Stand-Alone Functionality

1. General: These requirements clarify the requirement for stand-alone functionality relative to packaging I/O devices with a controller. Stand-alone functionality is specified with the controller and for each Application Category specified in Part 3. This item refers to acceptable paradigms for associating the points with the processor.

2. Functional Boundary: Provide controllers so that all points associated with and common to one unit or other complete system or equipment shall reside within a single control unit. The boundaries of a standalone system shall be as dictated in the contract documents. Generally systems specified for the Application Category will dictate the boundary of the standalone control functionality. See related restrictions below. When referring to the controller with respect to standalone functionality, reference is specifically made to the processor. One processor shall execute all the related I/O control logic via one operating system that uses a common programming and configuration tool.

3. The following configurations are considered acceptable with reference to a controller's standalone functionality:

a. Points packaged as integral to the controller such that the point configuration is listed as an essential piece of information for ordering the controller (having a unique ordering number).

b. Controllers with processors and modular back planes that allow plug in point modules as an integral part of the controller.

c. I/O point expander boards, plugged directly into the main controller board to expand the point capacity of the controller.

4. The following configurations are considered unacceptable with reference to a controller's standalone functionality:

a. Multiple controllers enclosed in the same control panel to accomplish the point requirement.

C. Building Controller (BC)

1. General Requirements

a. BCs shall be peer-to-peer devices connected to the Primary Controller LAN.

b. Each BC shall be capable of standalone direct digital operation utilizing its own microprocessor, internal RAM, non-volatile memory, input/output, wiring terminal strips, A/D converters, real-time clock/calendar and voltage transient and lightning protection devices, battery backup, regulated power supply, power conditioning equipment, ports for connection of operating interface devices, and control enclosure. Refer to standalone functionality specified above.

c. The BC(s) shall provide fully distributed control independent of the operational status of the OWSs and CSS. All necessary calculations required to achieve control shall be executed within the BC independent of any other device.

d. BCs shall perform overall system coordination, accept control programs, perform automated HVAC functions, control peripheral devices and perform all necessary mathematical and logical functions. BCs shall share information with the entire network of BCs and AACs/ASCs for full global control. Each controller shall permit multi-user operation from multiple workstations and portable operator terminals connected either locally or over the Primary Controller LAN.

e. BC shall contain sufficient memory for all specified global control strategies, user defined reports and trending, communication programs, and central alarming.

f. The BC may provide for point mix flexibility and expandability. This requirement may be met via either a family of expander boards, modular input/output configuration, or a combination thereof. Refer to standalone functionality specified above.

g. All BC point data, algorithms and application software shall be configurable, and all control strategies performed by the BC shall be both operator definable and modifiable, from Operator Interfaces. The point database and all application programs shall be stored in non-volatile or battery backed volatile memory within the BC and shall be able to upload to or download from the OWS or CSS.

h. BC shall provide buffer for holding alarms, messages, trends etc.

i. Each BC shall include self-test diagnostics, which allow the BC to automatically alarm any malfunctions or alarm conditions that exceed desired parameters as determined by programming input.

j. Each BC shall contain software to perform full DDC/PID control loops.

k. Memory

1) Memory for data trending shall reside in BCs; the Operator Workstation shall not need to be connected for data trending to occur. Memory shall be large enough to record 256 records of each hardware point on the panel and an equal number of software points, each record to include both data value and time of occurrence. See Paragraph 3.06H for trending software requirements.

2) Provide sufficient internal memory for the specified sequences of operation and trend logging. There shall be a minimum of approximately 25% of available memory free for future programming changes.

3) Provide an additional BC if needed to comply with this Paragraph.

l. For systems requiring end-of-line resistors those resistors shall be located in the BC.

m. Input-Output Processing

1) Digital Outputs (DO): Outputs shall be rated for a minimum 24 Vac or Vdc, 0.5 amp maximum current. Each shall be configurable as normally open or normally closed. Each DO shall be discrete outputs from the BC's board. Multiplexing to a separate manufacturer's board is unacceptable. Provide suppression to limit transients to acceptable levels.

2) Analog Inputs (AI): AI shall be 0-5 Vdc, 0-10 Vdc, and 0-20 mA. Provide signal conditioning and zero and span calibration for each input. Each input shall be a discrete input to the BC's board. Multiplexing to a separate manufacturer's board is unacceptable. A/D converters shall have a minimum resolution of 12 bits.

3) Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board. Software multiplexing of an AI and resistors is unacceptable.

4) Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.

5) Electronic Analog Outputs (AO): Voltage mode: 0-5 Vdc and 0-10 Vdc; Current mode: 4-20 mA. Provide zero and span calibration and circuit protection. Pulse Width Modulated (PWM) analog is not acceptable. D/A converters shall have a minimum resolution of 8 bits.

6) Pulsed Inputs: Capable of counting up to 8 pulses per second with buffer to accumulate pulse count. Pulses shall be counted at all times.

n. A communication port for operator interface through a terminal shall be provided in each BC. It shall be possible to perform all program and database back-up, system monitoring, control functions, and BC diagnostics through this port. Standalone BC panels shall allow temporary use of portable devices without

interrupting the normal operation of permanently connected printers, or workstations.

o. Each BC shall be equipped with loop tuning algorithm for precise proportional, integral, derivative (PID) control. Loop tuning tools provided with the Operator Workstation software is acceptable. In any case, tools to support loop tuning must be provided such that P, I, and D gains are automatically calculated.

p. All output points shall have a selectable failure setpoint or mode. The BC shall be capable of maintaining this failure setpoint or mode in the event of a system malfunction, which causes loss of BC control or loss of output signal as long as power is available at the BC. The failure setpoint or mode shall be selectable on a per point basis.

q. Slope intercepts and gain adjustments shall be available on a per-point basis.

r. BC Power Loss

1) Upon a loss of power to any BC, the other units on the primary controlling network shall not in any way be affected.

2) Upon a loss of power, all software, database parameters, and data (except trend data) shall be protected from memory loss per Paragraph 2.02A.2.

3) Upon restoration of power within the specified battery backup period, the BC shall resume full operation without operator intervention. The BC shall automatically reset its clock such that proper operation of any time dependent function is possible without manual reset of the clock. All monitored functions shall be updated.

4) Should the duration of a loss of power exceed the specified battery back-up period or BC panel memory be lost for any reason, the panel shall automatically report, or CSS shall automatically determine, the condition (upon resumption of power) and be capable of receiving a download via the network, and connected computer. In addition, the Owner shall be able to upload the most current versions of all energy management control programs, Direct Digital Control programs, database parameters, and all other

data and programs in the memory of each BC to the OWS via the local area network, or via the local RS-232C port to the POT.

s. BC Failure

1) Controller LAN Data Transmission Failure: BC shall continue to operate in stand-alone mode. BC shall store loss of communication alarm along with the time of the event. All control functions shall continue with the global values programmable to either last value or a specified value.

2) BC Hardware Failure: BC shall cease operation and terminate communication with other devices. All outputs shall go to their specified fail position.

t. Each BC shall be equipped with firmware resident or software self-diagnostics for sensors and be capable of assessing an open or shorted sensor circuit and taking an appropriate control action (close valve, damper, etc.).

u. BCs may include LAN communications interface functions for controlling secondary LANs. Refer to Paragraph 2.02C for requirements if this function is packaged with the BC.

v. BCs shall be mounted on equipment, in packaged equipment enclosures, or locking wall mounted in a NEMA 1 enclosure, as specified herein.

2. BACnet Building Controller Requirements

a. The BC(s) shall support all BIBBs defined in the BACnet Building Controller (B-BC) device profile as defined in the BACnet standard.

b. Each BC shall be connected to the BACnet Primary Controller LAN communicating to or from other BCs.

D. Advanced Application Controller (AAC) and Application Specific Controller (ASC)

1. General Requirements

a. AACs and ASCs shall be connected to the Primary or Secondary Controller LAN.

b. AACs and ASCs shall provide intelligent, standalone control of HVAC equipment. Each unit shall have its own internal RAM, non-volatile memory and will continue to operate all local control functions in the event of a loss of communications on the Secondary LAN. Refer to standalone requirements by application specified in Part 3 of this Section. In addition, it shall be able to share information with every other BC and AAC /ASC on the entire network.

c. Each AAC and ASC shall include self-test diagnostics that allow the AAC /ASC to automatically relay to the BC, LAN Interface Device or workstation, any malfunctions or abnormal conditions within the AAC /ASC or alarm conditions of inputs that exceed desired parameters as determined by programming input.

d. AACs and ASCs shall include sufficient memory to perform the specific control functions required for its application and to communicate with other devices.

e. Each AAC and ASC must be capable of stand-alone direct digital operation utilizing its own processor, non-volatile memory, input/output, voltage transient and lightning protection devices to perform all specified application sequences.

f. All point data; algorithms and application software within an AAC /ASC shall be modifiable from Operator Interfaces.

g. Memory

    1) Memory for data trending is not required for AACs and ASCs. If not provided in controller, memory for trend data shall reside in BCs connected to the same Network.

    2) Provide sufficient internal memory for the specified sequences of operation. For AACs, there shall be a minimum of approximately 25% of available memory free for future programming changes. Provide additional AACs or a BC if needed to comply with this requirement.

h. AAC Input-Output Processing. Same as BCs (Paragraph 2.02C.1.m) except A/D converters may be 10 bit.

i. ASC Input-Output Processing

1) Digital Outputs (DO): Outputs shall be rated for a minimum 24 Vac or Vdc, 0.5 amp maximum current. Each shall be configurable as normally open or normally closed. Each output shall have an LED to indicate the operating mode of the output. Each DO shall be discrete outputs from the ASC's board (multiplexing to a separate manufacturer's board is unacceptable). Provide suppression to limit transients to acceptable levels.

2) Analog Inputs (AI): AI shall be 0-5 Vdc or direct thermistor connection. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the ASC's board (multiplexing to a separate manufacturers board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 10 bits.

3) Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the ASC and shall be isolated from the main board. Software multiplexing of an AI and resistors may only be done in non-critical applications and only with prior approval of the Owner.

4) Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.

5) Electronic Analog Outputs (AO): Voltage mode: 0-5 Vdc and 0-10 Vdc; Current mode: 4-20 mA. Provide zero and span calibration and circuit protection. Pulse Width Modulated (PWM) analog is not acceptable. D/A converters shall have a minimum resolution of 8 bits.

2. BACnet AAC(s) and ASC(s) Requirements

a. The AAC(s) and ASC(s) shall support all BIBBs defined in the BACnet Building Controller (B-AAC and B-ASC) device profile as defined in the BACnet standard.

b. AAC(s) and ASC(s) shall communicate over the BACnet Primary Controller LAN or the Secondary LAN.

2.03 COMMUNICATION DEVICES

A. Controller Local Area Network Interface Devices (LANID)

1. The Controller LANID shall be a microprocessor-based communications device which acts as a gateway/router between the Primary LAN, Secondary LAN, an operator interface, or printer. These may be provided within a BC or as a separate device.

2. The LANID shall perform information translation between the Primary LAN and the Secondary LAN, supervise communications on a polling secondary LAN, and shall be applicable to systems in which the same functionality is not provided in the BC. In systems where the LANID is a separate device, it shall contain its own microprocessor, RAM, battery, real-time clock, communication ports, and power supply as specified for a BC in Paragraph 2.02C. Each LANID shall be mounted in a lockable enclosure.

3. Upon loss of power to a LANID, the battery shall provide for minimum 100-hour backup of all programs and data in RAM. The battery shall be sealed and self-charging.

4. The LANID shall be transparent to control functions and shall not be required to control information routing on the Primary LAN.

B. Supervisory LAN Routers

1. The Supervisory Router shall be a microprocessor-based communications device that acts as a router between the Supervisory LAN CSSs or OWS and the Primary LAN.

2. The Supervisory Router shall not perform information translation. Both Primary LAN and the Supervisory LAN shall use BACnet.

3. The Supervisory Router shall contain its own microprocessor, RAM, communication ports, and power supply. Each Supervisory Router shall be mounted in a lockable enclosure.

4. The Supervisory Router shall allow centralized overall system supervision, operator interface, management report generation, alarm annunciation, acquisition of trend data, and communication with control units. It shall allow system operators to perform the following functions from the CSS, OWSs, and POTs.

a. Configure systems.

b. Monitor and supervise control of all points.

c. Change control setpoints.

d. Override input values.

e. Override output values.

f. Enter programmed start/stop time schedules.

g. View and acknowledge alarms and messages.

h. Receive, store and display trend logs and management reports.

i. Upload/Download programs, databases, etc. as specified.

5. Upon loss of power to the Supervisory Router, the battery shall provide for minimum 100-hour backup of all programs and data in RAM. The battery shall be sealed and self-charging.

6. The Supervisory Router shall be transparent to control functions and shall not be required to control information routing on the Primary LAN.

C. BACnet broadcast message routing

1. To allow BACnet broadcast messages to be relayed from remote nodes communicating via the internet and connecting to the Supervisory Router through IP protocol, a BACnet/IP Broadcast Management Device (BBMD) shall be provided which conforms to the BACnet standard for two-hop distribution. Multicast messaging or one-hop distribution requiring configuration of IP routers which are not part of the BAS vendor's scope is not acceptable.

D. 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.

3. Each Gateway shall provide a way to collect and archive or trend (time, value) data pairs.

4. Each Gateway and any devices that the Gateway represents which have time-of-day information shall respond to workstation requests to synchronize the date and time. Each Gateway and any devices that the Gateway represents shall support dynamic device binding and dynamic object binding.

5. All points in the system shall be made network visible through the use of standard BACnet objects or through proprietary BACnet extensions that the workstation also supports. All points shall be writable using standard BACnet services.

6. All devices have a Device Object instance number that is unique throughout the entire inter-network. All BACnet devices shall be configured with a Device Object instance number that is based on the format specified. This includes all physical devices as well as any logical BACnet devices that are physically represented by Gateways.

7. Upon loss of power to a Gateway, the battery shall provide for minimum 500-hour backup of all programs and data in RAM. The battery shall be sealed and self-charging.

8. UL 916 CE FCC part 15 Subpart B – Class A with surge and transient protection circuitry for power and communications.

E. Gateway and Routers

Equipment/System	Interface		
	Type	Specified Under Division:	Connect to this Network:
Variable Speed Drives	BACnet/MSTP	23	Secondary
Chiller	BACnet/MSTP	23	Secondary
Refrigerant Detector	Modbus RTU	25	Secondary

2.04 BAS INTERFACE HARDWARE

A. Control System Server

1. Hardware:

    a. Intel Xeon Quad Core 3 GHz (minimum) Processor

    b. 4 GB DDR4 RAM (minimum)

    c. 1 TB SATA 7200 RPM hard disk (minimum)

    d. 16X SATA (minimum) Read/Write DVD drive

    e. One Ethernet 10/100 Mbps internal network card (for connection to Supervisory LAN)

    f. One Ethernet 10/100/1000 Mbps (1 Gbps) internal network card (for connection to Owner IT LAN)

    g. 24 inch color, 1920 x 1200 pixel flat panel display.

    h. 256 MB VGA/DVI graphics adapter

    i. 2-button with scroll optical USB mouse

    j. Enhanced USB 101-key keyboard

    k. Internal speakers

    l. High efficiency power supply; EnergyStar configured

    m. One spare serial port and one spare USB port in addition to those needed for specified peripherals

    n. 24x7 dedicated technical support service that delivers reduced hold time, direct access to advanced level technicians, and reduced time to resolution, minimum 3 years

    o. Tower cabinet

2. Software by PC Supplier (factory installed):

    a. Operating system: Microsoft Windows 7 Professional

    b. Browser: Microsoft Internet Explorer or Firefox

    c. Database: Oracle or MS SQL

    d. All software shall be at least the latest version available as of the date of purchase.

B. Operator Workstation

1. Hardware:

a. Intel Xeon Quad Core 3 GHz (minimum) Processor

b. 4 GB DDR4 RAM (minimum)

c. 1 TB SATA 7200 RPM hard disk (minimum)

d. 16X SATA (minimum) Read/Write DVD drive

e. One Ethernet 10/100 Mbps internal network card (for connection to Supervisory LAN)

f. One Ethernet 10/100/1000 Mbps (1 Gbps) internal network card (for connection to Owner IT LAN)

g. 24 inch color, 1920 x 1200 pixel flat panel display.

h. 256 MB VGA/DVI graphics adapter

i. 2-button with scroll optical USB mouse

j. Enhanced USB 101-key keyboard

k. Internal speakers

l. High efficiency power supply; EnergyStar configured

m. One spare serial port and one spare USB port in addition to those needed for specified peripherals

n. 24x7 dedicated technical support service that delivers reduced hold time, direct access to advanced level technicians, and reduced time to resolution, minimum 3 years

o. Tower cabinet

2. Software by PC Supplier (factory installed):

a. Operating system: Microsoft Windows 7 Professional

b. Browser: Microsoft Internet Explorer or Firefox

c. Office Suite: Microsoft Office Professional

d. DVD burner software: Standard software provided by computer supplier

e. All software shall be at least the latest version available as of the date of purchase.

2.05 TEMPERATURE CONTROL MATERIAL: ACTUATORS AND OPERATORS

A. General Requirements

1. Damper and valve actuators shall be electronic and/or pneumatic, as specified in the System Description section.
2. The manufacturer shall be ISO 9001 certified.

B. Electronic Damper Actuators

1. Spring Return Actuators:

a. Manufactured, brand labeled or distributed by Johnson Controls, Inc. or approved equivalent.

b. Regulatory Agency Listing: cULus ,CSA C22.2 No. 24-93, and CE marked

c. Direct-Coupled Design: Requires no crankarm or linkage for mounting to a shaft.

d. Coupling: toothed V-bolt clamp and nuts with toothed cradle.

e. Reversible Mounting: Provides either clockwise or counterclockwise operation.

f. Power Failure Operation: Mechanical spring return system drives load to the home position. Other forms of internal energy storage for power failure operation are not acceptable.

g. Motor Technology:

1) Modulating Types: Microprocessor-controlled Brushless DC motor

2) On/Off Types: DC brush motor.

h. Overload Protection: Electronic stall detection protects from overload at all angles of rotation without the use of end switches.

i. Enclosure Ratings:

1) NEMA type 2 / IP54 mounted in any orientation.

j. Double-Insulated construction: Eliminate the need for electrical ground wires.

k. Wiring: Integral cables with colored and numbered conductors.

l. Sized for torque required to seal damper at load conditions

m. Parallel Operation: Actuators shall be available that are capable of being mechanically or electrically paralleled.

n. Proportional actuators shall be user configurable without the use of external computer software or programming tools. Calibration, input signal range selection, and control logic reversal shall be selectable with an external mode selection switch.

o. Operating Temperature Range:

1) 70 lb·in. Torque and Below: -40°F to 140°F

2) 71 lb·in. Torque and above: -40°F to 131°F

p. Power Requirements:

1) Modulating Types:

- 27 lb·in. Torque and Below: 5VA maximum
- 70 lb·in. to 19 lb·in.Torque: 8VA maximum
- 89 lb·in. to 71 lb·in.Torque: 10VA maximum
- 90 lb·in. to 177 lb·in.Torque: 16VA maximum

2) 2-Position Types:

- 27 lb·in. Torque and Below: 5VA maximum

- 70 lb·in. to 19 lb·in.Torque: 7VA maximum
- 71 lb·in. to 177 lb·in.Torque: 25VA maximum

2. Non-Spring Return Actuators:

   a. Manufactured, brand labeled or distributed by Johnson Controls, Inc. or approved equivalent.

   b. Regulatory Agency: UL Listed ,CSA Certified, and CE marked

   c. Direct-Coupled Design: Requires no crankarm or linkage for mounting to a shaft.

   d. Coupling:

      1) Above 80 lb.·in.: toothed V-bolt clamp and nuts with toothed cradled

      2) 80 lb.·in.and below: single cup-point set screw and toothed cradle.

   e. Overload Protection: Electronic stall detection or magnetic slip clutch protects from overload at all angles of rotation without the use of end switches.

   f. Minimum Enclosure Ratings:

      1) Types with covered wiring terminals: NEMA type 2 / IP42 mounted in any orientation.

      2) Types without covered wiring terminals: NEMA type 1 / IP30 or IP40.

      3) Types with integrated cables: NEMA 2 / IP42 mounted in any orientation.

   g. Sized for torque required to seal damper at load conditions

   h. Parallel Operation: Actuators shall be available that are capable of being mechanically or electrically paralleled.

i. Proportional actuators shall be user configurable without the use of external computer software or programming tools.

j. Operating Temperature Range: -4°F to 122°F except for VAV and similar indoor applications in which case 32°F to 122°F is acceptable.

k. Power Requirements: 24 V with models available for both 24 VAC and 24 VDC operation, maximum

1) Above 80 lb.·in.: 7.5 VA at 24 VAC

2) 80 lb.·in.and below: 3.5 VA at 24VAC

l. The manufacturer shall provide 5-year limited warranty from the date of sale covering defects in material or workmanship.

2.06 TEMPERATURE CONTROL MATERIAL: SENSORS AND TRANSMITTERS

A. General requirements

1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

2. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and a to d conversion:

Point type	Accuracy
Room temp	+/- 0.5°f
Duct temperature	+/- 0.5°f
All other temperatures	+/- 0.75°f
Chilled and hot water	+/- 0.5°f
Chilled water and condenser water at central plant mains	+/- 0.2°f
Water flow	+/- 1% of reading

Point type	Accuracy
Air flow (terminal)	+/- 10% of reading
Air flow (measuring stations)	+/- 5% of reading
Air Pressure (ducts)	+/-0.05 inches
Air Pressure (space)	+/-0.01 inches
Water Pressure	+/-2% of reading

B. Temperature sensors

1. General requirements:

a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.

b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel rtd, or two-wire 1000 ohm platinum rtd.

2. Room temperature sensors

a. Room sensors shall be constructed for either surface or wall box mounting.

b. Room sensors shall have the following options when specified:

1) Setpoint warmer/cooler dial or reset slide switch providing a +3 degree (adjustable) range.

2) Individual heating/cooling setpoint slide switches.

3) A momentary override request push button for activation of after-hours operation.

4) Analog thermometer.

3. Room temperature sensors with integral display

a. Room sensors shall be constructed for either surface or wall box mounting.

b. Room sensors shall have an integral lcd display and four button keypad with the following capabilities:

1) Display room air temperatures.

2) Display and adjust room comfort setpoint.

3) Display and adjust fan operation status.

4) Timed override request push button with led status for activation of after-hours operation.

5) Display controller mode.

6) Password selectable adjustment of setpoint and override modes.

4. Water Temperature Sensors

a. Well mounted immersion sensor, ¼" stainless steel probe, double encapsulated sensor, with enclosure suitable for location.

b. Where used at central plant mains, same as above except provide extra precision (XP) temperature sensors to meet accuracy specified above.

5. Thermo wells

a. Thermowell manufacturer shall have models available in stainless steel, brass body, and copper bulb.

b. When □hermos wells are required, the sensor and well shall be supplied as a complete assembly, including wellhead and sensor.

c. Thermo wells shall be pressure rated and constructed in accordance with the system working pressure.

d. Thermo wells and sensors shall be mounted in a direct mount (no adapter) offering faster installation or ½" nft saddle and allow easy access to the sensor for repair or replacement.

e. Thermo wells constructed of 316 stainless steel shall comply with Canadian registration number (crn) pressure vessel rating.

6. Outside air sensors

a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.

b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.

c. Temperature transmitters shall be of nema 3r (ip54) or nema 4 (ip65) construction and rated for ambient temperatures.

d. The outdoor sensor can be easily mounted on a roof, pole or side of a building utilizing its already assembled mounting bracket.

e. Outside relative humidity sensors 0-100% full range of accurate measurement. Operating temperature -4 to 140f (-20 to 60c).

f. Outside temperature sensors operating temperature range is -40 to 140f, +/- .55f (+/- .3c).

7. Duct mount sensors

a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.

b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.

c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.

8. Averaging sensors

a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.

b. For plenum applications, such as mixed air temperature measurements, a continuous averaging sensor or a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.

c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

9. Acceptable manufacturers: Johnson Controls, Minco.

C. Humidity sensors

1. The sensor shall be a solid-state type, relative humidity sensor of the thin film capacitance or bulk polymer design. The sensor element shall resist service contamination.

2. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 ma, 0-100% linear proportional output.

3. The humidity transmitter shall meet the following overall accuracy, including lead loss and analog to digital conversion. 3% between 20% and 80% rh @ 77 deg f unless specified elsewhere.

4. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a nema 3r (ip54) or nema 4 (ip65) enclosure with sealtite fittings.

5. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.

6. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

7. Acceptable manufacturers: Johnson controls and vaisala.

D. CO2 sensors

1. Where shown on the drawings, c02 sensors shall have the following features:

a. Jumper selectable: 0-20ma, 4-20ma & 0-10vdc output

b. Liquid crystal display

2. The C02 sensors shall have the ability to monitor and output the following variables as required by the systems sequence of operations:

a. Zone carbon-dioxide

3. The C02 shall transmit the information back to the controller via jumper selectable 0-20ma, 4-20ma & 0-10vdc output signals.

    a. The c02 sensors shall provide a maximum output current of 25ma; maximum output voltage of 12.5v.

    b. The c02 sensors shall be fcc compliant to cfr47 part 15 subpart b class a.

4. The C02 sensors shall be available with

    a. Co2 reponse time (0-63%) of 1 minute

    b. Less than 0.083% of full scale/f˚ temperature dependence of co2 output

    c. Long term co2 stability ±5% of full scale for 5 years

    d. Co2 measurement accuracy of ±(40ppm + 2.0% of reading)

    e. Co2 non-linearity of less than 1.0% of full scale

5. The C02 sensors may include the following items :

    a. Relay output module

    b. Liquid crystal display module

    c. Analog temperature module with linear 0-10vdc output for 32-122f

E. Differential pressure transmitters

1. General air and water pressure transmitter requirements:

    a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.

    b. Pressure transmitters shall transmit a 0 to 5 vdc, 0 to 10 vdc, or 4 to 20 ma output signal.

    c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and owner permanent, easy-to-use connection.

d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.

2. Low differential water pressure applications (0” - 20” w.c.)

a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 ma output in response to variation of flow meter differential pressure or water pressure sensing points.

b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:

1) .01-20” w.c. Input differential pressure range.

2) 4-20 ma output.

3) Maintain accuracy up to 20 to 1 ratio turndown.

4) Reference accuracy: +0.2% of full span.

c. Acceptable manufacturers: Setra and Mamac.

3. Medium to high differential water pressure applications (over 21” w.c.)

a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:

1) Differential pressure range 10” w.c. To 300 psi.

2) Reference accuracy: +1% of full span (includes non-linearity, hysteresis, and repeatability).

b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to nema 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

c. Acceptable manufacturers: Setra and Mamac.

4. Building differential air pressure applications (+/- 0.25” w.c.)

    a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 ma output in response to variation of differential pressure or air pressure sensing points.

    b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:

        1) +/- 0.25” w.c. Input differential pressure ranges.
        2) Non-switch selectable

        3) 4-20 ma output.

        4) Maintain accuracy up to 20 to 1 ratio turndown.

        5) Reference accuracy: +0.2% of full span.

    c. Acceptable manufacturers: Johnson controls

5. Low differential air pressure applications (0” to 2.5” w.c.)

    a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 ma output in response to variation of differential pressure or air pressure sensing points.

    b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:

        1) (0.00 - 1.00” to 5.00”) w.c. Input differential pressure ranges. (select range appropriate for system application.)

        2) 4-20 ma, 0-5 vdc, 0-10 vdc, output.

        3) Maintain accuracy up to 20 to 1 ratio turndown.

        4) Reference accuracy: +0.25%, or 0.5% of full span.

    c. Acceptable manufacturers: Johnson Controls and Ruskin.

6. Medium differential air pressure applications (5” to 21” w.c.)

    a. The pressure transmitter shall be similar to the low air pressure transmitter, except that the performance

specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:

1) Zero & span: (c/o f.s./deg. F): .04% including linearity, hysteresis and repeatability.

2) Accuracy: 1% f.s. (best straight line) static pressure effect: 0.5% f.s. (to 100 psig.

3) Thermal effects: <+.033 f.s./deg. F. Over 40°f.

4) To 100°f. (calibrated at 70°f.).

a. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to nema 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

b. Acceptable manufacturers: Johnson Controls and Ruskin.

F. Flow Meters

1. 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

2. Vortex shedding flow meter (for steam)

a. Output: 4-20 mA, 0-10 Vdc, 0-5 Vdc.

b. Maximum Fluid Temperature: 800ºF (427 °C).

c. Wetted Parts: Stainless Steel.

d. Housing: NEMA 4X.

e. Turndown: 25:1 minimum.

f. Accuracy: 0.5% of calibrated span for liquids, 1% of calibrated span for steam and gases.

g. Each sensor shall be individually factory 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).

h. Body: Wafer style or ANSI flanged to match piping specification.

i. Manufacturers

1) Foxboro 83 series

2) Rosemount 8800 Series

3) Johnson-Yokagawa

4) Or equal

2.07 TEMPERATURE CONTROL MATERIAL: CONTROL VALVES

A. Ball Valves, 1/2 through 2 in.:

1. Ball Valves shall have forged brass bodies.
2. Valves shall have available either Chrome Plated Brass Balls or 300 Series Stainless Steel Balls in all sizes.
3. Valves shall have available either Nickel Plated Brass Stems or 300 Series Stainless Steel Stems with a blow-out proof stem design in all sizes.

4. Valves shall have Graphite reinforced Polytetrafluoroethylene (PTFE) seats with Ethylene Propylene Diene Monomer (EPDM) O-ring backing.
5. Stem seals shall be double EPDM O-rings.
6. Flow Characterization Disk shall be manufactured from Amodel AS-1145HS Polyphthalamide Resin and rated for 50 psid maximum differential pressure and shall be inserted against the casting of the valve.
7. All ball valves with internal pipe thread end connections shall be rated to 580 psi maximum static pressure at 203°F (95°C) fluid temperature.
8. All ball valves with sweat end connections or press end connection shall be rated to 300 psig maximum static pressure at 203°F (95°C) fluid temperature
9. All valves shall be rated for service with hot water, chilled water and 50% glycol solutions.
10. Ball Valves with stainless steel balls and stems shall be rated for use with 15 psig saturated steam.
11. Flow Characteristics shall be equal percentage on the control port. Bypass port on three-way valves shall have linear flow characteristics.
12. Valves shall have a maximum leakage specification of 0.01% of maximum flow for the control port, ANSI/FCI 70-2, Class 4 and 1% of maximum flow, bypass port.
13. Valves shall be maintenance free
14. Valves shall be provided with a 5 year warranty.
15. Valves shall be rated for 200 psid closeoff pressure.
16. Valve actuators shall be UL-recognized or CSA-certified.
17. Valves shall be Johnson Controls VG1000 Series ball valves or approved equal.

B. Ball Valves, 2-1/2 through 6 in. Flanged:

1. Ball Valves shall have forged brass bodies with ASME Class 150 ductile iron flanges.
2. Valves shall have 300 Series Stainless Steel Balls.
3. Valves shall have 300 Series Stainless Steel Stems with a blow-out proof stem design.
4. Valves shall have Graphite reinforced Polytetrafluoroethylene (PTFE) seats with Ethylene Propylene Diene Monomer (EPDM) O-ring backing.
5. Stem seals shall be double EPDM O-rings.
6. Flow Characterization Disk shall be manufactured from Amodel AS-1145HS Polyphthalamide Resin and rated for 50 psid maximum differential pressure.

7. Flow Characteristics shall be equal percentage on the control port. Bypass port on three-way valves shall have linear flow characteristics.
8. Valves shall have a maximum leakage specification of 0.01% of maximum flow for the control port, ANSI/FCI 70-2, Class 4 and 1% of maximum flow, bypass port.
9. All valves shall be rated for service with hot water, chilled water, 50% glycol solutions and rated for use with 25 psig saturated steam.
10. Two-Way Valves shall be rated for 100 psid closeoff pressure and Three-Way Valves shall be rated for 50 psid closeoff pressure.
11. Valves shall be maintenance free.
12. Valves shall be provided with a 5 year warranty.
13. Valve actuators shall be UL-recognized or CSA-certified.
14. Valves shall be Johnson Controls VG1000 Series ball valves or approved equal.

C. Butterfly Valves, 2 through 20 in. resilient seat ASME Class 125/150 Flanged:

1. Butterfly Valves shall have cast iron bodies meetings ASTM A126 Class B requirements and meet ASME class 125/150 flange requirements and shall be fully lugged.
2. Butterfly Valves seat shall be Ethylene Propylene Diene Monomer (EPDM).
3. Butterfly Valve disk shall be Ductile Iron with Nylon 11 coating.
4. Butterfly Valve stems shall be Stainless Steel.
5. Flow Characteristics shall be equal percentage up to 70° of disk rotation.
6. All valves shall be rated for service with hot water, chilled water and 50% glycol solutions.
7. Valves shall be maintenance free.
8. Valve shall be provided with a 3 year warranty.
9. Valve electric actuators shall be UL-recognized or CSA-certified.
10. Valves shall be Johnson Controls VF Series butterfly valves or approved equal.

D. Butterfly Valves, High Performance 2-1/2 through 16 in.

1. Butterfly Valves shall have bodies manufactured from Carbon Steel, ASTM A216 GR WCB/A516 GR 70 and shall be fully lugged per ASME Class 150 or ASME Class 300.
2. Butterfly Valves seat assembly shall be RPTFE (reinforced polytetrafluoroethylene) and the seat retainer shall be Carbon Steel, ASTM A516 GR 70
3. Butterfly Valve disk shall be Stainless Steel, ASTM A 351 GR CF8M

4. Butterfly Valve stems shall be 17-4 PH Stainless Steel, ASTM A564-Type 630
5. Butterfly Valve Stem Seals shall be One Carbon Fiber Ring and Three TFE Rings
6. Flow Characteristics shall be equal percentage up to 70° of disk rotation.
7. All valves shall be rated for service with hot water, chilled water, 50% glycol solutions and 50 psig saturated steam in modulating service or 150 psig saturated steam in two position service.
8. Butterfly Valves shall meet the performance requirements of ASME Class 150 or Class 300.
9. Valves shall be maintenance free.
10. Valves shall be provided with a 3 year warranty.
11. Valve electric actuators shall be UL-recognized or CSA-certified.
12. Valves shall be Johnson Controls VF Series butterfly valves or approved equal.

E. Electric Zone Valves, 1/2 through 1-1/4 in.

1. Valves shall have bodies manufactured from Forged Brass.
2. Valves stems shall be brass (Hard Chrome Plated)
3. Valve Actuator shall be UL, cUL listed or CSA certified.
4. Valves shall be rated for service with hot water, chilled water and 50% glycol solutions.
5. Two Position valves shall have models available rated for use with 15 psig saturated steam.
6. Valve Actuator shall be replaceable without removing valve from the pipe.
7. Modulating Valves flow characteristics shall be equal percentage
8. Valves shall be provided with a 2 year warranty.
9. Valve actuators shall be UL-recognized or CSA-certified.
10. Valves shall be Johnson Controls J Series electric zone valves or approved equal.

2.08 TEMPERATURE CONTROL MATERIAL: STATUS AND SAFETY SWITCHES

A. General Requirements

1. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BMS when a failure or abnormal condition occurs. Safety switches shall be

provided with two sets of contacts and shall be interlock wired to shut down respective equipment.

B. Current Sensing Switches

1. The current sensing switch shall be self-powered with solid-state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.

2. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.

3. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.

4. Acceptable manufacturers: Johnson Controls

C. Air Filter Status Switches

1. Differential pressure switches used to monitor air filter status shall be of the automatic reset type with SPDT contacts rated for 2 amps at 120VAC.

2. A complete installation kit shall be provided, including: static pressure tops, tubing, fittings, and air filters.

3. Provide appropriate scale range and differential adjustment for intended service.

4. Acceptable manufacturers: Johnson Controls, Cleveland Controls

D. Air Flow Switches

1. Differential pressure flow switches shall be bellows actuated mercury switches or snap acting micro-switches with appropriate scale range and differential adjustment for intended service.

2. Acceptable manufacturers: Johnson Controls, Cleveland Controls

E. Air Pressure Safety Switches

1. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120VAC.

2. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.

3. Acceptable manufacturers: Johnson Controls, Cleveland Controls

F. Water Flow Switches

1. Water flow switches shall be equal to the Johnson Controls P74.

G. Low Temperature Limit Switches

1. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.

2. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.

3. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.

4. The low temperature limit switch shall be equal to Johnson Controls A70.

2.09 SOFTWARE

A. Graphical User Interface

1. Trends

a. Trending and trend analysis capabilities are considered critical to system performance. The system shall be designed to upload and record large amounts of point data without causing network bottlenecks or affecting proper system operation. Data shall be stored on the CSS. The system as a whole shall be designed to comply with the trending capability test defined in Paragraph 3.06H.

b. Every point, both real and virtual, shall be available for data trending.

c. Trending software shall be capable of recording point values and time on a user specified regular time step and on a change-of-value (COV) basis (data is recorded when point changes by a specified amount for analog points or by changes of state for binary points), at the user's option. Sampling intervals shall be as small as one second. Each trended point shall have the ability to be trended at a different sampling interval.

d. Trend data shall be sampled and stored in control panel memory. If historical trending is enabled for the BACnet object, trend data shall be uploaded from control panels to the CSS on a user-defined interval, manual command, or automatically when the trend buffer becomes full. There shall be no limit to the amount of trend data stored at the CSS other than hard disk limitations.

e. Trends shall conform to the BACnet Trend Log Object specification. Trends shall both be displayed and user configurable through the GUI. Trend logs may comprise analog, digital or calculated points simultaneously. A trend log's properties shall be editable using the Navigation Tree and Graphic Pane.

f. Viewing Trends

1) Trend data shall be displayed graphically by the GUI. This shall be a capability internal to the workstation software and not a capability resulting from download of trend data on a third-party spreadsheet program unless such transfer is automatic and transparent to the operation and the third-party software is included with the workstation software package.

2) The software shall be capable of dynamically graphing the trend logged object data by creating two-axis (x, y) graphs that simultaneously display values relative to time for at least eight objects in different colors, even if objects have been trended at different time intervals. Where trended values are COV, software shall automatically fill the trend samples between COV entries. A graph legend shall identify each variable plotted.

3) Multiple scales shall be possible, one for each object, with range set automatically by the

software but capable of being manually adjusted by the operator.

4) Trend format, displayed points, etc. shall be capable of being saved as a template for future trend displays.

5) Trends shall be able to dynamically update at operator-defined intervals, including on a 1 second interval for loop tuning.

6) It shall be possible to zoom-in on a particular section of a trend for more detailed examination and pan through historical data by simply scrolling the mouse.

7) It shall be possible to pick (or float mouse over) any sample on a trend and have the numerical value displayed.

8) The operator shall have the ability to pan through a historical trend and copy the data viewed to the clipboard using standard Windows keystrokes.

g. 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 Owner'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).

h. Data export. Trends shall be exportable using one or more of the following methods:

i. SQL Query

1) Provide the exact syntax to allow extraction of data from the database in 4-column format as shown in Table 1 below.

2) Provide a windows-compatible ODBC driver for the database along with the installation of the database itself.

TrendName	DateTime	TimeZone	DataValue
B8.Plant.CH3.CHWS.Temp.F	2009-06-16 13:01:02	-0800	43.5
B8.Plant.CH3.CHWS.Temp.F	2009-06-16 13:06:06	-0800	45.2
B8.Plant.CH3.CHWS.Temp.F	2009-06-16 13:11:01	-0800	44.3

Table 1: Example of a Database Presentation

PART 3 - PRODUCTS

3.01 GENERAL:

A. Furnish all labor, materials, equipment, and service necessary for a complete and operating Direct Digital Control Building Automation Control System, as shown on the drawings and described herein.

B. All labor, material, equipment, and software necessary to meet the functional intent of the Building Automation Control System as specified herein and as shown on the drawings shall be included.

C. Drawings are diagrammatic only. Equipment and labor not specifically referred to herein, or on the plans, that are required to meet the functional intent of the Building Automation Control System, shall be provided without additional cost to Owner.

D. Equipment furnished by Electrical and/or Mechanical Contractor that is normally wired before installation shall be furnished completely wired. Wiring normally performed in field shall be furnished and installed by the Building Automation Control System contractor.

E. Control equipment having electrical connections only, which are furnished under this work, shall be installed and connected by the

Building Automation Control System contractor. Electrical devices requiring wet side piping connections shall be installed by the Mechanical Contractor.

F. Clearly identify and label equipment and controls, such as starters, switches, relays, as to function and position with permanently engraved plastic nameplates.

G. Wiring of control equipment in accordance with wiring diagrams and functional operation of the control system shall be the responsibility of the Building Automation Control System contractor.

H. Final Adjustment of Equipment: After completion of installation, adjust temperature sensors, control valves, actuators, motors, and similar equipment provided under the scope of work of this section. Cooperate with the air balance contractor as required.

I. Perform final adjustment by specially trained personnel in direct employ by the manufacturer of the primary Building Automation Control System.

J. Connect control valves with threaded connections with sufficient unions to permit valves to be readily removed from their installed locations for servicing, without disturbing adjacent piping. In no case shall this be less than three unions for three-way valves and one union for two-way valves.

K. Wiring and raceways included with the BACS scope of works includes but is not limited to the following:

1. Power wiring for all controllers, sensors, relays and other equipment shall be taken from the local HVAC controls panels except equipment provided with dedicated supplies provided by Division 16.

2. Controls wiring shall be routed from the local HVAC controls panels.

3. Conduit shall be used for the following:

a. All exposed and concealed low voltage wiring in all areas below 8 feet above floor level.

b. All mechanical and equipment rooms, exterior locations and any other areas where physical protection and/or access is required as defined elsewhere in the contract documents.

c. All in-wall drops to equipment monitoring and/or control points including but not limited to medical equipment,

kitchen service equipment, elevator sump and other moisture sensors, water flow meters, equipment mounted alarms, etc.

d. All areas where specifically indicated on the Drawings.

4. J-Hooks and or designated LV raceway shall be used for the following:

a. All low voltage wiring above 8 feet above floor level in open and accessible areas where conduit is not required, to cable trays or other conduits.

b. All areas where specifically indicated on the Drawings.

5. Conduit and J-Hook materials and installation requirements shall comply with the applicable sections of Division 16 unless specifically indicated otherwise on the Drawings.

3.02 WARRANTY:

A. The Building Automation Control System contractor shall provide a one-year warranty covering the Building Automation Control System, and all associated components installed by the Building Automation Control System contractor. Any manufacturing or installation defects arising during this warranty period shall be corrected without cost to the Owner. The Building Automation Control System contractor shall respond to the job site within a four (4) hour period for any emergency relating to the control system and associated components installed by the Building Automation Control System contractor. Warranty period shall commence after all operator instruction is completed and the entire system has been accepted by the Owner.

3.03 CARE AND CLEANING:

A. Repair or replace broken, damaged, or otherwise defective parts, materials, and work. Leave entire work in condition satisfactory to Owner's Representative. At completion, carefully clean and adjust equipment, fixtures, and trim installed as part of this work. Leave systems and equipment in satisfactory operating condition.

3.04 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. Refer to Paragraph 2.02B above for physical limitations of standalone functionality. 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	• Fan Coil Units • Terminal Units (such as VAV Boxes) • Miscellaneous heaters • Constant speed	X	X	X

Application Category	Examples	Acceptable Controller		
		ASC	AAC	BC
	exhaust fans and pumps • Packaged units with self-contained controls			
2	• "Slow" Lab Zone – Non-Hood Dominated	X (note 1)	X	X
3	• Air Handling Units • Central Hot Water Plant • "Fast" Lab Zone – Hood Dominated • Air-Cooled Chilled Water Plant		X (note 1)	X
4	• Water-Cooled Chilled Water Plant			X
Notes: 1. Controller may be used only if all control functions and physical I/O associated with a given unit resides in one AAC				

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.

   d. Furnish ASCs to the VAV terminal unit manufacturer for factory mounting.

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.

3.05 SOFTWARE INSTALLATION

A. General

1. Include costs for minor program modifications if required to provide proper performance of the system.

B. Provide graphics for the following as a minimum

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

2. 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, chilled/hot water flow, steam flow, and natural gas demand shown roughly on the map where the utilities connect to the site.

3. Electricity demand limiting & cost page.

a. 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.

b. Electricity rate calculation. Include a table of utility demand and consumption rates for each of the time-of-day rate periods included in the actual applicable utility rate. For each month, show actual peak kW, kWh, and cost 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.

4. Natural gas cost page. Include a table of utility consumption rates for each of the time-of-year rate periods and each usage block included in the actual applicable utility rate. For each month, show actual peak therms/hr, therms, and cost for each rate period. Show side-by-side as month-this-year and month-last-year, and month-to-date and year-to-date data. Include adjustable conversion of gas volumetric flow rate to therms.

5. Each occupied floor plan, to scale

    a. 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.

    b. 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.

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

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

8. 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 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.

9. Each zone terminal:

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

    b. 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.

10. Electrical power monitoring system: Show a schematic of the electrical system based on one-line diagrams with meter current kW reading and month-to-date kWh shown in actual locations.

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

12. 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:

    a. 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)

    b. VAV Zone terminal units: operating mode; airflow rate; airflow rate setpoint; zone temperature; zone temperature setpoint; damper position; HW valve position (reheat boxes); supply air temperature (reheat boxes); supply air temperature setpoint (reheat boxes); Fan start/stop command, speed, and status (fan-powered); 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).

    c. Fan-coil units: operating mode; zone temperature;

zone temperature setpoint; supply air temperature; supply air temperature setpoint (where applicable); fan status; fan speed (where applicable); HW/CHW valve position; Cooling CHWST Reset current requests, cumulative %-request-hours, and request Importance Multiplier; Heating HWST Reset current requests, cumulative %-request-hours, and request Importance Multiplier.

13. 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.

14. 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.

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

16. All other BAS controlled/monitored equipment.

17. On all major system graphics, include a “note” block that allows users to enter comments relevant to system operation. Major systems include AHUs and heating/cooling plants.

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

3.06 OPERATION TEST/SYSTEM COMMISSIONING:

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

1. Submit Hardware and Shop Drawings Submittal and receive approval.

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

3. Develop point database and application software.

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

5. Submit Programming and Graphics Submittal and receive approval.

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

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

8. Submit Functional Testing Submittal and receive approval.

9. Perform BAS Pre-functional Tests (start up, calibration and tuning) and submit completed Pre-functional Test Forms for approval.

10. Field test application programs prior to functional testing.

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

12. Prepare and initiate commissioning Trend Logs.

13. 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.

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

15. Assist in Title 24 Acceptance Testing.

16. Submit Training Materials and receive approval.

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

18. Perform Demonstration Tests to Commissioning Authority and Owner's Representatives and submit Demonstration Test Report.

19. Receive acceptance of Demonstration Tests.

20. Train Owner personnel on BAS operation and maintenance.

21. Substantial Completion

22. Submit Post-Construction Trend Logs in format specified for review and approval.

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

24. Provide Operation and Maintenance Manuals, project Record Drawings, Commissioning Reports, copies of inspection certificates, written guarantee and warranty documents, and training materials.

25. Provide administration level password access to the Owner.

26. Final Acceptance

27. Begin Warranty Period.

28. Prepare and initiate post-occupancy Trend Logs.

29. Receive amended BAS Functional Test Report approval.

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.

e. Complete work, document results on forms, and submit for approval as Pre-Functional Test Report.

2. Functional Tests

a. Owner's Representatives will prepare functional testing forms after Submittal Package 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 Owner'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.

e. Complete work, document results on forms, and submit for approval as Functional Test Report.

C. Assist Commissioning Authority including attending commissioning meetings.

D. 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 at least twice as accurate as respective field device.

3) Drywell Bath: Field calibrate using a 2-point procedure, using a drywell calibrator block constructed for that purpose, or an ice bath with a reference standard.

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 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. Not required for fans that operate at constant flow.

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.

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

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

6) Record minimum speeds in log and store in software point.

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.

11. Trending/Network Traffic Test: Perform this test to verify that system has been designed adequately to simultaneously capture trends and allow proper operation of the control system.

a. The test shall be performed after the verification trends have been set up and are operational.

b. Test 1

1) Randomly select a device whose failure will generate a Level 1 or 2 alarm and manually shut it off. The status points for the device must indicate the change of state of the device at the Operator Workstation within 5 seconds.

2) The test shall be repeated for four devices in each building.

c. Test 2

1) A clock signal from a field controller randomly selected will be sent as a programmable point to up to 3 BCs. The clock signal stored in BCs shall be sampled with the rest of the trend data. The system shall be considered acceptable if these clock signals are no more than 2 seconds off of the system clock as sampled concurrently during data collection.

d. If the system fails any test, the system architecture shall be revised as required (install more trend memory, more controllers with trend storage capability, network repeaters to allow an increase in network speed, etc.) followed by additional tests.

E. Testing, Adjusting, and Balancing (TAB) Coordination

1. Some balancing procedures require the BAS to be operational and require Contractor time and assistance.

2. Setpoint Determination

a. Perform pre-functional tests before assisting in setpoint determination.

b. Coordinate with TAB Work to determine fan and pump differential pressure setpoints, outdoor air damper minimum positions and DP setpoints, etc.

F. Functional Tests

1. Test schedule shall be coordinated with the Commissioning Authority and Owner's Representative.

2. Functional tests may be witnessed by Owner's Representative at the Owner'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 Owner for review and approval.

G. Demonstration Test

1. Demonstration tests consist of a small representative sample of functional tests and systems randomly selected by the Commissioning Authority. Tests will be designed to occur over no longer than 3 working days.

2. Schedule the demonstration with the Commissioning Authority and Owner'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 Authority will supply the test forms at the site at the start of the tests.

5. Demonstration tests may be witnessed by Owner's Representative at the Owner's option.

6. Contractor shall conduct tests as directed by and in the presence of the Commissioning Authority and complete test forms. Completed forms shall be submitted as the Demonstration Test Report to the Commissioning Authority after tests are complete.

7. Demonstration Tests shall be successfully completed and approved prior to Substantial Completion.

H. 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 Drawings 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 Owner'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 Drawings list with the following qualifications.

      1) For equipment of identical function, such as AHUs with identical components and control sequences, only a sample of such equipment need be trended. The sampling shall be 10% of the identical components, but no more than 10 and no less than three.

   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 Authority 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 herein.

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 Owner in an electronic format agreed to by the Owner and Contractor (such as CD-ROM or via direct access to the CSS via the internet).

h. Data will be analyzed by the Commissioning Authority.

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 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 Drawings points list.

I. Remedial Work

1. Repair or replace defective Work, as directed by Owner's Representative in writing, at no additional cost to the Owner.

2. Restore or replace damaged Work due to tests as directed by Owner's Representative in writing, at no additional cost to the Owner.

3. Restore or replace damaged Work of others, due to tests, as directed by Owner's Representative in writing, at no additional cost to the Owner.

4. Remedial Work identified by site reviews, review of submittals, demonstration test, trend reviews, etc. shall be performed to the satisfaction of the Owner's Representative, at no additional cost to the Owner.

5. Contractor shall compensate Owner's Representatives and Commissioning Authority 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 Owner.

3.07 OPERATOR INSTRUCTION:

A. During system commissioning and at such time acceptable performance of the Building Automation Control System hardware and software has been established, the Control Contractor shall schedule with the Owner's Representative and provide eight (8) hours of on site, or off site, operator instruction to the Owner's operating personnel. Operator instruction during normal working hours shall be performed by a competent representative familiar with the systems hardware, software, and accessories

END OF SECTION 23 09 00

SECTION 23 09 93
SEQUNCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK:

A. Refer to Basic Mechanical Requirements Section, for general mechanical requirements.

B. Refer to Mechanical Division for installation of instrument wells, valve bodies, dampers, etc. in mechanical systems.

C. Provide the following electrical work as work of this Section, complying with requirements of Electrical Division, and as outlined below:

1. All control wiring between field-installed controls, indicating devices, and unit control panels.

2. Interlock wiring between electrically interlocked devices, sensors, and between a hand or auto position of motor starters as indicated.

3. Wiring associated with indicating and alarm panels (remote alarm panels) and connections to their associated field devices.

4. Contractor shall provide and extend low voltage power source wiring required for operation of control devices provided.

5. Wiring for fully complete and functional controls system and as specified.
   a. Acceptable manufacturers: Johnson Controls

1.1 SEQUENCES OF OPERATION

A. General

1. 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.

2. Include costs for minor program modifications if required to provide proper performance of the system.

3. Unless otherwise indicated in SOOs, control loops shall be enabled and disabled based on the status of the system being controlled to prevent wind-up. Loops shall also be initiated with the output set to a neutral (deadband) condition, e.g. valves and dampers close, VFDs at minimum speed, etc.

4. When SOOs use outdoor air temperature present value and there are multiple outdoor air sensors, the physically closest valid sensor reading shall be used. 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 (airflow across the sensor). The outdoor air temperature used for graphics display, optimum start, plant OAT lockout, and other global sequences shall be the average of all valid sensor readings.

5. The term “proven” (i.e. “proven on”/ “proven off”) shall mean that the equipment’s DI status point matches the state set by the equipment’s DO command point.

6. The term “PID loop” or “control loop” is used generically for all control loops and shall not be interpreted as requiring proportional plus integral plus derivative gains 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 limiting loops, etc.) to ensure there is no integral windup.

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

7. All setpoints, timers, deadbands, PID gains, etc. listed in sequences shall be capable of being adjusted by the operator without having to access programming whether indicated as adjustable in sequences or not. Software (virtual) points shall be used for these setpoints. Fixed scalar numbers shall not be imbedded in programs unless the value will never need to be adjusted.

8. Values for all points, including real (hardware) points used in control sequences shall be capable of being overridden by the user (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. Exception: Not required for ASC hardware points.

9. VFD minimum speed setpoints

    a. Minimum speed setpoints for all VFD-driven equipment shall be determined in accordance with Paragraph 1.2C.7.

b. Minimum speed for each piece of equipment shall be stored in a single software point that shall be used in programming (such as PID loop output range) and its value shall be assigned to the minimum speed setpoint stored in the VFD via the drive network interface. In this way there is only one minimum setpoint, rather than setpoints both in the drive and in software which could differ.

10. Trim & Respond 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. "Requests" are pressure, cooling, or heating setpoint reset requests generated by zones or air handling systems.

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

a) Importance Multiplier (default = 1). This point is used to scale the number of requests the zone/system is generating. A value of zero causes the zone/system's requests to be ignored. A value greater than zero can be used to effectively increase the number of requests from the zone/system based on the critical nature of the spaces served, or to increase the requests beyond the number of ignored requests (defined below) in the Trim & Respond reset block.

b) Request-hours

(1) This point accumulates the integral of requests (prior to adjustment of Importance Multiplier) to help identify zones/systems that are driving the reset logic. Every x minutes (adjustable, default 5 minutes), add x/60 times the current number of requests to this request-hours accumulator point.

(2) The request-hours point is reset to zero upon a global command from the system/plant serving the zone/system – this global point simultaneously resets the request-hours point for all zones/systems served by this system/plant.

(3) Cumulative %-request-hours is the zone request-hours divided by the zone run-hours (the hours in any Mode other than Unoccupied Mode) since the last reset, expressed as a percentage.

(4) A Level 4 alarm is generated if the zone Importance Multiplier is greater than zero, the zone %-request-hours exceeds 70%, and the total number of zone 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. Variables. All variables below shall be adjustable from a reset graphic accessible from a hyperlink on the associated system/plant graphic. 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)
SP_0	Initial setpoint
SP_{min}	Minimum setpoint
SP_{max}	Maximum setpoint
T_d	Delay timer
T	Time step
I	Number of ignored requests
R	Number of requests from zones/systems
SP_{trim}	Trim amount
SP_{res}	Respond amount
$SP_{res\text{-}max}$	Maximum response per time interval

d. Trim & Respond logic shall reset setpoint within the range SP_{min} to SP_{max}. When the associated device is off, the setpoint shall be SP_0. The reset logic shall be active while the associated device is proven on, starting T_d after initial device start command. When active, every time step T, trim the setpoint by SP_{trim}. If there are more than I Requests, respond by changing the setpoint by SP_{res} times (R – I), i.e. (the number of Requests minus the number of Ignored requests). But the net response shall be no more than $SP_{res\text{-}max}$. The sign of SP_{trim} must be the opposite of SP_{res} and $SP_{res\text{-}max}$. For example, if SP_{trim} = -0.1, SP_{res} = +0.15, $SP_{res\text{-}max}$ = +0.35, R = 3, I = 2, then each time step, the setpoint change = -0.1 + (3-2)*0.15 = +0.05. If R=10, then setpoint change = -0.1 + (10-2)*0.15 = 1.1 but limited to a maximum of 0.35. If R≤2, the setpoint change is -0.1.

11. Lead/lag and lead/standby alternation

    a. Even Wear

        1) Lead/lag. Unless otherwise noted, parallel staged devices (such as pumps, towers) shall be lead/lag alternated when more than one is off or more than one is on so that the device with the most operating hours is made the later stage device and the one with the least number of hours is made the earlier stage device. For example, assuming there are three devices, if all three are off or all are on, the staging order will simply be based on run hours from lowest to highest. If two devices are on, the one with the most hours will be set to be stage 2 while the other is set to stage 1; this may be the reverse of the operating order when the devices were started. If two devices are off, the one with the most hours will be set to be stage 3 while the other is set to stage 2; this may be the reverse of the operating order when the devices were stopped.

        2) Lead/standby. Unless otherwise noted, parallel devices (such as pumps, towers) that are 100% redundant shall be lead/standby alternated when more than one is off so that the device with the most operating hours is made the later stage device and the one with the least number of hours is made the earlier stage device. For example, assuming there are three devices, if all three are off, the staging order will be based on run hours from lowest to highest. If devices run continuously, lead/standby shall switch at an adjustable runtime; standby device shall first be started and proven on before former lead device is changed to standby and shut off.

    b. Exceptions

        1) Operators shall be able to manually fix staging order via software points on graphics overriding the Even Wear logic above, but not overriding the Failure or Hand Operation logic below.

        2) Failure: If the lead device fails or has been manually switched off, the device shall be placed into high level alarm (Level 2) and set to the last stage position in the lead/lag order until alarm is reset by operator. Staging position of remaining devices shall follow the Even Wear logic. A failed device in alarm can only automatically move up in the staging order if another device fails. Note that a device in alarm will be commanded to run if the sequence calls for it to run. In

this way the BAS will keep trying to run device(s) until it finds enough that will operate. Failure is determined by:

a) Variable Speed Fans and Pumps

1. *VFD critical fault is ON, or*

2. *Status point not matching its on/off point for 3 seconds after a time delay of 15 seconds when device is commanded on, or*

3. *Supervised HOA at control panel in OFF position, or*

4. *Loss of power (e.g. VFD DC Bus voltage = zero)*

b) Constant Speed Fans and Pumps

1. *Status point not matching its on/off point for 3 seconds after a time delay of 15 seconds when device is commanded on, or*

2. *Supervised HOA at control panel in OFF position*

c) Chillers

1. *Chiller alarm contact, or*

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

3. *Chiller status remains off 5 minutes after command to start*

d) Cooling Towers

1. *Tower fan has failed as defined above for constant speed fans, or*

2. *Inlet end switch indicates valve is not open 90 seconds after device is commanded open, or*

3. *Outlet end switch indicates valve is not open 90 seconds after device is commanded open.*

e) Boilers

1. *Boiler alarm point is ON, or*

2. *If its leaving water temperature remains 15°F below setpoint for 30 minutes*

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

a) Variable Speed Fans and Pumps

1. Status point not matching its on/off point for 15 seconds when device is commanded off, or

2. VFD in local "hand" mode, or

3. Supervised HOA at control panel in ON position

b) Constant Speed Fans and Pumps

1. Status point not matching its on/off point for 15 seconds when device is commanded off, or

2. Supervised HOA at control panel in ON position

c) Chillers

1. Chiller is manually turned on as indicated by the status of the Local/auto switch from chiller gateway.

d) Cooling Towers

1. Inlet end switch indicates valve is open 90 seconds after device is commanded closed, or

2. Outlet end switch indicates valve is open 90 seconds after device is commanded closed

12. VAV Box Controllable Minimum

a. This section is used to determine the lowest possible VAV box airflow setpoint 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 controls simply stop moving the damper when the airflow reading becomes too low to register and then re-enables the damper when the airflow reading rises above that threshold, *Vm* shall be equal to zero.

c. Option 2: If the VAV box controller can control to 0.004", 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

d. Option 3: The minimum setpoint *Vm* shall be determined as follows:

1) Determine the velocity pressure sensor reading VP_m in inches H_2O that results 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) Using the velocity pressure sensor amplification factor *F* provided by the sensor manufacturer for each VAV box sensor size, calculated the minimum velocity v_m for each VAV box size as

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

Where F is not known it can be calculated from the measured CFM at 1 inch signal from the VP sensor

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

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

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

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

$$Vm = v_m A$$

B. 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.)

C. Demand Limiting and Rate Calculator

1. Electricity Demand Limiting

   a. Sliding Window: The demand control function shall utilize a sliding window method selectable in increments of one minute, up to 60 minutes, 15 minute default.

   b. Demand Levels: Demand time periods shall be set up as per utility rate schedule. For each On-Peak or Partial-Peak period, three demand level limits can be defined. When the measured demand exceeds the limit, the Demand Limit Level switch for that level shall be set; when demand is less than 10% (adjustable) below the limit for a minimum of 15 minutes, and the time is no longer within the On-Peak or Partial-Peak window, the switch shall be reset. These levels are used at the zone level (see Zone Control sequences) to shed demand.

2. Electricity Rate Calculation

   a. A program shall be created that calculates electricity cost as would be billed by the utility using the applicable utility rate schedule.

   b. Utility cost shall be calculated real-time and summed for each month and year. For each month, store peak kW, kWh, and cost for each time-of-day rate period. Retain data for one year so that data may be displayed side-by-side as month-this-year and month-last-year. Also store month-to-date and year-to-date data.

   c. Enter latest applicable rate schedule from utility upon start-up. Rates shall be stored in software points so that they may be easily displayed and edited.

3. Natural Gas Rate Calculation

   a. A program shall be created that calculates gas cost as would be billed by the utility using the applicable utility rate schedule.

b. Conversion of volumetric flow to therms shall be adjustable, default 1000 Btu/ft3 or 0.01 therms/ft3.

c. Utility cost shall be calculated real-time and summed for each month and year. For each month, store peak therms/hour, therms, and cost for each time-of-day rate period. Retain data for one year so that data may be displayed side-by-side as month-this-year and month-last-year. Also store month-to-date and year-to-date data.

d. Enter latest applicable rate schedule from utility upon start-up. Rates shall be stored in software points so that they may be easily displayed and edited.

D. Zones

1. This section applies to all single zone systems and sub-zones of air handling systems, such as VAV boxes, fan-powered boxes, etc.

2. Setpoints

a. Each zone shall have separate unoccupied and occupied setpoints, and separate heating and cooling setpoint. As a default:

Zone type	**Occupied**		**Unoccupied**	
	Heat	**Cool**	**Heat**	**Cool**
Patient areas, 24-7	70ºF	75ºF	n/a	n/a
Patient areas, scheduled	70ºF	75ºF	60ºF	90ºF
VAV exterior, non-patient	70ºF	75ºF	60ºF	90ºF
VAV interior, non-patient	70ºF	73ºF	60ºF	90ºF
Electrical and mechanical	60ºF	85ºF	60ºF	85ºF
IDF/MDF	60ºF	78ºF	60ºF	78ºF

b. The software shall prevent

1) The heating setpoint from exceeding the cooling setpoint minus 1℉ (in other words the minimum deadband shal l be 1℉);

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.

c. Where the zone has a local occupant adjustable setpoint adjustment knob/button

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

        a) As a default, occupied cooling setpoint shall be limited between 72℉ and 80℉.

        b) As a default, occupied heating setpoint shall be limited between 65℉ and 72℉.

    2) The adjustment shall move both the existing heating and cooling setpoints upwards or downwards by the same amount unless the limit has been reached.

    3) The adjustment shall only be active in Occupied mode.

    4) If a demand limit setpoint adjustment is in place, the local setpoint adjustment shall be disabled.

d. Demand Limit Setpoint Adjustment: Cooling setpoints shall be increased upon demand limit requests from the associated Zone Group.

    1) At Demand Limit Level 1, increase current setpoint by 1℉.

    2) At Demand Limit Level 2, increase current setpoint by 2℉.

    3) At Demand Limit Level 3, increase current setpoint by 4℉.

e. The operative setpoint shall be determined by the Zone Group's mode

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

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

f. Hierarchy of Setpoint Adjustments: The following adjustment restrictions shall prevail in order from highest to lowest priority:

    1) Setpoint overlap restriction (Paragraph 1.1D.2.b.1))

    2) Demand limit.

    3) Local setpoint adjustment

    4) Scheduled setpoints based on Zone Group mode

3. Local override: When thermostat override buttons are depressed, the request for Occupied Mode operation shall be sent up to the Zone Group control for 60 minutes. (This will cause all zones in the Zone Group to operate in Occupied Mode to ensure that the system has adequate load to operate stably.)

4. Control Loops

    a. Two separate control loops shall operate to maintain space temperature at setpoint, the Cooling Loop and the Heating Loop. Both loops shall be continuously active.

    b. The Cooling Loop shall maintain the space temperature at the active cooling setpoint. The output of the loop shall be a virtual 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 virtual point ranging from 0% (no heating) to 100% (full heating).

    d. Loops shall be use proportional + integral logic or fuzzy logic. 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 from the Operator Workstation.

    e. See other sections for how the outputs from these loops are used.

5. Zone Modes

    a. Heating Mode: when the output of the space heating control loop is greater than zero.

    b. Cooling Mode: when the output of the space cooling control loop is greater than zero and the output of the heating loop is equal to zero.

    c. Deadband Mode: when not in either the Heating or Cooling Mode.

6. Alarms

    a. Zone temperature alarms

        1) If the zone is 3℉ above cooling or below heatin g setpoint for 10 minutes, generate Level 3 alarm.

        2) If the zone is 5℉ above cooling or below heatin g setpoint for 10 minutes, generate Level 2 alarm.

        3) Suppress zone temperature alarms as follows:

a) After zone setpoint is changed for a period of 10 minutes per degree of difference between the zone temperature at the time of the change and the new setpoint. This suppression period applies any time that the zone setpoint is changed.

b) While Zone Group is in Warm-up or Cool-down Modes.

c) For zones with an Importance multiplier (see Trim & Respond sequences above) of zero.

E. VAV Cooling-only boxes

1. See Paragraph 1.1D for setpoints, loops, control modes, alarms, etc.

   a. If supply air temperature from air handler is greater than room temperature, Cooling Mode shall be locked out.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

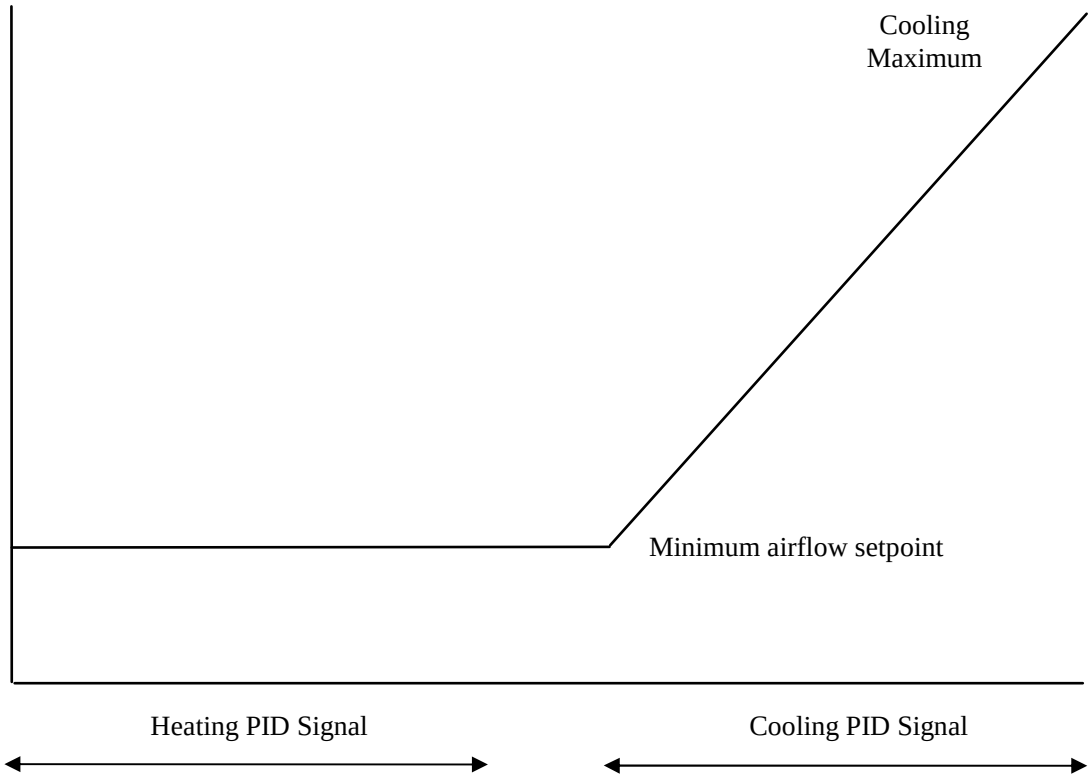
3. The occupied minimum Vmin* shall be equal to Vmin except as follows:

   a. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm determined in accordance with Paragraph 1.1A.12.

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 figure below and described in the following sections.



a. When the zone is in the Cooling Mode, the Cooling Loop output shall be mapped to the airflow setpoint from the cooling maximum to the minimum airflow setpoints.

b. When the zone is in the Deadband Mode or Heating Mode, the airflow setpoint shall be the minimum airflow setpoint.

c. The VAV damper shall be modulated to maintain the measured airflow at setpoint.

6. Alarms

a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) Suppress alarms for zones with an Importance Multiplier of 0.

b. Airflow sensor calibration. If the fan serving the zone has been shut off for 10 minutes and airflow sensor reading is above 20 cfm, generate a Level 3 alarm.

7. Testing/Commissioning Overrides: Provide software points 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)

8. System Requests

    a. This logic shall reside in the zone controllers if they are programmable and have sufficient memory. If not, move to the system controller, which will then poll zones for requests.

    b. Cooling SAT Reset Requests

        1) If the Cooling Loop is less than 85%, send 0 requests.

        2) If the Cooling Loop is greater than 95%, send 1 request.

        3) If the zone temperature exceeds the zone's cooling setpoint by 3℉ for 2 minutes, send 2 requests.

        4) If the zone temperature exceeds the zone's cooling setpoint by 5℉ for 2 minutes, send 3 requests.

    c. Static Pressure Reset Requests (for zones served by VAV AHUs only)

        1) If the Damper Loop is less than 85%, send 0 requests.

        2) If the Damper Loop is greater than 95%, send 1 request.

        3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 requests.

        4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 requests.

F. VAV Reheat boxes

1. See Paragraph 1.1D for setpoints, loops, control modes, alarms, etc.

    a. If supply air temperature from air handler is greater than room temperature, Cooling Mode shall be locked out.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

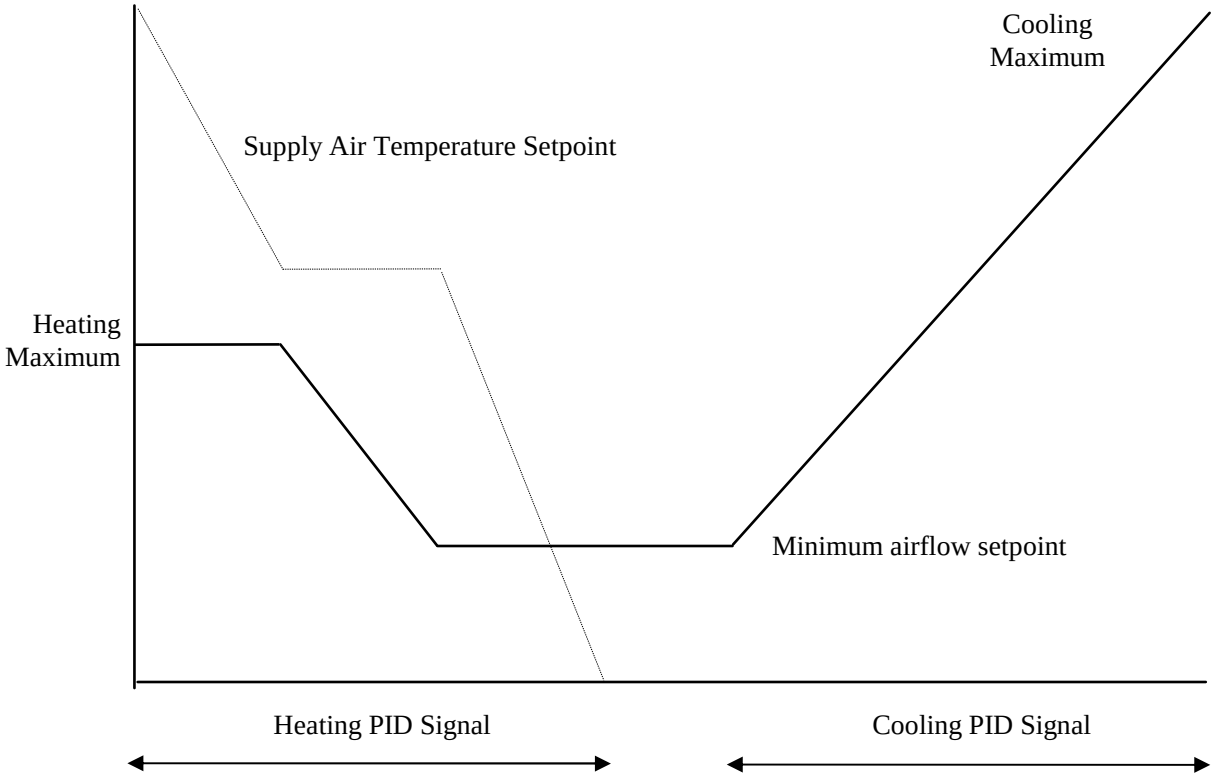
   c. Zone maximum heating airflow setpoint (Vheat-max)

3. The occupied minimum Vmin* shall be equal to Vmin except as follows:

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	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.



a. When the zone is in the Cooling Mode, the Cooling Loop output shall be mapped to the airflow setpoint from the cooling maximum to the minimum airflow setpoints.

b. When the zone is in the Deadband Mode, the airflow setpoint shall be the minimum airflow setpoint.

c. When the zone is in the Heating Mode, the Heating Loop shall be mapped as follows:

    1) From 0-33%, the Heating Loop output shall reset the discharge temperature from 50℉ to 95℉.

    2) From 33%-66%, if the supply air temperature is greater than the room temperature plus 5ºF, the Heating Loop output shall reset the zone airflow setpoint from the minimum airflow setpoint to the maximum heating airflow setpoint.

    3) From 66-100%, the Heating Loop output shall reset the discharge temperature from 95℉ to 115℉.

d. The hot water valve shall be modulated using P+I loop to maintain the discharge temperature at setpoint. (Directly controlling HW valve off zone temperature PID loop is not acceptable.)

e. The VAV damper shall be modulated to maintain the measured airflow at setpoint.

6. Alarms

    a. Low airflow

        1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

        2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

        3) Suppress alarms for zones with an Importance Multiplier of 0.

    b. Low supply air temperature

        1) If boiler plant is proven on and the supply air temperature is 15℉ less than setpoint for 10 minutes, generate a Level 3 alarm.

2) If boiler plant is proven on and the supply air temperature is 30℉ less than setpoint for 10 minutes, generate a Level 2 alarm.

c. Airflow sensor calibration. If the fan serving the zone has been shut off for 10 minutes and airflow sensor reading is above 20 cfm, generate a Level 3 alarm.

7. Testing/Commissioning Overrides: Provide software points 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)

8. System Requests

   a. This logic shall reside in the zone controllers if they are programmable and have sufficient memory. If not, move to the system controller, which will then poll zones for requests.

   b. Cooling SAT Reset Requests

      1) If the Cooling Loop is less than 85%, send 0 requests.

      2) If the Cooling Loop is greater than 95%, send 1 request.

      3) If the zone temperature exceeds the zone's cooling setpoint by 3℉ for 2 minutes, send 2 requests.

      4) If the zone temperature exceeds the zone's cooling setpoint by 5℉ for 2 minutes, send 3 requests.

   c. Static Pressure Reset Requests (for zones served by VAV AHUs only)

      1) If the Damper Loop is less than 85%, send 0 requests.

      2) If the Damper Loop is greater than 95%, send 1 request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 requests.

G. Kitchen Make-Up

1. When grease exhaust KEF-1 fan is proven on, EHAHU-3 shall run and kitchen shall be placed in Occupied mode, overriding any other logic.

2. Alarms

a. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

b. Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2

2) Commanded off, status on: Level 4

H. Chiller plant

1. Secondary Chilled water pumps:

a. Pumps shall be lead/lag alternated per Paragraph 1.1A.11.

b. Lead pump shall operate if there are any Chiller Plant Requests and OAT>LOT and shall stop when there are zero Requests. Lockout temperature (LOT) shall be 60ºF (adjustable).

c. When lead pump is commanded on, pump speed shall be controlled by a PID loop maintaining the differential pressure signal at setpoint (see CHW Plant Reset below). Each DP sensor shall have its own setpoint and control loop, and the pump speed shall be determined by the largest loop output. All pumps receive the same speed signal. See 1.1A.9 for minimum speed setpoint. Pump speed is zero when lead pump is commanded off.

d. When the lead pump speed exceeds 90% for 2 minutes, the lag pump shall start. The lag pump shall stop after it has run a minimum of 10 minutes and pump speed is below 40%.

2. Chillers shall be lead/lag alternated per Paragraph 1.1A.11 and as described below. If a chiller is in alarm, its CHW pump shall be disabled.

3. Chillers are staged in part based on calculated load. Load is calculated by delta-T and measured flow through the primary circuit flow meter, as shown in equation below. For 15 minutes after a stage up or stage down transition, do not recalculate load and instead keep calculated load constant at the value at the initiation of the transition. This allows steady-state to be achieved and ensures a minimum on- and off-time before changing stages.

$$Q = GPM_P(T_{CHWR} - T_{CHWS})/24$$

4. Staging shall be as follows. Timers shall reset to zero after every stage change. Each stage shall have a minimum runtime of 15 minutes (including Stage 0). Percent load values are percent of total plant design load (Q divided by total chiller design load as scheduled on Drawings). The chiller 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 chiller plant; the default schedule shall be 24/7 (adjustable).

Stage	**Chillers on**	**Nominal Capacity**	**Stage up to next stage if either:**		**Stage down to lower stage if:**
0	All off	0	–	Any Secondary Pump is proven on	–
1	CH-1 or CH-2	43%	for 15 minutes load greater than: 30% @ CWST ≤ 65℉ to 43% @ CWST ≥75℉	CHW Plant Reset = 100 for 15 minutes, and load greater than 25%	All Secondary Pumps are disabled
2	CH-1 and CH-2	87%	for 15 minutes load greater than: 60% @ CWST ≤ 65℉ to 87% @ CWST ≥75℉	CHW Plant Reset = 100 for 15 minutes, and load greater than 50%	for 15 minutes load less than: 25% @ CWST ≤ 65℉ to 40% @ CWST ≥75℉

Stage	Chillers on	Nominal Capacity	Stage up to next stage if either:		Stage down to lower stage if:
3	All Chillers	100%	–	–	for 15 minutes load less than: 50% @ CWST ≤ 65℉ to 80% @ CWST ≥75℉

5. Whenever there is a stage-up command:

    a. Command operating chillers to reduce demand to 50% of their current load. Wait until actual demand <55% up to a maximum of 5 minutes before proceeding.

    b. Start the next CW and CHW pump. After next CW pump has proven on, the next condenser isolation valve shall be opened.

    c. One minute after valve commanded open, enable the next stage chiller.

    d. Release the demand limit.

6. Whenever there is a stage-down command:

    a. Disable last stage chiller

    b. When the controller of the chiller being disabled indicates no request for chilled water flow or a minimum of 1 minute has passed, its condenser water isolation valve shall be closed and the last stage condenser water pump and chilled water pump shall be disabled.

7. Condenser water pumps:

    a. Condenser water pumps shall be lead/lag alternated per Paragraph 1.1A.11.

    b. See Paragraph 1.1H.5 and Paragraph 1.1H.6 for on/off staging sequence.

    c. When CWP-3 is enabled, its pump speed shall be set to 100%.

8. Primary chilled water pumps:

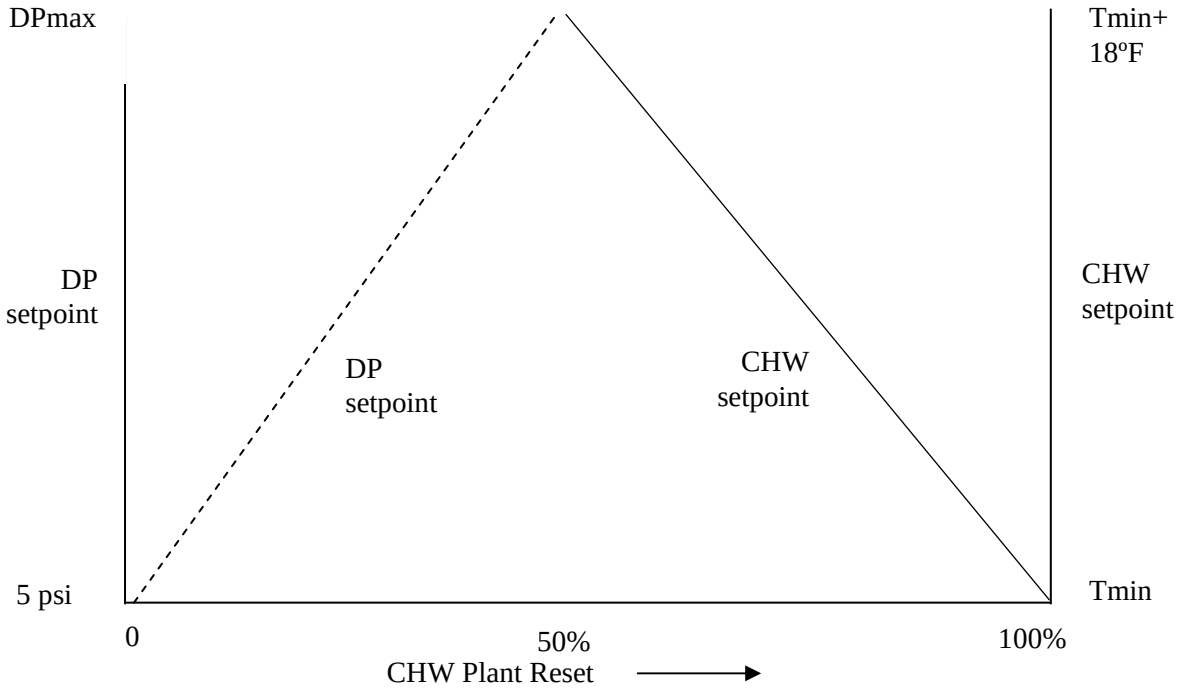
a. Primary chilled water pumps shall be lead/lag alternated with the associated dedicated chillers.

b. See Paragraph 1.1H.5 and Paragraph 1.1H.6 for on/off staging sequence.

9. CHW Plant Reset

a. Each secondary loop shall have its own CHW Plant Reset. The temperature setpoint commanded to the operating chillers shall be the lowest chilled water supply temperature setpoint among each reset.

b. Chilled water supply temperature setpoint and secondary pump differential static pressure setpoint shall be reset based on the figure below and the value CHW Plant Reset determined as described below. DPmax shall be determined in conjunction with balancer or existing DP setpoint. Tmin is the design chilled water temperature of 44℉.



1) CHW Plant Reset shall be reset using Trim & Respond logic (see Paragraph 1.1A.10) with the following parameters:

Variable	Value
Device	Any CHW Pump
SP_0	0%
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%

2) CHW Plant Reset logic shall be disabled and value fixed at its last value for 15 minutes after the plant stages up or down.

10. Cooling tower

a. Tower cells are lead/lag alternated per Paragraph 1.1A.11.

b. Tower staging is based on chiller stage:

Stage	Number of active Cells
1	2
2	3
3	3

c. Tower fan is enabled when its isolation valves are commanded opened and any CW pump is proven on. Fans are controlled off of CW return temperature (leaving chiller) rather than supply. Tower fan is enabled when any CW pump is proven on and CWRT rises above setpoint by 1°F. If CWRT drops be low setpoint and fans have been at low speed for 5 minutes, fans shall cycle off for at least 3 minutes and until CWRT rises above setpoint by 1°F.

d. Condenser water temperature control

1) Condenser water return temperature setpoint shall normally be

CWRTsp = CHWST + LIFTx

LIFTx= A * PLR + B

Where PLR is the plant part load ratio (actual chiller load divided by total plant design capacity), A =34.4 and B =8.6 but in no case shall LIFTx be less than the minimum lift at low load from the manufacturer (12°F) nor more than the design lift (43°F).

2) When chiller CH-3 is enabled, condenser water return temperature setpoint shall be 78℉ (adjustable) to avoid oil migration issues.

e. Temperature control

1) PID loop shall maintain CWRT at setpoint. PID loop output shall be mapped to fans as follows:

a) Low on lead tower: on at 17%, off at 0%

b) Low on lag tower: on at 33%, off at 17%

c) Low on next lag tower: on at 50%, off at 33%

d) High on lead tower: at 67%, off at 50%

e) High on lag tower: at 83%, off at 67%

f) High on next lag tower: 100%, off at 83%

11. Performance Monitoring

a. Total plant power. Calculate total plant power as the sum of chiller power, pump power, and cooling tower fan power. For motors with VFDs, power shall be actual power as indicated by the VFD. For fixed speed motors (e.g. CW pumps), power shall be assumed to be fixed at BHP (from equipment schedule) * 0.746 / 0.93 (approximate motor efficiency).

b. Summary Data. For each chiller and total plant, statistics shall be retained and displayed on graphic for runtime, average actual efficiency (kW/ton), and average demand (tons) and load (ton-hours). Show on chiller plant graphic: instantaneous values, year-to-date totals/averages and previous-year totals/averages.

12. Alarms

a. Maintenance interval alarm when pump has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

b. Maintenance interval alarm when chiller has operated for more than 1000 hours: Level 5. Reset interval counter when alarm is acknowledged.

c. Chiller alarm: Level 2

d. Emergency off switch: Level 1

e. Tower level

1) If tower water level sensor indicates low water level, generate a Level 2 alarm.

2) If tower water level sensor indicates high water level, generate a Level 3 alarm.

f. High chiller leaving chilled water temperature (more than 5℉ above setpoint) for more than 15 minutes when chiller has been enabled for longer than 15 minutes: Level 3

g. Pump or tower fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2

2) Commanded off, status on: Level 4

h. Tower valve alarm is indicated by the status input being different from the output command after a period of 90 seconds after a change in output status.

1) Commanded open, status closed: Level 2

2) Status neither open or closed: Level 2

3) Commanded closed, status open: Level 4

i. Emergency power off switch: Level 1

j. Refrigerant detector indicates evacuate level alarm: Level 1

k. Refrigerant detector malfunction or warning level alarm: Level 2

l. Refrigerant caution level alarm: Level 3

m. Excessive CW approach indicating water side fouling: If leaving condenser water temperature is more than 3℉ below refrigerant condensing temperature for 15 minutes at least 15 minutes after chiller start.

n. Excessive CHW approach indicating water side fouling: If leaving chilled water temperature is more than 3℉ above refrigerant evaporator temperature for 15 minutes at least 15 minutes after chiller start.

I. Boiler Plant

1. Boilers

a. Boilers shall be lead/lag alternated per Paragraph 1.1A.11.

b. Lead boiler

1) The lead system shall be continuously enabled

c. Lag boiler

1) The next lag system shall be enabled if:

a) The lead boiler is enabled and the HWST remains 10℉ below setpoint (see reset strategy below) for 15 minutes.

2) The next lag system shall be disabled if:

a) The lead system is disabled or

b) The lag system has run at least 10 minutes and the 10 minute rolling average HW load in Btuh (500 * HW GPM * HW ΔT) is less than 90% of the nominal capacity of the lead boiler in Btuh

2. Pumps

a. Primary pumps

1) Primary pumps shall be lead/lag alternated per Paragraph 1.1A.11. Third pump is currently standby.

2) When the lead system is enabled, first start the lead primary pump, then after 30 seconds, enable the lead boiler. When the lead system is disabled, first disable the boiler, then after 3 minutes turn off the lead pump. Use similar logic for the lag system.

b. Secondary pumps

1) Pumps shall be lead/lag alternated per Paragraph 1.1A.11.

2) Lead secondary pump shall start if associated Zone Groups are in any mode other than Unoccupied Mode, and shall otherwise be disabled.

3) When the lead pump is above 90% speed for 3 minutes, stage on the lag pump. When both pumps are below 40% speed for 5 minutes, stage off the lag pump.

c. When any pump is proven on, pump speed will be controlled by a PID loop maintaining the differential pressure signal at a setpoint determined in conjunction with the balancer, or the existing DP

setpoint. All parallel pumps receive the same speed signal. See 1.1A.9 for minimum speed setpoint.

3. Supply Temperature Control

    a. Leaving water temperature setpoint shall be set internally at boilers and also from BMS graphics.

    b. Hot Water Supply Temperature Reset

        1) Each tertiary loop shall have its own setpoint as described below

            a) Loops that serve DHW generators: Setpoint shall be fixed at 180℉ (adjustable)

            b) Otherwise: Hot water supply temperature setpoint shall be reset from 180℉ at outside air temperatures of 50° F or below to 120℉ at outside air temperatures of 80℉ or above (all adjustable).

    c. The tertiary hot water supply temperature shall be maintained at setpoint by modulating the 3-way bypass valve. Bypass valve shall be set to normal position when tertiary loop pumps are disabled.

4. Alarms

    a. Maintenance interval alarm when pump has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

    b. Maintenance interval alarm when boiler has operated for more than 2000 hours: Level 5. Reset interval counter when alarm is acknowledged.

    c. Boiler alarm: Level 2

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

    e. Low secondary loop supply temperature (more than 15℉ below setpoint) for more than 15 minutes when boiler has been enabled for longer than 15 minutes: Level 3

    f. Pump alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2

2) Commanded off, status on: Level 4

J. Steam Plant

1. Steam boilers shall be lead/lag alternated per Paragraph 1.1A.11.

2. Lead process steam boiler shall be continuously enabled.

3. Lead kitchen steam boiler shall be enabled based on schedule.

4. Lag boilers shall be staged to maintain system pressure. Specific staging sequence shall match existing logic.

5. Pressure setpoints

   a. Process steam: 80 psi (adj via BMS)

   b. Kitchen steam: 90 psi (adj via BMS)

6. Kitchen condensate return

   a. Condensate return valve shall be controlled to maintain the steam conductivity at a setpoint of TBD.

7. Alarms

   a. Maintenance interval alarm when boiler has operated for more than 2000 hours: Level 5. Reset interval counter when alarm is acknowledged.

   b. Boiler alarm: Level 2

   c. Boiler low water cutoff: Level 2

   d. Boiler relief valve open: Level 2

   e. Automatic feedwater system alarm: Level 2

   f. Automatic blowdown system alarm: Level 2

   g. Low steam pressure (match existing): Level 3

   h. High steam pressure (match existing): Level 3

K. Fixed Speed 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 5 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 after a period of 15 seconds after a change in output status.

        1) Commanded on, status off: Level 2

        2) Commanded off, status on: Level 4

L. 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. Fire alarm (via contact from Division 26 fire alarm system): Level 1

3. Fire alarm trouble (via contact from Division 26 fire alarm system): Level 2

4. Equipment alarm (for equipment with alarm contacts such as VFDs, AC units): Level 2

5. Failure or disconnection of a sensor as indicated by signal widely out of range: Level 2.

6. Panel or LAN failure: Level 2

7. 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).

1.2 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.

16. Assist in Title 24 Acceptance Testing.

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 Authority and Owner's Representatives and submit Demonstration Test Report.

20. Receive acceptance of Demonstration Tests.

21. Train Owner 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.

26. Provide administration level password access to the Owner.

27. Final Acceptance

28. Begin Warranty Period.

29. Prepare and initiate post-occupancy Trend Logs.

30. Receive amended BAS Functional Test Report approval.

31. Update all software as specified.

32. 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. Owner'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 Owner'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. 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 that is 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).

3) Drywell Bath: Field calibrate using a 2-point procedure, using a drywell calibrator block constructed for that purpose, or an ice bath with a reference standard.

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 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 Paragraph 1.1A.9.

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 printing, logging, paging, emailing etc. are functional and per requirements.

c. The test shall be performed after the verification trends (see Paragraph 1.2G.1) have been set up and are operational.

d. Test 1

1) Randomly select a device whose failure will generate a Level 1 or 2 alarm and manually shut it off. The status points for the device must indicate the change of state of the device at the Operator Workstation within 5 seconds.

2) The test shall be repeated for four devices in each building.

e. Test 2

1) A clock signal from a field controller randomly selected will be sent as a programmable point to up to 3 BCs. The clock signal stored in BCs shall be sampled with the rest of the trend data. The system shall be considered acceptable if these clock signals are no more than 2 seconds off of the system clock as sampled concurrently during data collection.

f. If the system fails any test, the system architecture shall be revised as required (install more trend memory, more controllers with trend storage capability, network repeaters to allow an increase in network speed, etc.) followed by additional tests.

D. Testing, Adjusting, and Balancing (TAB) Coordination

1. Coordinate with Work performed by TAB contractor. 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 by TAB contractor.

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 by TAB contractor.

c. Provide sufficient training to those performing TAB Work 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 1.2B.1 before assisting in setpoint determination.

b. Coordinate with Work performed by TAB contractor to determine fan and pump differential pressure setpoints, outdoor air damper minimum positions and DP setpoints, etc.

E. Functional Tests

1. Test schedule shall be coordinated with the Commissioning Authority and Owner’s Representative.

2. Functional tests may be witnessed by Owner’s Representative at the Owner’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 Owner for review and approval.

F. Demonstration Test

1. Demonstration tests consist of a small representative sample of functional tests and systems randomly selected by the Commissioning Authority. Tests will be designed to occur over no longer than 4 working days.

2. Schedule the demonstration with the Commissioning Authority and Owner'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 Authority will supply the test forms at the site at the start of the tests.

5. Demonstration tests may be witnessed by Owner's Representative at the Owner's option.

6. Contractor shall conduct tests as directed by and in the presence of the Commissioning Authority and complete test forms. Completed forms shall be submitted as the Demonstration Test Report to the Commissioning Authority after tests are complete.

7. Demonstration Tests shall be successfully completed and approved prior to Substantial Completion.

G. Trend Log Tests

1. Trends shall be fully configured to record and store data to the server for the points and at the interval listed in points lists on Drawings 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 Owner'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 points lists on Drawings.

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 Authority 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.

f. Trend logs of all points indicated above shall be collected for a 4 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 Owner in an electronic format agreed to by the Owner and Contractor (such as CD-ROM or via direct access to the CSS via the internet).

h. Data will be analyzed by the Commissioning Authority.

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 the points list on the Drawings.

H. Remedial Work

1. Repair or replace defective Work, as directed by Owner's Representative in writing, at no additional cost to the Owner.

2. Restore or replace damaged Work due to tests as directed by Owner's Representative in writing, at no additional cost to the Owner.

3. Restore or replace damaged Work of others, due to tests, as directed by Owner's Representative in writing, at no additional cost to the Owner.

4. Remedial Work identified by site reviews, review of submittals, demonstration test, trend reviews, etc. shall be performed to the satisfaction of the Owner's Representative, at no additional cost to the Owner.

5. Contractor shall compensate Owner's Representatives and Commissioning Authority 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 Owner.

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