1. Fan coils

I. Section 15840 - Air terminal units

1. CAV/CEV/VAV/VEV boxes

J. Section 16435 – Paralleling Switchgear system

K. Section 15269 - Variable frequency motor controllers

1. Variable frequency drives

1.4 RELATED SECTIONS

A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.

B. The following sections constitute related work:

1. Section 01600 - Submittal Requirements
2. Section 01810 - Commissioning
3. Section 13700 - Security Access and Surveillance
4. Section 13850 - Detection and Alarm (Fire and Smoke Alarm Systems)
5. Section 15050 - Basic Mechanical Materials and Methods
6. Section 15500 - Heat-Generation Equipment (Boilers and draft controls)
7. Section 15700 - Heating, Ventilating, and Air-Conditioning Equipment (Fan Coils, Air handling units, humidifiers, etc.)
8. Section 15840 - Air Terminal Units
9. Section 15950 - Testing, Adjusting, and Balancing
10. Section 16050 - Basic Electrical Materials and Methods
11. Section 16100 - Wiring Methods
12. Section 15269- Variable frequency motor controllers
13. Section 16400 - Low-Voltage Distribution

1.5 DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

B. System software shall be based on a server/thin client architecture, designed around the open standards of internet technology. The control system server shall be accessed using a Web browser over a control system network independent of the Owner's IT infrastructure, with connectivity to the intranet via the Owner's protected firewall system. The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.

C. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends and alarms specified in 15900 Appendix A (Sequences of Operation) shall be BACnet objects.

1.6 APPROVED CONTROL SYSTEM MANUFACTURERS

A. The following are approved control system suppliers, manufacturers, and product lines:

Supplier	Manufacturer	Product Line
Sunbelt Controls	Automated Logic Corporation	WebCTRL
Siemens	Siemens	Apogee
JCI	Johnson Controls	Metasys
Climatec	Alerton	BacTalk
Advanced Automated Systems	Andover	Continuum

The above list does not indicate order of preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification and project contract documents (inlcuding drawings) as applicable.

1. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
2. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.7 ALTERNATE BID

A. Bidders shall include separate pricing to integrate the new hospital building controls with the existing Johnson Controls system (instead of an independent stand-alone controls system for the new hospital building).

1.8 QUALITY ASSURANCE

A. Installer and Manufacturer Qualifications

1. Installer shall have an established working relationship with Control System Manufacturer.
2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
3. Installer shall maintain an office within 100 miles of the project location which has inventory of product controllers, sensors, transmitters, and other applicable components for service, maintenance, and repair.
4. Provide resumes of the primary project contact, lead programmer(s), including certificates of training from the manufacturer of the product represented.

1.9 CODES AND STANDARDS

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with the current editions in effect 30 days prior to the receipt of bids of the following codes:

1. ANSI/ASHRAE 135-2004: Data Communication Protocol for Building Automation and Control Systems (BACNET)
2. ANSI/ASHRAE Standard 135, BACnet - A Data Communication Protocol for Building Automation and Control Systems

1.10 SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

1. Graphic Display. A graphic with 20 dynamic physical points from a minimum of 5 different controllers shall display with current data within 10 sec.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec.and shall automatically refresh every 15 sec.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 45 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 1 second. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 sec of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
10. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table-1
Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5°C (±1°F)
Ducted Air	±0.5°C (±1°F)
Outside Air	±1.0°C (±2°F)
Dew Point	±1.5°C (±3°F)

Water Temperature	±0.5°C (±1°F)
Delta-T	±0.15° (±0.25°F)
Relative Humidity	±3% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO2)	±50 ppm

Note 1: Accuracy applies to 10%–100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

Table 2
Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0–1.5 kPa (0–6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±0.5°C (±1.0°F)	
Duct Temperature	±1°C (±2°F)	
Humidity	±5% RH	
Fluid Pressure	±7 kPa (±1 psi) ±120 Pa (±0.5 in. w.g.)	MPa (1–150 psi) 0–12.5 kPa (0–50 in. w.g.) differential

1.11 SUBMITTALS

A. Product Data and Shop Drawings: Meet requirements of Section 01600 on Shop Drawings, Product Data, and Samples. In addition, the contractor shall provide shop drawings and other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2006 (or newer) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and three 11" x 17" prints of each drawing. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility

to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:

1. DDC System Hardware

    a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used including operating span and operating point
    b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

        i. Direct digital controllers (controller panels)
        ii. Transducers and transmitters
        iii. Sensors (including accuracy data)
        iv. Actuators
        v. Valves
        vi. Relays and switches
        vii. Control panels
        viii. Power supplies
        ix. Batteries
        x. Operator interface equipment
        xi. Wiring

    c. Wiring diagrams and layouts for each control panel. Show termination numbers.
    d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.

2. Central System Hardware and Software

    a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.
    b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:

        1.1 Central Processing Unit (CPU) or web server
        1.2 Monitors
        1.3 Keyboards
        1.4 Power supplies
        1.5 Battery backups
        1.6 Interface equipment between CPU or server and control panels
        1.7 Operating System software
        1.8 Operator interface software
        1.9 Color graphic software
        1.10 Third-party software

    c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with

computer manufacturers' model numbers and functions. Show interface wiring to control system.

d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems

   a. Riser diagrams showing control network layout, communication protocol, and wire types.
   b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system. Schematic diagram shall be representative of the system being controlled/monitored.
   c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
   d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
   e. A mounting, wiring, and routing plan-view drawing. The design shall take into account HVAC, electrical, and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.
   f. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
   g. A point list for each control system. List I/O points and software points specified in Section 15900 Appendix A. Indicate alarmed and trended points.

4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.
5. Description of process, report formats, and checklists to be used in Section 15900 Article 3.16 (Control System Demonstration and Acceptance).
6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules

1. Within one month of contract award, provide a schedule of the work indicating the following:

   a. Intended sequence of work items
   b. Start date of each work item
   c. Duration of each work item
   d. Planned delivery dates for ordered material and equipment and expected lead times
   e. Milestones indicating possible restraints on work by other trades or situations

2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

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

1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2006 (or newer) compatible files on magnetic or optical media (file format: .DWG, .DXF, .VSD, or comparable) and as 11" x 17" prints.
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 15900 Article 3.16 (Control System Demonstration and Acceptance).
3. Operation and Maintenance (O&M) Manual.
4. As-built versions of submittal product data.
5. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
6. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
7. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
8. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
9. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
10. Graphic files, programs, and database on magnetic or optical media.
11. List of recommended spare parts with part numbers and suppliers.
12. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
13. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
14. Licenses, guarantees, and warranty documents for equipment and systems.
15. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

D. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Engineer will modify course outlines and materials if necessary to meet Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

1.11 WARRANTY

A. Warrant work as follows:

1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
3. If the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.12 OWNERSHIP OF PROPRIETARY MATERIAL

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

1. Graphics
2. Record drawings
3. Database
4. Application programming code
5. Documentation

1.13 DEFINITIONS

Term	Definition
BACnet Interoperability Building Blocks (BIBB)	A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database.
Controller	Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.

Direct Digital Control	Microprocessor-based control including Analog/Digital conversion and program logic.
Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token Passing	Data link protocol as defined by the BACnet standard.
Point-to-Point	Serial communication as defined in the BACnet standard.
Primary Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.
Protocol Implementation Conformance Statement	A written document that identifies the particular options specified by BACnet that are implemented in a device.
Router	A device that connects two or more networks at the network layer.
Wiring	Raceway, fittings, wire, boxes and related items.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2004 Annex J, BACnet.

B. Install new wiring and network devices as required to provide a complete and workable control network which is independent of the Owner's IT infrastructure with the single exception of a single connection to the Owner's IT infrastructure for VPN remote access

C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.

2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Division 23 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

E. Workstations, Building Control Panels, and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.

F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

G. Controllers shall have at least 50% spare input and output capacity.

2.3 OPERATOR INTERFACE

A. The Operator Workstation or server shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L.

B. Operator Interface. Web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.

C. Communication. Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J.

D. Hardware. Each workstation or web server shall consist of the following:

1. Computer. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The following hardware requirements also apply:

a. The hard disk shall have sufficient memory to store:

i. All required operator workstation software.
ii. A DDC database at least twice the size of the delivered system database.
iii. One year of trend data based on the points specified to be trended at their specified trend intervals.

b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
c. Minimum hardware configuration shall include the following:

i. Dual or Quad Core Processor
ii. 6 GB RAM

iii. 500 GB hard disk providing data at 3.0 Gb/sec
iv. 16x DVD-RW drive
v. Serial, parallel, and network communication ports and cables as required for proper DDC system operation

E. System Software.

1. Operating System. Web server or workstation shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the DDC System manufacturers minimum requirements for their software. Typically acceptable systems include Microsoft Windows7,Microsoft Vista, Microsoft Windows XP Pro, Windows Server 2003 or 2008, Red Hat Enterprise Linux, or Ubuntu Desktop 10.04.

2. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

   a. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.
   b. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
   c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
   d. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Adobe Flash).

3. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics that are saved in the same formats as are used for system graphics.

4. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

F. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

1. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
2. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password protection. Operators shall be able to configure the system.
4. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.
5. Security. Each operator shall be required to log on to the system with user name and password in order to view, edit, add, or delete data.

    a. Operator Access. The user name and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System Administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.
    b. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time shall be user adjustable.
    c. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

6. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.
7. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Division 23 Appendix A (Sequences of Operation). Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
8. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms.
9. Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
10. Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms, and archive closed alarms to the workstation or web server hard disk.
11. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to

retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified in Division 23 Appendix A (Sequences of Operation). Trends shall be BACnet trend objects.

12. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.
13. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
14. Standard Reports. Furnish the following standard system reports:

    a. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
    b. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    c. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

        i. Alarm History.
        ii. Trend Data. Operator shall be able to select trends to be logged.
        iii. Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

G. Workstation Application Editors. Each PC or browser workstation shall support editing of all system applications. The applications shall be downloaded and executed at one or more of the controller panels.

1. Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and set points for all controllers.
2. Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and schedule type. Exception schedules and holidays shall be shown clearly on the calendar. The start and stop times for each object shall be adjustable from this interface.
3. Custom Application Programming. Provide the tools to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

    a. Language. Language shall be graphically based or English language oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall allow for free-form programming that is not column-oriented or "fill-in-the-blanks."
    b. A full-screen character editor programming environment shall be provided. The editor shall be cursor/mouse-driven and allow the user to insert, add, modify, and delete

custom programming code. It also shall incorporate features such as cut/ paste and find.

c. The programming language shall allow independently executing program modules to be developed. Each module shall be able to independently enable and disable other modules.
d. The editor/programming environment shall have a debugging/simulation capability that allows the user to step through the program and observe any intermediate values and/or results.
e. The programming language shall support conditional statements (IF/THEN/ELSE/ ELSE-IF) using compound Boolean (AND, OR, and NOT) and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
f. The programming language shall support floating-point arithmetic using the following operators: +, , ÷, ×, and square root. The following mathematical functions also shall be provided: absolute value and minimum/maximum value.
g. The programming language shall have predefined variables that represent time of day, day of the week, month of the year, and the date. Other predefined variables shall provide elapsed time in seconds, minutes, hours, and days. These elapsed time variables shall be able to be reset by the language so that interval-timing functions can be stopped and started within a program. Values from all of the above variables shall be readable by the language so that they can be used in a program for such purposes as IF/ THEN comparisons, calculations, etc.
h. The language shall be able to read the values of the variables and use them in programming statement logic, comparisons, and calculations.
i. The programming language shall have predefined variables representing the status and results of the system software and shall be able to enable, disable, and change the setpoints of the system software described below.

H. Portable Operator's Terminal. Provide all necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting. Connectivity shall be at all zone terminal unit thermostats without the need to access the controller above the ceiling.

2.4 CONTROLLER SOFTWARE

A. Furnish the following applications for building and energy management. All software application shall reside and operate in the system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security. See Paragraph 2.3.E.5 (Security) and Paragraph 2.3.E.14.c.iii (Operator Activity).

C. Scheduling. Provide the capability to execute control functions according to a user created or edited schedule. Each schedule shall provide the following schedule options as a minimum:

1. Weekly Schedule. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
2. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance.

Once an exception schedule has executed, the system shall discard and replace the exception schedule with the standard schedule for that day of the week.

3. Holiday Schedules. Provide the capability for the operator to define up to 24 special or holiday schedules. These schedules will be repeated each year. The operator shall be able to define the length of each holiday period.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. Binary Alarms. Each binary object shall have the capability to be configured to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.

F. Analog Alarms. Each analog object shall have both high and low alarm limits. The operator shall be able to enable or disable these alarms.

G. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display on graphics.

H. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.

I. Maintenance Management. The system shall be capable of generating maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Division 23 Appendix A (Sequences of Operation).

J. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Section 15900 Appendix A (Sequences of Operation).

K. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs. The calculation interval, PID gains, and other tuning parameters shall be adjustable by a user with the correct security level.

L. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

M. Energy Calculations.

1. The system shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
2. The system shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

N. Anti-Short Cycling. All binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

O. On and Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and a setpoint. The algorithm shall be direct-acting or reverse-acting.

P. Runtime Totalization. Provide software to totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Division 23 Appendix A (Sequence of Operations).

2.5 CONTROLLERS

A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Division 23 Article 1.9 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

B. BACnet.

1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L, and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing. Contractor is repsonsible for sequence of operation compatibility when using B-ASC controllers.
4. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
5. BACnet Communication.

    a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
    b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
    c. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    d. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

e. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

C. Communication

1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports..
2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
4. Stand-Alone Operation. Each piece of equipment specified in Division 23 Appendix A shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

D. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

E. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.

F. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

G. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

H. Memory.

1. Controller memory shall support operating system, database, and programming requirements.

2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

I. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

J. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.6 INPUT AND OUTPUT INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

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

C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.

E. Analog Inputs. Analog inputs shall monitor low-voltage (0–10 Vdc), current (4–20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices. Note: 0-10 Vdc inputs shall utilize the full 10 Vdc span and not electronically scale to 0-5 Vdc over the space of the A/D converter.

F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0–10 Vdc or a 4–20 mA signal as required to properly control output devices. Analog outputs shall not drift more than 0.4% of range annually.

G. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

H. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated

devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system

2.7 POWER SUPPLIES AND LINE FILTERING

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

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

a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.

1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

a. Dielectric strength of 1000 V minimum
b. Response time of 10 nanoseconds or less
c. Transverse mode noise attenuation of 65 dB or greater
d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

2.8 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers, unless otherwise specified elsewhere, shall be as follows.

1. Type. Control dampers shall be the parallel or opposed-blade type as specified below or as scheduled on drawings.

a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
b. Other modulating dampers shall be opposed-blade.
c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.

2. Frame. Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (⅛ in.) extruded aluminum with reinforced corner bracing.
3. Blades. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).

4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 50 L/s·m^2(10 cfm per ft^2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).
6. Sections. Individual damper sections shall not exceed 125 cm × 150 cm (48 in. × 60 in.). Each section shall have at least one damper actuator.
7. Modulating dampers shall provide a linear flow characteristic where possible.
8. Linkages. Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators.

1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range. Proportional actuators shall accept a 0–10 Vdc or a 0–20 mA control signal and shall have a 2–10 Vdc or 4–20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)
4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.

C. Control Valves.

1. Control valves shall be two-way or three-way type for two-position or modulating service as shown. Note: Water control valves for air handling units and fan coils shall be provided by the mechanical contractor (Similar to Griswold Pressure independent control valves PIC-V or MVP valves) for connection by the controls contractor. Actuators will not be provided by the mechanical contractor and must be coordinated, supplied and installed by the controls contractor in the field or by the valve factory. Pressure Independent control valves are specified in Division 23 "Hydronic Piping Specialties"

2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:

   a. Water Valves:

      i. Two-way: 150% of total system (pump) head.
      ii. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

   b. Steam Valves: 150% of operating (inlet) pressure.

3. Water Valves.

a. Body and trim style and materials shall be in accordance with manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.
b. Sizing Criteria:

i. Two-position service: Line size.
ii. Two-way modulating service: Pressure drop shall be equal to twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi, whichever is greater.
iii. Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 35 kPa (5 psi) maximum.
iv. Valves ½ in. through 2 in. shall be bronze body or cast brass ANSI Class 250, spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or stainless steel ball.
v. Valves 2½ in. and larger shall be cast iron ANSI Class 125 with guided plug and PTFE packing.

c. Water valves shall fail normally open or closed, as scheduled on plans, or as follows:

i. Heating zone valves (terminal units and fan coils)—normally closed
ii. Heating coils in air handlers—normally closed.
iii. Chilled water control valves—normally open.
iv. Other applications—as scheduled or as required by sequences of operation.

4. Steam Valves.

a. Body and trim materials shall be in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service.
b. Sizing Criteria:

i. Two-position service: pressure drop 10% to 20% of inlet psig.
ii. Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig.
iii. Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig.
iv. Modulating service: over 350 kPa (50 psig); pressure drop as scheduled on plans.
v. Spring return to fail in the closed position.

D. Binary Temperature Devices.

1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C–30°C (55°F–85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C–30°C (55°F–85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

E. Temperature Sensors.

1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2(10 ft^2) of duct cross-section.
3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities. Install with conductive thermal compound where applicable.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown. Provide insulation backing on all wall mounted space temperature sensors to eliminate any effect of sensor readings from in-wall conditions.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.

F. Humidity Sensors.

1. Duct and room sensors shall have a sensing range of 10% to 95%.
2. Duct sensors shall have a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 0-100% RH and shall be suitable for ambient conditions of -40°C–75°C (-40°F–170°F).
4. Humidity sensors shall not drift more than 1% of full scale annually.

G. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).

1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

H. Relays.

1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

I. Override Timers.

1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0–6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

J. Current Transmitters.

1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4–20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.
4. Provide all necessary shorting blocks where applicable to ensure safe operation.

K. Current Transformers.

1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.
4. Provide all necessary shorting blocks where applicable to ensure safe operation.

L. Voltage Transmitters.

1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4–20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100–130 Vac, 200–250 Vac, 250–330 Vac, and 400–600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

M. Voltage Transformers.

1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C–55°C (40°F–130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

N. Power Monitors.

1. Selectable rate pulse output for kWh reading, 4–20 mA output for kW reading, N.O. alarm contact, and ability to operate with 5.0 amp current inputs or 0–0.33 volt inputs.
2. 1.0% full-scale true RMS power accuracy, +0.5 Hz, voltage input range 120–600 V, and auto range select.

3. Under voltage/phase monitor circuitry.
4. NEMA 1 enclosure.
5. Current transformers having a 0.5% FS accuracy, 600 VAC isolation voltage with 0–0.33 V output. If 0–5 A current transformers are provided, a three-phase disconnect/shorting switch assembly is required.

O. Hydronic Flowmeters

1. Magnetic Flow-Tube Type Flowmeter

a. Sensor shall be a magnetic flowmeter, which utilizes Faraday's Law to measure volumetric fluid flow through a pipe. The flowmeter shall consist of two elements, the sensor and the electronics. The sensor shall generate a measuring signal proportional to the flow velocity in the pipe. The electronics shall convert this EMF into a standard current output. *Note: Magnetic flowmeters shall be furnished and installed by the mechanical contractor, under the supervision of the controls contractor. Final connection of controls and start-up by the controls contractor. Magnetic flowmeters are specified under Division 23 "Meters and Gauges".*

P. Thermal Energy Meters
1. Matched RTD, solid state, or thermistor temperature sensors with a differential temperature accuracy of ±0.15°F.
2. Flow meter : See "Hydronic Flowmeters" section.
3. Unit accuracy of ±1% factory calibrated, traceable to NIST with certification.
4. NEMA 1 enclosure.
5. Panel mounted display.
6. UL listed.
7. Isolated 4–20 ma signals for energy rate and supply and return temperatures and flow.

Q. Current Switches.

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

R. Pressure Transducers.

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4–20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.)Transducer shall have 4–20 mA output, suitable mounting provisions, and 5-valve manifold.

S. Differential Pressure Switches. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

T. Pressure-Electric (PE) Switches.

1. Shall be metal or neoprene diaphragm actuated, operating pressure rated for 0–175 kPa (0–25 psig), with calibrated scale minimum setpoint range of 14–125 kPa (2–18 psig) minimum, UL listed.
2. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application Electrically rated for pilot duty service (125 VA minimum) and/or for motor control.
3. Switches shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
4. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

U. Occupancy Sensors. Occupancy sensors shall utilize Passive Infrared (PIR) and/or Microphonic Passive technology to detect the presence of people within a room. Sensors shall be mounted as indicated on the approved drawings. The sensor output shall be accessible by any lighting and/or HVAC controller in the system. Occupancy sensors shall be capable of being powered from the lighting or HVAC control panel, as shown on the drawings. Occupancy sensor delay shall be software adjustable through the user interface and shall not require manual adjustment at the sensor.

V. Local Control Panels.

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
2. Interconnections between internal and face-mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600 volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.

2.9 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 16.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

2.10 FIBER OPTIC CABLE SYSTEM

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

PART 3 - EXECUTION

3.1 EXAMINATION

A. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.

B. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

3.2 PROTECTION

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

A. Site

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

B. Submittals. See Division 23 Article 1.10 (Submittals).

C. Test and Balance.

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

2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

D. Life Safety.

1. Duct smoke detectors required for air handler shutdown are provided under Division 16. Interlock smoke detectors to air handlers for shutdown as specified in Division 23 Appendix A (Sequences of Operation).
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 15. Interlock smoke dampers to air handlers as specified in Division 23 Appendix A (Sequences of Operation).
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 15. Fire and smoke damper control is provided under Division 16.

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

1. All communication media and equipment shall be provided as specified in Division 23 Article 2.2 (Communication).
2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Division 23 Appendix A.
3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4 GENERAL WORKMANSHIP

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

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

C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Division 23 Article 1.8 (Codes and Standards).

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

3.6 WIRING

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 16 of this specification, Where the requirements of this section differ from Division 16, the requirements of this section shall take precedence.

B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 16 requirements.

C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.

E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway at levels below 3 m (10ft).

F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

G. Do not install wiring in raceway containing tubing.

H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.

I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.

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

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

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

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

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

O. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.

P. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

Q. Use color-coded conductors throughout with conductors of different colors.

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

S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).

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

U. Adhere to this specification's Division 16 requirements where raceway crosses building expansion joints.

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

W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

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

3.7 COMMUNICATION WIRING

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.

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

C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.

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

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

F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer's instructions.

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

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

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

J. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

K. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

1. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
3. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
4. An MS/TP EIA-485 network shall have no T connections.

3.8 FIBER OPTIC CABLE

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

B. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

3.9 INSTALLATION OF SENSORS

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

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

C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.

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

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

F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2(1 ft^2) of coil area.

G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.

H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.

J. Differential Air Static Pressure.

1. Supply Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the height-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
3. Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.

6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.

K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

L. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch according to manufacturer's instructions.

3.11 ACTUATORS

A. General. Mount and link control damper actuators according to manufacturer's instructions.

1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
3. Provide all mounting hardware and linkages for actuator installation.

B. Electric/Electronic

1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall be mounted following manufacturer's recommendations.
2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

C. Pneumatic Actuators.

1. Size pneumatic damper actuator to operate the related control damper(s) with sufficient reserve power to provide smooth modulating action or two-position action. Actuator also shall be sized for proper speed of response at the velocity and pressure conditions to which the control damper is subject.
2. Pneumatic damper actuators shall produce sufficient torque to close off against the maximum system pressures encountered. Size the pneumatic damper actuator to close off against the fan shutoff pressure, as a minimum.
3. Where two or more pneumatic damper actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive pilot

positioner. The positive pilot positioner shall be directly mounted to the pneumatic damper actuator and have pressure gauges for supply input and output pressures.

4. The total damper area operated by an actuator shall not exceed 80% of the manufacturer's maximum area rating. Provide at least one actuator for each damper section. Each damper actuator shall not power more than 2 m^2(20 ft^2) of damper.
5. Use line shafting or shaft couplings (jackshafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.

3.12 WARNING LABELS

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

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows.

CAUTION
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to"Off"position before servicing.

B. Permanent warning labels shall be affixed to all motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows.

CAUTION
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.13 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels shall be labeled at each end within 5 cm (2 in.) of termination with control system address or termination number.

B. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.

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

D. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

E. Identify all other control components with permanent labels. All plug-in components shall be labeled such that label removal of the component does not remove the label.

F. Identify room sensors related to terminal boxes or valves with nameplates.

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

H. Identifiers shall match record documents.

3.14 CONTROLLERS

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in 15900 Appendix A (Sequences of Operation).

3.15 PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.

B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Division 23 Appendix A (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix B to Division 23 may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.

C. Software Programming.

1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Embed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:

a. Text-based:

i. Must provide actions for all possible situations
ii. Must be modular and structured
iii. Must be commented

b. Graphic-based:

i. Must provide actions for all possible situations
ii. Must be documented

c. Parameter-based:

i. Must provide actions for all possible situations
ii. Must be documented.

D. Operator Interface.

1. Standard Graphics. Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in Division 23 Appendix A.
2. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

3.16 CONTROL SYSTEM CHECKOUT AND TESTING

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

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
7. Alarms and Interlocks:

    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action

3.17 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration.

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
5. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:

    a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
    b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
    c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
    d. Interface to the building fire alarm system.
    e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and disk formats.

10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

B. Acceptance.

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

3.18 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

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

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

3.19 TRAINING

A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.

B. Training shall enable students to accomplish the following objectives.

1. Day-to-day Operators:

a. Proficiently operate the system
b. Understand control system architecture and configuration
c. Understand DDC system components
d. Understand system operation, including DDC system control and optimizing routines (algorithms)
e. Operate the workstation and peripherals
f. Log on and off the system

g. Access graphics, point reports, and logs
h. Adjust and change system set points, time schedules, and holiday schedules
i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
j. Understand system drawings and Operation and Maintenance manual
k. Understand the job layout and location of control components
l. Access data from DDC controllers and ASCs
m. Operate portable operator's terminals

2. Advanced Operators:

a. Make and change graphics on the workstation
b. Create, delete, and modify alarms, including annunciation and routing of these
c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
d. Create, delete, and modify reports
e. Add, remove, and modify system's physical points
f. Create, modify, and delete programming
g. Add panels when required
h. Add operator interface stations
i. Create, delete, and modify system displays, both graphical and others
j. Perform DDC system field checkout procedures
k. Perform DDC controller unit operation and maintenance procedures
l. Perform workstation and peripheral operation and maintenance procedures
m. Perform DDC system diagnostic procedures
n. Configure hardware including PC boards, switches, communication, and I/O points
o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
p. Adjust, calibrate, and replace system components

3. System Managers/Administrators:

a. Maintain software and prepare backups
b. Interface with job-specific, third-party operator software
c. Add new users and understand password security procedures

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.

D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.

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

F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.20 SEQUENCES OF OPERATION

See Division 23 , Appendix A (Sequences of Operation, With Points Lists).

3.21 CONTROL VALVE INSTALLATION

A. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.

B. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball type control valves shall be installed with the stem in the horizontal position.

C. Valves shall be installed in accordance with the manufacturer's recommendations.

D. Control valves shall be installed so that they are accessible and serviceable and so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.

E. Isolation valves shall be installed so that the control valve body may be serviced without draining the supply/return side piping system. Unions shall be installed at all connections to screw-type control valves.

F. Provide tags for all control valves indicating service and number. Tags shall be brass, 1.5 inch in diameter, with ¼ inch high letters. Securely fasten with chain and hook. Match identification numbers as shown on approved controls shop drawings.

3.22 CONTROL DAMPER INSTALLATION

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure ¼ in. larger than damper dimensions and shall be square, straight, and level.

C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8 in.) of each other.

D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

E. Install extended shaft or jackshaft according to manufacturer's instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.

G. Provide a visible and accessible indication of damper position on the drive shaft end.

H. Support ductwork in area of damper when required to prevent sagging due to damper weight.

I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.23 SMOKE DAMPER INSTALLATION

A. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the engineer no less than two weeks prior to inspection by the code authority having jurisdiction.

B. Provide complete submittal data to controls system subcontractor for coordination of duct smoke detector interface to HVAC systems.

3.24 DUCT SMOKE DETECTION

A. Submit data for coordination of duct smoke detector interface to HVAC systems as required in Part 1, "Submittals."

B. This Contractor shall provide a dry-contact alarm output in the same room as the HVAC equipment to be controlled.

3.25 CONTROLS COMMUNICATION PROTOCOL

A. General. The electronic controls packaged with this equipment shall communicate with the building direct digital control (DDC) system. The DDC system shall communicate with these controls to read the information and change the control setpoints as shown in the points list, sequences of operation, and control schematics. The information to be communicated between the DDC system and these controls shall be in the standard object format as defined in ANSI/ASHRAE Standard 135 (BACnet). Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of Standard 135.

B. Distributed Processing. The controller shall be capable of stand-alone operation and shall continue to provide control functions if the network connection is lost.

C. I/O Capacity. The controller shall contain sufficient I/ O capacity to control the target system.

D. The Controller shall have a physical connection for a laptop computer or a portable operator's tool.

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

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 40°C to 60°C (40°F to 140°F).
2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

F. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.

G. Memory. The Controller shall maintain all BIOS and programming information in the event of a power loss for at least 30 days.

H. Power. Controller shall be able to operate at 90% to 110% of nominal voltage rating.

I. Transformer. Power supply for the Controller must be rated at minimum of 125% of ASC power consumption and shall be fused or current limiting type.

3.26 START-UP AND CHECKOUT PROCEDURES

A. Start up, check out, and test all hardware and software and verify communication between all components.

1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
2. Verify that all analog and binary input/output points read properly.
3. Verify alarms and interlocks.
4. Verify operation of the integrated system.

APPENDIX A: SEQUENCES OF OPERATION

1. Constant Air Volume - typical of AHU (7)

Run Conditions - Continuous:
The unit shall run continuously and maintain a constant airflow (downstream static pressure) despite filter loading.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a low entering air temperature status.
High Static Shutdown (Supply):
The unit shall shut down and generate an alarm upon receiving a high static supply duct shutdown signal.
High Static Shutdown (Exhaust):
The unit shall shut down and generate an alarm upon receiving a high negative static exhaust duct shutdown signal.
Supply Air Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.
Supply Fans:
The supply fans shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fans shall have a user definable (adj.) minimum runtime. Note: Each fan in the array has it's own VFD.

Supply Air Duct Static Pressure Control:

The controller shall measure duct static pressure and shall modulate the supply fan VFD's speed to maintain a duct static pressure setpoint of 1.5in H2O (adj.). The supply fan VFD's speed shall not drop below 50% (adj.). This will ensure all supply terminal units maintain constant volumetric airflows (CFM) despite increased pressure drop of the AHU as filters load up.

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan Failure: commanded on, but the status is entire fan array off.
- Supply fan in hand: commanded off, but the status is entire fan array on.
- Supply Fan General VFD Fault.
- Supply backup fan loss: One of the fans in the array has failed. *Note: AHU has N+1 redundancy in fan array so that the remaining fans will automatically speed up to compensate for the loss.*

Exhaust Fans:
The exhaust fans shall run whenever the supply fans run. Note: Each fan in the array has it's own VFD.

Alarms shall be provided as follows:

- Exhaust Fan Failure: Commanded on, but the status is entire fan array off.
- Exhaust Fan in Hand: Commanded off, but the status is entire fan array on.
- Exhaust Fan General VFD Fault.
- Exhaust backup fan loss: One of the fans in the array has failed. *Note: AHU has N+1 redundancy in fan array so that the remaining fans will automatically speed up to compensate for the loss.*

Exhaust Airflow:
The exhaust fan VFD's shall modulate to maintain a constant CFM (see equipment schedule for specific CFM settings for each AHU). Fan flow sensors provided integral with the AHU shall provide signal for this function.

Alarms shall be provided as follows:

- High Exhaust Airflow: If the exhaust airflow is an adjustable percentage greater than setpoint.
- Low Exhaust Airflow: If the exhaust airflow is an adjustable percentage less than setpoint.
- High duct static pressure: If the negative static pressure in the exhaust duct is 25% (adj.) above a preset limit (-2.0 inches).

Preheating Coil Valve:
The controller shall modulate the preheating coil valve to maintain a 55 deg F (adj) supply air temperature setpoint.

The preheating shall be enabled whenever:

- Outside air temperature is less than 53°F (adj.).
- AND both the AHU supply and AHU exhaust fan status is on.

The preheating coil valve shall open for freeze protection whenever:

- Entering air temperature drops below 35°F (adj.).

Supply Air Temperature Setpoint - Optimized:
The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on zone cooling and heating requirements of the associated zone terminal units. A sampling of ten (10) zone terminal units shall be selected and the error from setpoint shall be used for the reset schedule.

The supply air temperature setpoint shall be reset for cooling based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 55°F (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 53°F (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 72°F (adj.) .

Cooling Coil Valve:
The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Both the AHU supply and AHU exhaust fan status is on.
- AND the pre-heating is not active.
- OR the AHU exhaust air relative humidity level exceeds 60% (adj) RH.

As a protective measure, the cooling coil valve shall open to 50% (adj.) whenever the supply air temperature drops to 35 deg F to prevent freezing of the coil.
Dehumidification Control:
The controller shall measure the relative humidity level in the main AHU exhaust duct as well as any spaces under humidity control served by the AHU. If the RH level in the main AHU exhaust duct or in any of the humidity controlled spaces rises above 60% RH, then the AHU unit shall go into Dehumidification mode and override normal cooling mode, opening the cooling coil valve in order to remove moisture from the entering air stream. Note that reheat will be accomplished by the AHU motor heat and at the terminal unit reheat coils. Once the RH level has been lowered below 55% RH (adj.), then the AHU shall resume normal cooling mode.

Alarms shall be provided as follows:

- High Supply Air Temperature: If the supply air temperature is 5 deg F (adj.) greater than setpoint
- Low Supply Air Temperature: If the supply air temperature is less than 45 deg. F (adj.)
- High Exhaust Air Relative Humidity: If the exhaust air relative humidity exceeds 60% RH (adj.)

Prefilter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the prefilter.

Alarms shall be provided as follows:

- Prefilter Change Required: Prefilter differential pressure exceeds a user definable limit (adj.).

Final Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the final filter.

Alarms shall be provided as follows:

- Final Filter Change Required: Final filter differential pressure exceeds a user definable limit (adj.).

Entering Air Temperature:
The controller shall monitor the entering air temperature and use as required for preheating control.
Supply Air Temperature:
The controller shall monitor the supply air temperature.
Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Supply Air Static Pressure	x								x	x	x
Exhaust Air Static Pressure	x								x		x
Supply Airflow	x								x		x
Exhaust Airflow	x								x		x
Prefilter Differential Pressure	x								x		
Final Filter Differential Pressure	x								x		
Supply Air Temp	x								x		x
Exhaust Air Relative Humidity	x								x		x
Supply Fan VFD Speed		x							x		x
Exhaust Fan VFD Speed		x							x		x
Preheating Valve		x							x		x
Cooling Valve		x							x		x
High Static Shutdown			x						x	x	x
Supply Air Smoke Detector			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Exhaust Fan VFD Fault			x							x	
Exhaust Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x
Exhaust Fan Start/Stop				x					x		x
Supply Air Static Pressure Setpoint					x				x		x
Exhaust Airflow Setpoint					x				x		x
Supply Air Temp Setpoint					x				x		x
High Supply Air Static Pressure										x	

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Low Supply Air Static Pressure										x	
High Exhaust Air Negative Static Pressure										x	
High Exhaust Air Relative Humidity										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Exhaust Fan Failure										x	
Exhaust Fan in Hand										x	
High Exhaust Airflow										x	
Low Exhaust Airflow										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Prefilter Change Required										x	x
Final Filter Change Required										x	x
High Entering Air Temp										x	
Low Entering Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Supply backup fan failure										x	
Exhaust backup fan failure										x	
Totals	8	4	6	2	3	0	0	0	-21	24	22
Total Hardware (20)					Total Software (48)						

2. Constant Air Volume - Terminal Unit (typical of 343)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 74°F (adj.) cooling setpoint
  - A 70°F (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.
Constant Volume Terminal Unit - Flow Control:
The unit shall maintain constant airflow through one of the following:

- The zone damper shall modulate to maintain a constant occupied airflow (adj.) distributed into the zone.
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its heating setpoint.

Automatic damper calibration:

To ensure accurate readings are maintained throughout the life of the system, dampers shall automatically reset to zero for calibration weekly (adj.) at a time of day agreed upon by the owner.
Reheating Coil Valve:
The controller shall measure the zone temperature and modulate the reheating coil valve open on dropping temperature to maintain its heating setpoint.

Reheating - High Discharge Air Temperature Limit:
The controller shall measure the discharge air temperature and limit reheating if the discharge air temperature is more than 25°F (adj.) above the zone temperature.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Airflow	x								x		x
Discharge Air Temp	x								x		x
Zone Damper		x									x
Reheating Valve		x							x		x
Airflow Setpoint					x				x		x
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Totals	4	2	0	0	1	0	0	0	7	4	9
Total Hardware (6)					Total Software (12)						

3. Venturi Air Valve - Isolation room supply (typical of 14)

Run Conditions - Continuous:
The unit shall run continuously and shall maintain:

- A 74°F (adj.) cooling setpoint
- A 70°F (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Constant Volume Terminal Unit - Flow Control:
The unit shall maintain constant airflow through one of the following:

- The zone damper shall modulate to maintain a constant occupied airflow (adj.) distributed into the zone.
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its heating setpoint.

Reheating Coil Valve:
The controller shall measure the zone temperature and modulate the reheating coil valve open on dropping temperature to maintain its heating setpoint.

Reheating - High Discharge Air Temperature Limit:
The controller shall measure the discharge air temperature and limit reheating if the discharge air temperature is more than 15°F (adj.) above the zone temperature.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Airflow	x								x		x
Discharge Air Temp	x								x		x
Zone Damper		x									x
Reheating Valve		x							x		x
Airflow Setpoint					x				x		x
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	

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Low Zone Temp										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Totals	4	2	0	0	1	0	0	0	7	4	9
Total Hardware (6)					Total Software (12)						

4. Venturi Air Valve - Isolation room exhaust (typical of 14)

Run Conditions - Continuous:
The unit shall run continuously.
Alarms shall be provided as follows:

- If isolation room does not maintain negative pressure (as measured by the Isolation Room control panel).

Constant Volume Terminal Unit - Flow Control:
The unit shall maintain constant airflow and a negative pressure setpoint as controlled by the Isolation Room control panel.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Negative Pressure Failure										X	
Totals	1	0	0	0	0	0	0	0	0	1	0
Total Hardware (1)					Total Software (1)						

5. Isolation room exhaust fans (typical of 4)

Run Conditions - Continuous:
The fan shall run continuously.

Fan:
The fan shall have a user definable (adj.) minimum runtime.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Fan Status			x						x		x
Fan Start/Stop				x					x		x
Fan Failure										x	
Fan in Hand										x	
Totals	0	0	1	1	0	0	0	0	2	2	2
Total Hardware (2)					Total Software (4)						

6. Hot Lab Exhaust Fan (EF-19)

Run Conditions - Continuous:
The fans shall run continuously unless shutdown on safeties.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:
- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.

Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the filter
Alarms shall be provided as follows:
- Filter Change Required: Filter diffential pressure exceeds a user definable limit (adj).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Fan Status			x						x		x
Fan Start/Stop				x					x		x
Fan Failure										x	
Fan in Hand										x	
Filter Diffential Pressure	x								x		x
Filter Change Required										x	
Totals	1	0	1	1	0	0	0	0	3	3	3
Total Hardware (3)					Total Software (6)						

7. Exhaust Fans (Gen/Radiology/pharmacy/morgue/kitchen) (typical of 11)

Run Conditions - Continuous:
The fans shall run continuously unless shutdown on safeties.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:
- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Fan Status			x						x		x
Fan Start/Stop				x					x		x
Fan Failure										x	
Fan in Hand										x	
Totals	0	0	1	1	0	0	0	0	2	2	2

Total Hardware (2)	Total Software (4)

8. Fan Coil Unit (typical of 16)

Run Conditions – Continuously :
The unit shall run continuously.

- The unit shall maintain
  - A 74°F (adj.) cooling setpoint. *Note: Some rooms such as data/electrical rooms may require colder cooling setpoints (70 deg. F).*
  - A 70°F (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a smoke detector status (where scheduled).

Fan:
The fan shall run continuously, unless shutdown on safeties.
Cooling Coil Valve:
The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- The zone temperature is above cooling setpoint.

Heating Coil Valve: (where scheduled)
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- The zone temperature is below heating setpoint.

Pre-Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the filter.
Final Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the filter (only where final filters are noted in schedule):

Alarms shall be provided as follows:

- Filter Change Required: Filter differential pressure exceeds a user definable limit (adj.).

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Pre Filter Differential Pressure	x								x		x
Final Filter Differential Pressure *only select units	x								x		x
Discharge Air Temp	x								x		x
Cooling Valve		x							x		x
Heating Valve *only select units		x							x		x
Smoke Detector *only select units			x						x	x	x
Fan Status			x								x
Heating Setpoint *only select units									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Pre-Filter Change Required										x	
Final Filter Change Required *only select units										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Fan Failure										x	
Fan in Hand										x	
Totals	5	2	2	0	0	0	0	0	9	9	11
Total Hardware (9)					Total Software (18)						

9. Fan/Filter units (typical of 7)

Run Conditions - Continuous:
The unit shall run continuously.

The integral ECM motor shall ensure constant airflow despite filter loading.

Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the filter.

Alarms shall be provided as follows:

- Filter Change Required: Filter differential pressure exceeds a user definable limit (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Filter Differential Pressure	x								x		x
Fan Status			x						x		x
Filter Change Required										x	
Fan Failure										x	
Fan in Hand										x	
Totals	1	0	1	0	0	0	0	0	2	3	2
Total Hardware (2)					Total Software (5)						

10. Boiler draft supply fans (typical of 2)

Run Conditions - Interlocked:
Both fans shall be interlocked to run whenever the boilers or water heaters run unless shutdown on safeties.

Fan:
The fan shall have a user definable (adj.) minimum runtime.

Fan Status:
The controller shall monitor the fan status. Upon failure of one of the two (2) supply fans, two of the three (3) hydronic (space heating boilers) shall be shut down, allowing only one (1) hydronic (space heating) boiler to run, along with all domestic water heaters and steam boiler. Upon failure of *both* supply fans, *all* gas-fired equipment (all boilers and water heaters) shall be shut down.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic

Fan Status			x						x		x
Fan Start/Stop				x					x		x
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	0	0	1	1	0	0	0	0	2	3	2
Total Hardware (2)					Total Software (5)						

11. Dryer Vent exhaust system (typical of 1)

Alarms shall be provided as follows:

- Dryer fan controller alarm.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Vent Control Failure Alarm			x							x	
Totals	0	0	1	0	0	0	0	0	0	1	0
Total Hardware (1)					Total Software (1)						

12. Boiler/water heater vent system

Vent fan status:
Upon failure of vent fan, all boilers and domestic water heaters shall shut down.
Alarms shall be provided as follows:

- Boiler/water heater vent fan controller alarm.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Vent Control Failure Alarm			X							x	
Totals	0	0	1	0	0	0	0	0	0	0	0
Total Hardware (1)					Total Software (1)						

13. Food Service Referigerator/Freezer Temperature Monitor [typical of 5: 1135 SREFR Inventory Cooler and 1133 SREFR Coolers/Freezer (Reference Sheet K1.1)]
Should temperature of freezer or refrigerator exceed a preset limit (adj.), then alarm shall be triggered.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Refrigerator/Freezer temperature	x								x	x	
Totals	1	0	0	0	0	0	0	0	1	1	0
Total Hardware (1)					Total Software (1)						

14. Pharmacy Referigerator/Freezer Temperature Monitor [typical of 12: REUC -5 (Room 1044A Secure Storage), REUC – 5 (Room 1044 Narcotic Storage), REFS-2, 3 and 4 (Room 1034B Refrigerator), and FLRP (Room 1034A Freezer).

Should temperature of freezer or refrigerator exceed a preset limit (adj.), then alarm shall be triggered.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Refrigerator/Freezer temperature	x								x	x	
Totals	1	0	0	0	0	0	0	0	1	1	0
Total Hardware (1)					Total Software (2)						

15. Water Heater Monitor (typical of 3)
On/off status of reticulating pumps shall be monitored.
Alarm shall be provided as follows:
    - Water heater alarm

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Water heater alarm			x							x	x
Recirculating hot water pump status			x							x	x
Totals	0	0	2	0	0	0	0	0	0	2	2
Total Hardware (2)					Total Software (2)						

16. Medical Vacuum Pump and Medical Air Compressor (typical of 1)
Alarm shall be provided as follows:
    - Medical Vacuum pump alarm
    - Medical Air Compressor alarm

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Medical Vacuum Pump Alarm			X							x	
Medical Air Compressor Alarm			X							X	
Totals	0	0	2	0	0	0	0	0	0	2	0
Total Hardware (2)					Total Software (2)						

17. Medical Gas Manifold
Alarm shall be provided as follows:
    - Med Gas Manifold alarm (Nitrous Oxide)
    - Med Gas Manifold alarm (Nitrogen)

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Medical Gas Manifold Alarm (NO)			x							x	
Medical Gas Manifold Alarm (N)			x							x	
Totals	0	0	2	0	0	0	0	0	0	2	0
Total Hardware (2)					Total Software (2)						

18. Domestic Hot Water mixing valve
Alarm shall be provided as follows:
- High Temperature (126° F or higher)- .

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
High temperature alarm			x							x	
Totals	0	0	1	0	0	0	0	0	0	1	0
Total Hardware (1)					Total Software (1)						

19. Boiler Feed Unit
Alarm shall be provided as follows:
- Boiler feed unit alarm

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Boiler feed unit alarm			x							x	
Totals	0	0	1	0	0	0	0	0	0	1	0
Total Hardware (1)					Total Software (1)						

20. Electrical Generator (typical 2)

Generators shall be monitored as follows:
- Status (on/off)
- Alarm (Failure)

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Status			x								x
Alarm			x							x	
Totals	0	0	2	0	0	0	0	0	0	1	1
Total Hardware (0)					Total Software (0)						

21. Electrical Uninterruptable Power Supply (UPS) (typical 1)

UPS shall be monitored as follows:
- Status (on/off)
- Alarm (Failure)

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Status			x								x
Alarm			x							x	
Totals	0	0	2	0	0	0	0	0	0	1	1
Total Hardware (0)					Total Software (0)						

22. Automatic Transfer Switch
Status shall be monitored:

- Normal utility power
- Emergency power

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Status			x								
Totals	0	0	1	0	0	0	0	0	0	0	0
Total Hardware (1)					Total Software (1)						

23. Electrical Switchgear
Power consumption shall be monitored.
- KwH

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Power consumption	x								x		x
Totals	0	0	1	0	0	0	0	0	1	0	1
Total Hardware (1)					Total Software (1)						

24. Fire Alarm

Combination smoke fire dampers and smoke damper positions shall be monitored through the fire alarm panel.

Alarm shall be provided as follows:
- Fire alarm panel trouble condition
- Fire alarm panel alarm condition

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Smoke Damper positions			x							x	
Fire Alarm panel trouble			x							X	
Fire Alarm panel alarm			x							X	
Totals	0	0	1	0	0	0	0	0	0	3	0
Total Hardware (1)					Total Software (3)						

25. Pump (MP-4)
Status (on/off) shall be monitored.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Pump status			x								x
Totals	0	0	1	0	0	0	0	0	0	0	1
Total Hardware (1)					Total Software (0)						

26. Dialysis Duplex Booster Pump System

Status (on/off) shall be monitored.

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Alarm shall be provided as follows:

- Booster pump panel alarm condition.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Booster system status			x								x
Booster pump panel alarm			X							x	
Totals	0	0	2	0	0	0	0	0	0	1	1
Total Hardware (2)					Total Software (1)						

27. Humidifiers (typ. 18)

Zone Humidity:
The controller shall monitor the zone relative humidity and modulate the steam valve to maintain the zone humidity setpoint of 45% RH (adj.). To avoid prevent nuisance shutdown by the duct humidistat, the control system shall compare the duct relative humidity with the duct high limit setpoint of 80% RH (adj.) and slow the rate of valve opening as the duct relative humidity approaches the high limit setpoint.
The duct-mounted high limit humidistat and air flow proving differential switch shall be interlocked with the steam humidifier control valve to prevent the steam valve from opening if there is inadequate airflow or if the duct RH is above the humidistat maximum setting (90% RH). A condensate temperature switch (provided by the humdifier manufacturer) sahll prevent the steam valve from opening if the condensate temperature is at or below 210 deg F. (adj.)
Where a humidifier serves more than one room (each with a temperature control zone), the steam control valve shall be modulated to maintain a room humidity setpoint of 45% RH (adj) in the room with the lowest temperature setpoint. If any room RH falls below 30%, the humidifier steam valve shall be modulated open. If any room RH rises above 60%, the humidifier steam valve shall be modulated closed.

Alarms shall be provided as follows:

a. High Zone Humidity: If the zone humidity is greater than 60% (adj.).
b. Low Zone Humidity: If the zone humidity is less than 30% (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Zone Humidity Setpoint		x							x		x
Duct Humidity	x								x		x
Zone Humidity	x								x		x
High limit duct humidistat			x							x	
High Zone Humidity										x	
Low Zone Humidity										x	
Totals	2	1	1	0	0	0	0	0	3	3	3
Total Hardware (4)					Total Software (6)						

28. Fuel Oil Monitoring

Point Name	Hardware Points				Software Points						Show On Graphic
	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	
Transition Sump Leak			X							X	
Common Vacuum Leak			X							X	
Main Tank Low Leak			X							X	
Main Tank High Leak			X							X	
Day Tank Low Leak			X							X	
Day Tank High Leak			X							X	
Pump Failure			X							x	
Totals	0	0	7	0	0	0	0	0	0	7	0
Total Hardware (7)					Total Software (7)						

29. Paralleling Gear

The controller shall report the following points when requested by the user:

Note that this will be a "screen shot" directly from the paralleling gear controller.

Point Name	Hardware Points				Software Points						Show On Graphic
	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	
Panel Screen Shot					x						x
Totals	0	0	0	0	1	0	0	0	0	0	1
Total Hardware (0)					Total Software (1)						

KP South Bay Paralleling Gear				
Address	Description	Off State	On State	Alarm?
%Q01537	Gen. 1 Low Water Temperature	Off	Active	Yes
%Q01539	Gen. 1 High Water Temperature	Reset	Active	Yes
%Q01540	Gen. 1 Low Water Level	Off	Active	Yes
%Q01542	Gen. 1 Low Oil Pressure	Reset	Active	Yes
%Q01543	Gen. 1 Engine Over Crank	Reset	Active	Yes
%Q01545	Gen. 1 Genset Switch not in Auto	Off	Active	Yes
%Q01546	Gen. 1 Day Tank Low Fuel	Off	Active	Yes
%Q01547	Gen. 1 Day Tank High Fuel	Off	Active	Yes
%Q01548	Gen. 1 Day Tank Rupture	Off	Active	Yes
%Q01549	Gen. 1 Battery Charger Alarm	Off	Active	Yes
%Q01551	Gen. 1 Engine Comm Failure	Off	Active	Yes
%Q01555	Gen. 1.4 Control Voltage Failure	Off	Active	Yes
%Q01561	Gen. 1 Breaker Fail to Trip	Reset	Active	Yes
%Q01562	Gen. 1 Ground Fault	Off	Active	Yes

%Q01563	Gen. 1 Summary Alarm	Off	Active	Yes
%Q01565	Gen. 1 Protective Relay Self-Test Failure	Off	Active	Yes
%Q01585	Gen. 1 Summary Shutdown	Reset	Active	Yes
%Q01587	Gen. 1 Local Emergency Stop	Reset	Active	Yes
%Q01591	Gen. 1 Critical Control Voltage Failure	Reset	Active	Yes
%Q01596	Gen. 1 Fail to Sync	Reset	Active	Yes
%Q01597	Gen. 1 Voltage Regulator Shutdown	Reset	Active	Yes
%Q01598	Gen. 1 Gen Mounted Breaker Open	Reset	Active	Yes
%Q01601	Gen. 2 Low Water Temperature	Off	Active	Yes
%Q01603	Gen. 2 High Water Temperature	Reset	Active	Yes
%Q01604	Gen. 2 Low Water Level	Off	Active	Yes
%Q01606	Gen. 2 Low Oil Pressure	Reset	Active	Yes
%Q01607	Gen. 2 Engine Over Crank	Reset	Active	Yes
%Q01609	Gen. 2 Genset Switch not in Auto	Off	Active	Yes
%Q01610	Gen. 2 Day Tank Low Fuel	Off	Active	Yes
%Q01611	Gen. 2 Day Tank High Fuel	Off	Active	Yes
%Q01612	Gen. 2 Day Tank Rupture	Off	Active	Yes
%Q01613	Gen. 2 Battery Charger Alarm	Off	Active	Yes
%Q01615	Gen. 2 Engine Comm Failure	Off	Active	Yes
%Q01619	Gen. 2 Control Voltage Failure	Off	Active	Yes
%Q01625	Gen. 2 Breaker Fail to Trip	Reset	Active	Yes
%Q01626	Gen. 2 Ground Fault	Off	Active	Yes
%Q01627	Gen. 2 Summary Alarm	Off	Active	Yes
%Q01629	Gen. 2 Protective Relay Self-Test Failure	Off	Active	Yes
%Q01649	Gen. 2 Summary Shutdown	Reset	Active	Yes
%Q01651	Gen. 2 Local Emergency Stop	Reset	Active	Yes
%Q01655	Gen. 2 Critical Control Voltage Failure	Reset	Active	Yes
%Q01660	Gen. 2 Fail to Sync	Reset	Active	Yes
%Q01661	Gen. 2 Voltage Regulator Shutdown	Reset	Active	Yes
%Q01662	Gen. 2 Gen Mounted Breaker Open	Reset	Active	Yes
%Q00401	Gen. 1 Breaker Status	Open	Closed	No
%Q00402	Gen. 1 Breaker Status	Racked-In	Racked-Out	No
%Q00406	Gen. 1 Breaker Status	Unloaded	Loaded	No
%Q00409	Gen. 1 Breaker Fail to Close	Reset	Active	Yes
%Q00410	Gen. 1 Breaker Fail to Open	Reset	Active	Yes
%Q00412	Gen. 1 Breaker Over Current	Reset	Active	Yes
%Q00413	Gen. 1 Reverse Power	Reset	Active	Yes
%Q00425	Gen. 2 Breaker Status	Open	Closed	No
%Q00426	Gen. 2 Breaker Status	Racked-In	Racked-Out	No
%Q00430	Gen. 2 Breaker Status	Unloaded	Loaded	No
%Q00433	Gen. 2 Breaker Fail to Close	Reset	Active	Yes
%Q00434	Gen. 2 Breaker Fail to Open	Reset	Active	Yes
%Q00436	Gen. 2 Breaker Over Current	Reset	Active	Yes
%Q00437	Gen. 2 Reverse Power	Reset	Active	Yes
%Q00641	CC SWB. EMSB Breaker Status	Open	Closed	No
%Q00642	CC SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00646	CC SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00649	CC SWB. EMSB Breaker Fail to Close	Reset	Active	Yes

%Q00650	CC SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00652	CC SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00657	CC SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00664	CC SWB. EMSB Normally Closed Breaker Open	Off	Active	Yes
%Q00665	D1B SWB. EMSB Breaker Status	Open	Closed	No
%Q00666	D1B SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00670	D1B SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00673	D1B SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00674	D1B SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00676	D1B SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00681	D1B SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00688	D1B SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00689	D1C SWB. EMSB Breaker Status	Open	Closed	No
%Q00690	D1C SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00694	D1C SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00697	D1C SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00698	D1C SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00700	D1C SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00705	D1C SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00712	D1C SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00713	D2A SWB. EMSB Breaker Status	Open	Closed	No
%Q00714	D2A SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00718	D2A SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00721	D2A SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00722	D2A SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00724	D2A SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00729	D2A SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00736	D2A SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00737	D2B SWB. EMSB Breaker Status	Open	Closed	No
%Q00738	D2B SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00742	D2B SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00745	D2B SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00746	D2B SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00748	D2B SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00753	D2B SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00760	D2B SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00761	D2C SWB. EMSB Breaker Status	Open	Closed	No
%Q00762	D2C SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00766	D2C SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00769	D2C SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00770	D2C SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00772	D2C SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00777	D2C SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00784	D2C SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00785	D2D SWB. EMSB Breaker Status	Open	Closed	No
%Q00786	D2D SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00790	D2D SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00793	D2D SWB. EMSB Breaker Fail to Close	Reset	Active	Yes

%Q00794	D2D SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00796	D2D SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00801	D2D SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00808	D2D SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00809	D2E SWB. EMSB Breaker Status	Open	Closed	No
%Q00810	D2E SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00814	D2E SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00817	D2E SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00818	D2E SWB. EMSB Breaker Fail to Open	Open	Active	Yes
%Q00820	D2E SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00825	D2E SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00832	D2E SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q00833	D2F SWB. EMSB Breaker Status	Open	Closed	No
%Q00834	D2F SWB. EMSB Breaker Status	Racked-In	Racked-Out	No
%Q00838	D2F SWB. EMSB Breaker Status	Unloaded	Loaded	No
%Q00841	D2F SWB. EMSB Breaker Fail to Close	Reset	Active	Yes
%Q00842	D2F SWB. EMSB Breaker Fail to Open	Reset	Active	Yes
%Q00844	D2F SWB. EMSB Breaker Over Current	Reset	Active	Yes
%Q00849	D2F SWB. EMSB Breaker Ground Fault	Reset	Active	Yes
%Q00856	D2F SWB. EMSB Breaker Closed Breaker Open	Off	Active	Yes
%Q01130	SWB. EMSB Overload	Reset	Active	Yes
%Q01132	SWB. EMSB Load Shed	Off	Active	Yes
%Q01134	SWB. EMSB Frequency	Normal	High	No
%Q01135	SWB. EMSB Voltage	Normal	High	No
%Q01136	SWB. EMSB Voltage	Normal	Low	No
%Q01137	SWB. EMSB Frequency	Normal	Low	No
%Q01148	SWB. EMSB Sensing Relay Failure	Off	Active	Yes
%Q01149	SWB. EMSB Sync Interlock	Off	On	No
%Q01150	SWB. EMSB Main Breaker Close Interlock	Off	On	No
%Q00010	Gen. 1 Breaker Trip	Off	On	Yes
%Q00026	Gen. 2 Breaker Trip	Off	On	No
%Q00040	CC SWB. EMSB Breaker Trip	Off	On	No
%Q00066	D1B SWB. EMSB Breaker Trip	Off	On	No
%Q00068	D1C SWB. EMSB Breaker Trip	Off	On	No
%Q00070	D2A SWB. EMSB Breaker Trip	Off	On	No
%Q00072	D2B SWB. EMSB Breaker Trip	Off	On	No
%Q00074	D2C SWB. EMSB Breaker Trip	Off	On	No
%Q00076	D2D SWB. EMSB Breaker Trip	Off	On	No
%Q00078	D2E SWB. EMSB Breaker Trip	Off	On	No
%Q00080	D2F SWB. EMSB Breaker Trip	Off	On	No
%Q00012	Gen. 1 Engine Control Light – Breaker Failure	Off	On	No
%Q00028	Gen. 2 Engine Control Light - Breaker Failure	Off	On	No
%Q00014	Gen. 1 Engine Control Light - Engine Alarm	Off	On	No
%Q00030	Gen. 2 Engine Control Light - Engine Alarm	Off	On	No
%Q00013	Gen. 1 Engine Control Light - Engine Running	Off	On	No
%Q00029	Gen. 2 Engine Control Light - Engine Running	Off	On	No
%Q00011	Gen. 1 Engine Control Light - Protective Relay Tripped	Off	On	No

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%Q00027	Gen. 2 Engine Control Light - Protective Relay Tripped	Off	On	No
%Q01419	ES1 ATS Engine Start Control Voltage	Restored	Failed	Yes
%Q01425	Main Tank Low Fuel Level	Reset	Active	Yes
%Q01426	Station Battery Charger Alarm	Reset	Active	Yes
%Q00098	ATS-01 Relay - Load Shed	Off	On	No
%Q00100	ATS-02 Relay - Load Shed	Off	On	No
%Q00102	ATS-03 Relay - Load Shed	Off	On	No
%Q00104	ATS-04 Relay - Load Shed	Off	On	No
%Q00106	ATS-05 Relay - Load Shed	Off	On	No
%Q00108	ATS-06 Relay - Load Shed	Off	On	No
%Q00110	ATS-07 Relay - Load Shed	Off	On	No
%Q00112	ATS-08 Relay - Load Shed	Off	On	No
%Q00081	ATS-01 Relay - Load Test	Off	Active	No
%Q00082	ATS-02 Relay - Load Test	Off	Active	No
%Q00083	ATS-03 Relay - Load Test	Off	Active	No
%Q00084	ATS-04 Relay - Load Test	Off	Active	No
%Q00085	ATS-05 Relay - Load Test	Off	Active	No
%Q00086	ATS-06 Relay - Load Test	Off	Active	No
%Q00087	ATS-07 Relay - Load Test	Off	Active	No
%Q00088	ATS-08 Relay - Load Test	Off	Active	No
%Q00037	Relay - Master Controls in Auto	Off	On	No
%Q00009	Gen. 1 Relay - Summary Shutdown	Off	On	No
%Q00025	Gen. 2 Relay - Summary Shutdown	Off	On	No
%Q00004	Gen. 1 Relay - Start	Off	On	No
%Q00020	Gen. 2 Relay - Start	Off	On	No

Address	Description	Format
%AI0957	Gen. 1 Voltage Phase A-B	Real
%AI0959	Gen. 1 Voltage Phase B-C	Real
%AI0961	Gen. 1 Voltage Phase C-A	Real
%AI0963	Gen. 1 Current Phase A	Real
%AI0965	Gen. 1 Current Phase B	Real
%AI0967	Gen. 1 Current Phase C	Real
%AI0969	Gen 1. Frequency	Real
%AI0971	Gen. 1 kW	Real
%AI0973	Gen. 1 kVAr	Real
%AI0975	Gen. 1 kVA	Real
%AI0981	Gen 1. Oil Pressure in PSI	Real
%AI0983	Gen. 1 Cooant Temperature in Deg. F	Real
%AI0985	Gen. Battery Voltage	Real
%A10989	Gen. 1 Operating Hours	Real
%AI0993	Gen 1. Oil Temperature in Deg. F	Real
%AI1007	Gen 2 Voltage Phase A-B	Real
%AI1009	Gen 2 Voltage Phase B-C	Real
%AI1011	Gen 2 Voltage Phase C-A	Real
%AI1013	Gen 2. Current Phase A	Real

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%AI1015	Gen 2. Current Phase B	Real
%AI1017	Gen 2. Current Phase C	Real
%AI1019	Gen. 2 Frequency	Real
%AI1021	Gen. 2 kW	Real
%AI1023	Gen. 2 kVAr	Real
%AI1025	Gen. 2 kVA	Real
%AI1031	Gen. 2 Oil Pressure in PSI	Real
%AI1033	Gen. 2 Coolant Temperature in Deg. F	Real
%AI1035	Gen. 2 Battery Voltage	Real
%AI1039	Gen. 2 Operating Hours	Real
%AI1043	Gen. 2 Oil Temperature in Deg. F	Real
%AI0501	SWB.EMSB kW – Total	Real
%AI0903	Latest Runtime – Hours	Real
%AI0621	ATS-01 Setpoint – Priority	Real
%AI0623	ATS-01 Setpoint – Expected kW	Real
%AI0625	ATS-02 Setpoint – Priority	Real
%AI0627	ATS-02 Setpoint – Expected kW	Real
%AI0629	ATS-03 Setpoint – Priority	Real
%AI0631	ATS-03 Setpoint – Expected kW	Real
%AI0633	ATS-04 Setpoint – Priority	Real
%AI0635	ATS-04 Setpoint – Expected kW	Real
%AI0637	ATS-05 Setpoint – Priority	Real
%AI0639	ATS-05 Setpoint – Expected kW	Real
%AI0641	ATS-06 Setpoint – Priority	Real
%AI0643	ATS-06 Setpoint – Expected kW	Real
%AI0645	ATS-07 Setpoint – Priority	Real
%AI0647	ATS-07 Setpoint – Expected kW	Real
%AI0649	ATS-08 Setpoint – Priority	Real
%AI0651	ATS-08 Setpoint – Expected kW	Real

30. Miscellaneous

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Outside Air Temp	x										x
Outside Air Relative Humidity	x										x
Chilled Water Differential Pressure (by JCI) [for connection to CUP]	x										x
Body Holding Room Temp	x										x
Body Holding Room Temp Alarm										x	
Body Holding Room Refrigeration Condenser Unit Failure Alarm										X	
Totals	4	0	0	0	0	0	0	0	0	2	4
Total Hardware (4)					Total Software (2)						

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31. Hot Water Loop Pumps (typical of 3)

Hot Water Pump Run Conditions:
The hot water pumps shall be enabled whenever:

a. A definable number of hot water coils need heating.
b. AND outside air temperature is less than 54°F (adj.).

The pumps shall run for freeze protection anytime outside air temperature is less than 38°F (adj.).

To prevent short cycling, the pump shall run for a minimum time and be off for a minimum time (both user adjustable).

Hot Water Pump Lead/Lag Operation - Three Equal Sized Pumps Running in Parallel:
The three variable speed hot water pumps shall operate in a lead/lag fashion.

c. The lead pump shall run first.
d. If any pump fails, the next available pump shall stage on and the failed pump shall be removed from operation.
e. Additional pumps shall stage on as required to maintain hot water differential pressure.
f. If one pump is in operation, pump flow shall not decrease below minimum flow capacity of boiler (175 GPM)
g. If two boilers run, minimum flow shall be 350 GPM
h. Pump to run for 5 minutes (adj.) when entire boiler system is shutdown.
i. No single pump shall operate until boiler shut-off valve has opened. Allow 1 minute delay (adj.) before commanding pump on.

The designated staging order (user definable) of the pumps shall rotate on one of the following conditions (user selectable):

j. manually through a software switch
k. if pump runtime (adj.) is exceeded
l. daily
m. weekly
n. monthly

Alarms shall be provided as follows:

o. Hot Water Pump 1
p. Failure: Commanded on, but the status is off.
q. Running in Hand: Commanded off, but the status is on.
r. Runtime Exceeded: Status runtime exceeds a user definable limit.
s. VFD Fault.

t. Hot Water Pump 2
u. Failure: Commanded on, but the status is off.
v. Running in Hand: Commanded off, but the status is on.
w. Runtime Exceeded: Status runtime exceeds a user definable limit.

x. VFD Fault.

y. Hot Water Pump 3
z. Failure: Commanded on, but the status is off.

aa. Running in Hand: Commanded off, but the status is on.
bb. Runtime Exceeded: Status runtime exceeds a user definable limit.
cc. VFD Fault.

Hot Water Differential Pressure Control:
The controller shall measure the hot water differential pressure and modulate the three hot water pump VFDs in sequence to maintain its hot water differential pressure setpoint. The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate the hot water pump speeds to maintain a hot water differential pressure of 12lbf/in2 (adj.). The VFDs minimum speed shall not drop below 20% (adj.).

The lead pump shall run anytime the manager is enabled. On dropping hot water differential pressure, additional pumps shall stage on and modulate to maintain setpoint as follows:

dd. The controller shall modulate the lead pump to maintain setpoint.
ee. If the lead pump cannot maintain setpoint and its speed rises above 90% (adj.), the second pump shall stage on and modulate in unison with the lead pump.
ff. If both pumps cannot maintain setpoint and their speed rises above 90% (adj.), the third pump shall stage on and modulate in unison with the other two pumps.

On rising hot water differential pressure, the pumps shall stage off as follows:

gg. If the setpoint is maintained and the speed of the three pumps drops by a user definable amount, the third pump shall stage off.
hh. If the setpoint is maintained and the speed of the remaining two pumps drops by a user definable amount, the second enabled pump shall stage off.
ii. The controller shall continue to modulate the lead pump to maintain setpoint.

To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

jj. High Hot Water Differential Pressure: If the hot water differential pressure is 25% (adj.) greater than setpoint.
kk. Low Hot Water Differential Pressure: If the hot water differential pressure is 25% (adj.) less than setpoint.

Water Flowrate Monitoring:
Heating hot water flow rate (GPM) shall be measured continuously and trended.
Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

ll. Hot water supply.
mm. Hot water return.

Alarms shall be provided as follows:

nn. High Hot Water Supply Temp: If the hot water supply temperature is greater than 200°F (adj.).
oo. Low Hot Water Supply Temp: If the hot water supply temperature is less than 100°F (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Hot Water Flowrate	x								x		x
Hot Water Differential Pressure	x								x		x
Hot Water Return Temp	x								x		x
Hot Water Supply Temp	x								x		x
Hot Water Pump 1 VFD Speed		x							x		x
Hot Water Pump 2 VFD Speed		x							x		x
Hot Water Pump 3 VFD Speed		x							x		x
Hot Water Pump 1 Status			x						x		x
Hot Water Pump 2 Status			x						x		x
Hot Water Pump 3 Status			x						x		x
Hot Water Pump 1 VFD Fault			x							x	x
Hot Water Pump 2 VFD Fault			x							x	x
Hot Water Pump 3 VFD Fault			x							x	x
Hot Water Pump 1 Start/Stop				x					x		x
Hot Water Pump 2 Start/Stop				x					x		x
Hot Water Pump 3 Start/Stop				x					x		x
Outside Air Temp					x						x
Hot Water Differential Pressure Setpoint					x						x
Hot Water Pump 1 Failure										x	
Hot Water Pump 2 Failure										x	
Hot Water Pump 3 Failure										x	
Hot Water Pump 1 Running in Hand										x	
Hot Water Pump 2 Running in Hand										x	
Hot Water Pump 3 Running in Hand										x	
Hot Water Pump 1 Runtime Exceeded										x	
Hot Water Pump 2 Runtime Exceeded										x	
Hot Water Pump 3 Runtime Exceeded										x	
Low Hot Water Differential Pressure										x	
High Hot Water Differential										x	

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Pressure											
High Hot Water Supply Temp										x	
Low Hot Water Supply Temp										x	
Totals	4	3	6	3	2	0	0	0	13	16	18
Total Hardware (16)					Total Software (31)						

32. Three Hydronic Boiler System (Typical of 1)

Boiler System Run Conditions:
The boiler system shall be enabled to run whenever.

- A definable number of hot water coils need heating.
- AND outside air temperature is less than 65°F (adj.)

To prevent short cycling, the boiler system shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The boiler shall run subject to its own internal safeties and controls.

The boiler system shall also run for freeze protection whenever the outside air temperature is less than 38°F (adj.)

Boiler 1 Safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Flame failure.

Alarms shall be provided as follows:

- Boiler alarm.
- Flame failure.

Boiler 2 safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Flame failure.

Alarms shall be provided as follows:

- Boiler alarm.
- Flame failure.

Boiler 3 safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Flame failure.

Alarms shall be provided as follows:

- Boiler alarm.
- Flame failure.

Boiler Lead/Standby Operation:

The three boilers shall operate in a lead/standby fashion when called to run and flow is proven.

- The lead boiler shall run first.
- On a continuous failure of a lead boiler lasting longer than 20 minutes a standby boiler shall run and the failed lead boiler shall turn off.
- When supply water temperature setpoint cannot be maintained, 2 boilers shall be activated.
- When flowrate drops below 400 GPM (adj.) shut off 1 boiler (close isolation valve) and run 1 boiler only.

The designated lead boiler shall rotate automatically through the BAS upon one of the following conditions: (user selectable):

- Weekly
- Monthly

Hot Water Supply Temperature Setpoint:

The hot water supply temperature setpoint shall be a fixed setpoint of 180°F (adj.)

Alarm shall be provided as follows:

- High Hot Water Supply Temp: If greater than 200°F (adj.)
- Low Hot Water Supply Temp: If less than 130°F (adj.)

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Hot Water Differential Pressure	x								x		x
Hot Water Supply Temp	x								x		x
Hot Water Return Temp	x								x		x
Heating Hot Water Flow Rate	x								x		x
Boiler 1 Status			x						x		x
Boiler 2 Status			x						x		x
Boiler 3 Status			x						x		x
Boiler 1 Enable				x							x
Boiler 2 Enable				x							x
Boiler 3 Enable				x							x
Outside Air Temp					x						x
Hot Water Differential Pressure Setpoint					x				x		x
Hot Water Supply Temp Setpoint					x				x		x
High Hot Water Differential										x	

Pressure											
Low Hot Water Differential Pressure										x	
Boiler 1 General Alarm										x	
Boiler 2 General Alarm										x	
Boiler 3 General Alarm										x	
High Hot Water Supply Temp										x	
Low Hot Water Supply Temp										x	
Boiler 1 Flame Failure										x	
Boiler 2 Flame Failure										x	
Boiler 3 Flame Failure										x	
Totals	4	0	3	3	3	0	0	0	9	10	13
Total Hardware (11)					Total Software (19)						

33. Three Steam Boiler System (Typical of 1)

Steam Boiler System Run Conditions:
The boiler system shall be enabled to run whenever.

The boiler shall run subject to its own internal safeties and controls.

Boiler 1 Safeties:
The following safeties shall be monitored:

- Boiler alarm.

Alarms shall be provided as follows:

- Boiler alarm.

Boiler 2 safeties:
The following safeties shall be monitored:

- Boiler alarm.

Alarms shall be provided as follows:

- Boiler alarm.

Boiler 3 safeties:
The following safeties shall be monitored:

- Boiler alarm.

Alarms shall be provided as follows:

- Boiler alarm.

Boiler Lead/Standby Operation:
The three boilers shall operate in a lead/standby fashion when called to run and flow is proven.

- Lead/lag operation shall be done by Falcon Controller, integrated to each boiler.

Steam Supply Pressure Setpoint:
The steam supply pressure setpoint shall be a fixed setpoint of 15 psi (adj.)

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Boiler 1 Status			x						x		x
Boiler 2 Status			x						x		x
Boiler 3 Status			x						x		x
Boiler 1 Enable				x							x
Boiler 2 Enable				x							x
Boiler 3 Enable				x							x
Steam Pressure Setpoint	x				x				x		x
Steam Supply Pressure		x			x				x		x
Boiler 1 General Alarm										x	
Boiler 2 General Alarm										x	
Boiler 3 General Alarm										x	
Boiler Feed Water Pump Relay			x						x		x
Draft Fan Failure				x					x	x	
Totals	1	1	4	4	2	0	0	0	8	4	10
Total Hardware (10)					Total Software (14)						

34. Point Summary

		Hardware Points				Software Points						
Point Name	Qty	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Variable Air Volume - AHU (Typical of 7)	Each	8	4	6	2	3	0	0	0	21	24	22
	Total (x7)	56	28	42	14	21	0	0	0	147	168	154
Constant Air Volume - Terminal Unit (Typical of 343)	Each	4	2	0	0	1	0	0	0	7	4	9
	Total (x343)	1372	686	0	0	343	0	0	0	2401	1372	3087
Venturi Air Valve - Isolation room supply (Typical of 14)	Each	4	2	0	0	1	0	0	0	7	4	9
	Total (x14)	56	28	0	0	14	0	0	0	98	56	126
Venturi Air Valve - Isolation room exhaust (Typical of 14)	Each	1	0	0	0	0	0	0	0	0	1	0
	Total (x14)	14	0	0	0	0	0	0	0	0	14	0
Isolation room exhaust fans (Typical of 4)	Each	0	0	1	1	0	0	0	0	2	2	2
	Total (x4)	0	0	4	4	0	0	0	0	8	8	8
Exhaust Fans	Each	0	0	1	1	0	0	0	0	2	2	2

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(Gen/Radiology/pharmacy/morgue/kitchen) (Typical of 11)	Total (x11)	0	0	11	11	0	0	0	0	22	22	22
Fan Coil Unit (Typical of 16)	Each	5	2	2	0	0	0	0	0	9	9	11
	Total (x16)	80	32	32	0	0	0	0	0	144	144	176
Fan/Filter units (Typical of 7)	Each	1	0	1	0	0	0	0	0	2	3	2
	Total (x7)	7	0	7	0	0	0	0	0	14	21	14
Dryer Vent exhaust fan (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	1	0
	Total (x1)	0	0	1	0	0	0	0	0	0	1	0
Boiler draft supply fans (Typical of 2)	Each	0	0	1	1	0	0	0	0	2	3	2
	Total (x2)	0	0	2	2	0	0	0	0	4	6	4
Boiler exhaust vent fans (Typical of 2)	Each	0	0	1	0	0	0	0	0	0	0	0
	Total (x2)	0	0	2	0	0	0	0	0	0	0	0
								0	0	6	6	12
Food Service Referigerator/Freezer Temperature Monitor (Typical of 5)	Each	1	0	0	0	0	0	0	0	1	1	0
	Total (x5)	5	0	0	0	0	0	0	0	5	5	0
Pharmacy Referigerator/Freezer Temperature Monitor (Typical of 12)	Each	1	0	0	0	0	0	0	0	1	1	0
	Total (x12)	12	0	0	0	0	0	0	0	12	12	0
Water Heater Monitor (Typicl of 3)	Each	0	0	2	0	0	0	0	0	0	2	2
	Total (x3)	0	0	6	0	0	0	0	0	0	6	6
Medical Vacuum Pump and Medical Air Compressor (Typical of 1)	Each	0	0	2	0	0	0	0	0	0	2	0
	Total (x1)	0	0	2	0	0	0	0	0	0	2	0
Medical Gas Manifold (Typical of 1)	Each	0	0	2	0	0	0	0	0	0	2	0
	Total (x1)	0	0	2	0	0	0	0	0	0	2	0
Domestic Hot Water Mixing Valve (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	1	0
	Total (x1)	0	0	1	0	0	0	0	0	0	1	0
Boiler Feed Unit (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	1	0
	Total (x1)	0	0	1	0	0	0	0	0	0	1	0
Electrical Generator (Typical of 2)	Each	0	0	2	0	0	0	0	0	0	1	1
	(Total (x2)	0	0	4	0	0	0	0	0	0	2	2
Electrical Uninterruptable Power Supply (UPS)	Each	0	0	2	0	0	0	0	0	0	1	1
	Total (x1)	0	0	2	0	0	0	0	0	0	1	1

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(Typical of 1)												
Automatic Transfer Switch (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	0	0
	Total (x1)	0	0	1	0	0	0	0	0	0	0	0
Electrical Switchgear (Typical of 1)	Each	0	0	1	0	0	0	0	0	1	0	1
	Total (x1)	0	0	1	0	0	0	0	0	1	0	1
Fire Alarm (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	3	0
	Total (x1)	0	0	1	0	0	0	0	0	0	3	0
Pump (MP-4) (Typical of 1)	Each	0	0	1	0	0	0	0	0	0	0	1
	Total (x1)	0	0	1	0	0	0	0	0	0	0	1
Humidifiers (Typical of 17	Each	2	1	1	0	0	0	0	0	3	3	3
	Total (x17)	34	17	17	0	0	0	0	0	51	51	51
Fuel Oil Monitoring (Typical of 1)	Each	0	0	7	0	0	0	0	0	0	7	1
	Total (x1)	0	0	7	0	0	0	0	0	0	7	1
Miscellaneous (Typical of 1)	Each	4	0	0	0	0	0	0	0	0	2	4
	Total (x1)	4	0	0	0	0	0	0	0	0	2	4
Hot Water Loop Pumps (Typical of 3)	Each	4	3	6	3	2	0	0	0	13	16	18
	Total (x3)	12	9	18	9	6	0	0	0	39	48	54
Hydronic Boiler System (Typical of 1)	Each	4	0	3	3	3	0	0	0	9	10	13
	Total (x1)	4	0	3	3	3	0	0	0	9	10	13
Steam Boiler System (Typical of 1)	Each	1	1	4	4	2	0	0	0	8	4	10
	Total (x1)	1	1	4	4	2	0	0	0	8	4	10
Hot Lab Exhaust Fan	Each	1	0	1	1	0	0	0	0	3	3	3
	Total (x1)	1	0	1	1	0	0	0	0	3	3	3
Dialysis Duplex Booster Pump System	Each	0	0	2	0	0	0	0	0	0	1	1
	Total (x1)	0	0	2	0	0	0	0	0	0	1	1
Paralleling Gear	Each	0	0	0	0	1	0	0	0	0	0	1
	Total (x1)	0	0	0	0	1	0	0	0	0	0	1
Project Totals		1658	801	175	48	390	0	0	0	2972	1979	3752
Total Hardware (2682)						Total Software (5341)						

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APPENDIX B: GLOSSARY OF TERMS
Terms used within the Specification Text:

- Advanced Application Controller (AAC):

A fully programmable control module. This control module may be capable of some of the advanced features found in Building Controllers (storing trends, initiating read and write requests, etc.) but it does not serve as a master controller. Advanced Application Controllers may reside on either the Ethernet/IP backbone or on a subnet.

- Application Specific Controller (ASC):

A pre-programmed control module which is intended for use in a specific application. ASCs may be configurable, in that the user can choose between various pre-programmed options, but it does not support full custom programming. ASCs are often used on terminal equipment such as VAV boxes or fan coil units. In many vendors' architectures ASCs do not store trends or schedules but instead rely upon a Building Controller to provide those functions.

- BACnet/IP:

An approved BACnet network type which uses an Ethernet carrier and IP addressing.

- BACnet MS/TP:

An approved BACnet network type which uses a Master-Slave Token Passing configuration. MS/TP networks are unique to BACnet and utilize EIA485 twisted pair topology running at 9600 to 76,800 bps.

- BACnet over ARCNET:

An approved BACnet network type which uses an ARCNET (attached resource computer network) carrier. ARCNET is an industry standard that can utilize several speeds and wiring standards. The most common configuration used by BACnet controllers is an EIA485 twisted pair topology running at 156,000 bps.

- Building Controller (BC):

A fully programmable control module which is capable of storing trends and schedules, serving as a router to devices on a subnet, and initiating read and write requests to other controllers. Typically this controller is located on the Ethernet/IP backbone of the BAS. In many vendors' architectures a Building Controller will serve as a master controller, storing schedules and trends for controllers on a subnet underneath the Building Controller.

- Direct Digital Control (DDC):

A control system in which a digital computer or microprocessor is directly connected to the valves, dampers, and other actuators which control the system, as opposed to indirectly controlling a system by resetting setpoints on an analog pneumatic or electronic controller.

- PICS - Protocol Implementation Conformance Statement:

A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.

- Smart Actuator (SA):

An actuator which is controlled by a network connection rather than a binary or analog signal. (0-10v, 4-20mA, relay, etc.)

- Smart Sensor (SS):

A sensor which provides information to the BAS via network connection rather than a binary or analog signal. (0-10000 ohm, 4-20mA, dry contact, etc.)

•Web services:

Web services are a standard method of exchanging data between computer systems using the XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services can be used at any level within a Building Automation System (BAS), but most commonly they are used to transfer data between BAS using different protocols or between a BAS and a non-BAS system such as a tenant billing system or a utility management system.

Terms used within the Sequences of Operation:

- adj.

Adjustable by the end user, through the supplied user interface.

- AI, AO, etc. (Column Headings on Points List)

AI = Analog Input. A physical input to the control module.
AO = Analog Output. A physical output from the control module.
AV = Analog Value. An intermediate (software) point that may be editable or read-only. Editable AVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only AVs are typically used to display the status of a control operation.
BI = Binary Input. A physical input to the control module.
BO = Binary Output. A physical output from the control module.
BV = Binary Value. An intermediate (software) point that may be editable or read-only. Editable BVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only BVs are typically used to display the status of a control operation.
Loop = A control loop. Most commonly a PID control loop. Typically a control loop will include a setpoint, an input which is compared to the setpoint, and an output which controls some action based upon the difference between the input and the setpoint. A PID control loop will also include gains for the proportional, integral, and derivative response as well as an interval which controls how frequently the control loop updates its output. These gains may be adjustable by the end user for control loop "tuning," but in self-tuning control loops or loops which have been optimized for a specific application the gains may not be adjustable.
Sched = Schedule. The control algorithm for this equipment shall include a user editable schedule.
Trend. The control system shall be configured to collect and display a trend log of this object. The

trending interval shall be no less than one sample every 5 minutes. (Change of Value trending, where a sample is taken every time the value changes by more than a user-defined minimum, is an acceptable alternative.)
Alarm. The control system shall be configured to generate an alarm when this object exceeds user definable limits, as described in the Sequence of Controls.

Note:If the specifications require use of the BACnet protocol, all of the above shall be provided as BACnet objects.

- KW Demand Limiting: *

An energy management strategy that reduces energy consumption when a system's electric power meter exceeds an operator-defined threshold.

When power consumption exceeds defined levels, the system automatically adjust setpoints, de-energizes low priority equipment, and takes other pre-programmed actions to avoid peak demand charges. As the demand drops, the system restores loads in a predetermined manner.

- Occupant Override Switch, or Timed Local Override:

A control option that allows building occupants to override the programmed HVAC schedule for a limited period of time.

When the override time expires, the zone returns to its unoccupied state.

- Occupant Setpoint Adjustment:

A control option that allows building occupants to adjust - within limits set by the HVAC control system - the heating and cooling setpoints of selected zones. Typically the user interface for this function is built into the zone sensor.

- Optimal Start-Up: *

A control strategy that automatically starts an HVAC system at the latest possible time yet ensures comfort conditions by the time the building becomes occupied.

In a typical implementation, a controller measures the temperature of the zone and the outside air. Then, using design heating or cooling capacity at the design outside air temperature, the system computes how long a unit must run at maximum capacity to bring the zone temperature to its occupied setpoint.

The optimal start algorithm often includes a self-learning feature to adjust for variations from design capacity.

A distributed system must use Run on Request with Optimal Start. (See below.)

- Requested, or Run on Request: *

A control strategy that optimizes the runtime of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service. Source equipment runs only when needed, not on a fixed schedule.

The source equipment runs when one or more receiving units request its services. An operator determines how many requests are required to start the source equipment.

For example, if all the zones in a building are unoccupied and the zone terminal units do not need heating or cooling, the AHU will shut down. However, if a zone becomes occupied or needs cooling, the terminal unit will send a run request to the AHU to initiate the start-up sequence. If this AHU depends on a central chiller, it can send a run request to the chiller.

The run on request algorithm also allows an operator to schedule occupancy for individual zones based on the needs of the occupants without having to adjust the schedules of related AHUs and chillers.

- Trim and Respond, or Setpoint Optimization: *

A control strategy that optimizes the setpoint of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service.

The source unit communicates with receiving units to determine heating, cooling, and other requirements, and then adjusts its setpoint.

For example, if all zones are comfortable and do not request cooling, the AHU will gradually increase (trim) its supply air setpoint. When a zone requests cooling, the AHU responds by dropping its setpoint. The more zones that request cooling, the more it drops the setpoint. The AHU repeats this process throughout the day to keep zones cool, but with a supply air setpoint that is no cooler than necessary.

Contracting Terms:

- Furnished or Provided:

The act of supplying a device or piece of equipment as required meeting the scope of work specified and making that device or equipment operational. All costs required to furnish the specified device or equipment and make it operational are borne by the division specified to be responsible for providing the device or equipment.

- Install or Installed:

The physical act of mounting, piping or wiring a device or piece of equipment in accordance with the manufacturer's instructions and the scope of work as specified. All costs required to complete the installation are borne by the division specified to include labor and any ancillary materials.

- Interface:

The physical device required to provide integration capabilities from an equipment vendor's product to the control system. The equipment vendor most normally furnishes the interface device. An example of an interface is the chilled water temperature reset interface card provided by the chiller manufacturer in order to allow the control system to integrate the chilled water temperature reset function into the control system.

- Integrate:

The physical connections from a control system to all specified equipment through an interface as required to allow the specified control and monitoring functions of the equipment to be performed via the control system.

APPENDIX C: ABBREVIATIONS

The following abbreviations may be used in graphics, schematics, point names, and other UI applications where space is at a premium.

AC - Air Conditioning
ACU - Air Conditioning Unit
AHU - Air Handling Unit
AI - Analog Input
AO - Analog Output
AUTO - Automatic
AUX - Auxiliary
BI -Binary Input
BO -Binary Output
C -Common
CHW - Chilled Water
CHWP - Chilled Water Pump
CHWR - Chilled Water Return
CHWS - Chilled Water Supply
COND - Condenser
CW - Condenser Water
CWP - Condenser Water Pump
CWR - Condenser Water Return
CWS - Condenser Water Supply
DA - Discharge Air
EA - Exhaust Air
EF - Exhaust Fan
EVAP - Evaporators
FCU - Fan Coil Unit
HOA - Hand / Off / Auto
HP - Heat Pump
HRU - Heat Recovery Unit
HTEX - Heat Exchanger
HW - Hot Water
HWP - Hot Water Pump
HWR - Hot Water Return
HWS - Hot Water Supply
MAX - Maximum
MIN - Minimum
MISC - Miscellaneous
NC - Normally Closed
NO - Normally Open
OA - Outdoor Air
PIU - Powered Induction Unit
RA - Return Air
RF - Return Fan
RH - Relative Humidity
RTU - Roof-top Unit
SA - Supply Air
SF - Supply Fan
SP - Static Pressure
TEMP - Temperature

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UH - Unit Heater
UV - Unit Ventilator
VAV - Variable Air Volume
VVTU - Variable Volume Terminal Unit
W/ - with
W/O - without
WSHP - Water Source Heat Pump

END OF SECTION

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SECTION 23 2113

HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Hot-water heating piping.
2. Chilled-water piping.
3. Makeup-water piping.
4. Condensate-drain piping.

B. Related Sections:

1. Division 23 "Hangers and Supports for HVAC Piping and Equipment".
2. Division 23 "Seismic Restraint of Mechanical Utilities".

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Chemical treatment.

B. Delegated-Design Submittal:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
2. Locations of pipe anchors and alignment guides and expansion joints and loops.
3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Suspended ceiling components.
2. Other building services.

3. Structural members.

B. Qualification Data: For Installer.

C. Welding certificates.

D. Field quality-control reports.

E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.5 QUALITY ASSURANCE

A. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

B. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Hot-Water Heating Piping: 150 psig at 200 deg F.
2. Chilled-Water Piping: 150 psig at 200 deg F.
3. Makeup-Water Piping: 80 psig at 150 deg F.
4. Condensate-Drain Piping: 150 deg F.

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L and ASTM B 88, Type M.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.

C. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube.

1. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated or comparable product by one of the following:

a. T-DRILL Industries Inc.

D. Wrought-Copper Unions: ASME B16.22.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

H. Grooved Mechanical-Joint Fittings and Couplings:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

a. Anvil International, Inc.
b. Central Sprinkler Company.
c. Star Pipe Products.
d. Victaulic Company.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or ASTM A 106/A 106M, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.
3. Couplings: Ductile- or malleable-iron housing and EPDM gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

I. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

D. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

E. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

F. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.5 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

a. A.Y. McDonald Mfg. Co.
b. Capitol Manufacturing Company.
c. Central Plastics Company.
d. Hart Industries International, Inc.
e. Jomar International Ltd.
f. Watts Regulator Co.
g. Zurn Industries, LLC.

2. Description:

a. Standard: ASSE 1079.
b. Pressure Rating: 150 psig.
c. End Connections: Solder-joint copper alloy and threaded ferrous.

C. Dielectric Flanges:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

   a. Capitol Manufacturing Company.
   b. Central Plastics Company.
   c. Watts Regulator Co.
   d. Zurn Industries, LLC.

2. Description:

   a. Standard: ASSE 1079.
   b. Factory-fabricated, bolted, companion-flange assembly.
   c. Pressure Rating: 150 psig.
   d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

   a. Advance Products & Systems, Inc.
   b. Calpico, Inc.
   c. Central Plastics Company.
   d. Pipeline Seal and Insulator, Inc.

2. Description:

   a. Nonconducting materials for field assembly of companion flanges.
   b. Pressure Rating: 150 psig.
   c. Gasket: Neoprene or phenolic.
   d. Bolt Sleeves: Phenolic or polyethylene.
   e. Washers: Phenolic with steel backing washers.

2.6 BYPASS CHEMICAL FEEDER

A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.
2. Manufacturer: J.L. Wingert or approved equivalent.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Hot-water heating piping, aboveground, NPS 2 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
2. Schedule 40, Grade B, Type 96 steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

B. Hot-water heating piping, aboveground, NPS 2-1/2 and larger, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
2. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints. ALLOWED FOR OUTDOORS PIPING AND IN MECHANICAL ROOMS ONLY. Grooved piping and mechanical joint fittings shall not be used for any permanent installation.

C. Chilled-water piping, aboveground, NPS 2 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
2. Schedule 40 steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

D. Chilled-water piping, aboveground, NPS 2-1/2 and larger, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
2. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints. ALLOWED FOR OUTDOORS PIPING AND IN MECHANICAL ROOMS ONLY. Grooved piping and mechanical joint fittings shall not be used for any permanent installation.

E. Makeup-water piping installed aboveground shall be the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

F. Condensate-Drain Piping: Type M, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

3.2 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Select system components with pressure rating equal to or greater than system operating pressure.

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Division 23 "General-Duty Valves for HVAC Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Division 23 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

U. Comply with requirements in Division 23 "Identification for HVAC Piping and Equipment" for identifying piping.

V. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Division 23 "Sleeves and Sleeve Seals for HVAC Piping."

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges.

D. Dielectric Fittings for NPS 5 and Larger: Use dielectric flange kits.

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Division 23 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.

B. Comply with requirements in Division 23 "Seismic Restraint of Suspended Mechanical Utilities" for seismic restraints.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.
5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 7 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
4. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
5. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 1/2 inch.
6. NPS 3 through 4: Maximum span, 12 feet; minimum rod size, 1/2 inch.
7. NPS 5 through 6: Maximum span, 12 feet; minimum rod size, 3/4 inch.

E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 6 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 6 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
4. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
5. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
6. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 1/2 inch.
7. NPS 3 and Larger: Maximum span, 10 feet; minimum rod size, 1/2 inch.

F. Support vertical runs at roof, at each floor, and at 10-foot intervals between floors.

3.5 PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

H. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

I. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Division 23 "Meters and Gages for HVAC Piping."

3.7 CHEMICAL TREATMENT

A. Perform an analysis of makeup water to determine type and quantities of chemical treatment needed to keep system free of scale, corrosion, and fouling, and to sustain the following water characteristics:

1. pH: 9.0 to 10.5.
2. "P" Alkalinity: 100 to 500 ppm.
3. Boron: 100 to 200 ppm.
4. Chemical Oxygen Demand: Maximum of 100 ppm.
5. Corrosion Inhibitor:

    a. Sodium Nitrate: 1000 to 1500 ppm.
    b. Molybdate: 200 to 300 ppm.
    c. Chromate: 200 to 300 ppm.
    d. Sodium Nitrate Plus Molybdate: 100 to 200 ppm each.
    e. Chromate Plus Molybdate: 50 to 100 ppm each.

6. Soluble Copper: Maximum of 0.20 ppm.
7. Tolyiriazole Copper and Yellow Metal Corrosion Inhibitor: Minimum of 10 ppm.
8. Total Suspended Solids: Maximum of 10 ppm.
9. Ammonia: Maximum of 20 ppm.
10. Free Caustic Alkalinity: Maximum of 20 ppm.
11. Microbiological Limits:

    a. Total Aerobic Plate Count: Maximum of 1000 organisms/mL.
    b. Total Anaerobic Plate Count: Maximum of 100 organisms/mL.
    c. Nitrate Reducers: 100 organisms/mL.
    d. Sulfate Reducers: Maximum of zero organisms/mL.
    e. Iron Bacteria: Maximum of zero organisms/mL.

B. Install bypass chemical feeders in each hydronic system where indicated.

1. Install in upright position with top of funnel not more than 48 inches above the floor.
2. Install feeder in minimum NPS 3/4 bypass line, from main with full-size, full-port, ball valve in the main between bypass connections.
3. Install NPS 3/4 pipe from chemical feeder drain to nearest equipment drain and include a full-size, full-port, ball valve.

C. Fill system with fresh water and add liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products from piping. Circulate solution for a minimum of 24 hours, drain, clean strainer screens, and refill with fresh water.

D. Add initial chemical treatment and maintain water quality in ranges noted above for the first year of operation.

3.8 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.

2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 100 psig and 50 psig more than the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 30 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

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RIVERSIDE COUNTY REGIONAL MEDICAL CENTER
ED REMODEL
MORENO VALLEY, CALIFORNIA

SECTION 23 2113.13

UNDERGROUND HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Cased piping system.

1.3 PERFORMANCE REQUIREMENTS

A. Provide components and installation capable of producing hydronic piping systems with the following minimum working-pressure ratings:

1. Chilled-Water Piping: 150 psig.

1.4 ACTION SUBMITTALS

A. Product Data: For the following:

1. Cased piping.

B. Shop Drawings: All underground Chilled and heat distribution lines, as shown on the contract drawings, shall be factory pre-engineered, pre-fabricated and pre-insulated. All straight sections, fittings, anchors and other accessories shall be factory prefabricated excluding fittings requiring thrust blocks. Each system layout shall be computer analyzed and submitted by the piping system manufacturer to determine stresses and movements of the service pipe. The system design shall be in strict conformance with ANSI B31.1 latest edition, and stamped by a registered professional engineer employed by the pre-insulated piping system manufacturer.

1. Calculate requirements for expansion compensation for underground piping.
2. Show expansion compensators, offsets, and loops with appropriate materials to allow piping movement in the required locations. Show anchors and guides that restrain piping movement with calculated loads, and show concrete thrust block dimensions.
3. Show pipe sizes, locations, and elevations. Show piping in trench, conduit, and cased pipe with details showing clearances between piping, and show insulation thickness.

1.5 INFORMATIONAL SUBMITTALS

A. Profile Drawings: Show system piping in elevation. Draw profiles at horizontal scale of ¼ = 1'-0". Indicate manholes and piping. Show types, sizes, materials, and elevations of other utilities crossing hydronic piping.

B. Qualification Data: For qualified Installer.

C. Welding certificates.

D. Material Test Reports: For cased piping.

E. Source quality-control reports.

F. Field quality-control reports.

1.6 QUALITY ASSURANCE

A. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.

B. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

PART 2 - PRODUCTS

2.1 CASED PIPING SYSTEM

A. Description: Factory-fabricated piping with carrier pipe, insulation, and casing.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Perma-Pipe, Inc.
b. Rovanco Piping Systems, Inc.
c. Urecon Ltd.

B. Carrier Pipe:

1. Chilled Water Piping: Filament-wound, fiberglass reinforced polyester resin (FRP).

C. Carrier Pipe Insulation:

1. Polyurethane Foam with 2lb/ft^3 minimum density, 90% minimum closed cell content, insulation compressive strength of 40 psi. Pipe Insulation: Rigid, cellular, high-pressure injected between carrier pipe and jacket.

a. Comply with ASTM C 591; thermal conductivity (k-value) shall not exceed 0.14 Btu x in./h x sq. ft. x deg F at 75 deg F after 180 days of aging.

D. Casing: Type 1 Polyvinyl Chloride (PVC).

E. Casing accessories include the following:

1. Joint Kit: Half-shell, pourable or split insulation, casing sleeve, and shrink-wrap sleeve.
2. Expansion Blanket: Elastomeric foam, formed to fit over piping.
3. End Seals: Shrink wrap the casing material to seal watertight around casing and carrier pipe.

F. Source Quality Control: Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

PART 3 - EXECUTION

3.1 EARTHWORK

A. See Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.2 PIPING APPLICATION

A. Chilled-Water Piping:

1. Cased piping with polyurethane carrier-pipe insulation.

a. Piping Insulation Thickness: 2 inches.

B. Condenser-Water Piping:

3.3 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Remove standing water in the bottom of trench.

C. Do not backfill piping trench until field quality-control testing has been completed and results approved.

D. Install piping at uniform grade of 0.2 percent. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points and elsewhere as required for system drainage. Install manual air vents at high points.

E. Install components with pressure rating equal to or greater than system operating pressure.

F. Install piping free of sags and bends.

G. Install fittings for changes in direction and branch connections.

H. See Section 230517 "Sleeves and Sleeve Seals for HVAC Piping" for sleeves and mechanical sleeve seals through exterior building walls.

I. Secure anchors with concrete thrust blocks. Concrete is specified in Section 033000 "Cast-in-Place Concrete."

3.4 JOINT CONSTRUCTION

A. See Section 330500 "Common Work Results for Utilities" for basic piping joint construction.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

E. Conduit and Cased Piping Joints: Assemble sections and finish joints with pourable or split insulation and exterior jacket sleeve, and apply shrink-wrap seals.

3.5 IDENTIFICATION

A. Install continuous plastic underground warning tapes during back filling of trenches for underground hydronic piping. Locate tapes 6 to 8 inches below finished grade, directly over piping. See Section 312000 "Earth Moving" for warning-tape materials and devices and their installation.

3.6 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Tests and Inspections:

1. Prepare hydronic piping for testing according to ASME B31.9 and as follows:

a. Leave joints, uninsulated and exposed for examination during test.
b. Fill system with water. Where there is risk of freezing, air or a safe, compatible liquid may be used.
c. Use vents installed at high points to release trapped air while filling system.

2. Test hydronic piping as follows:

a. Subject hydronic piping to hydrostatic test pressure that is not less than 1.5 times the design pressure.
b. After hydrostatic test pressure has been applied for 10 minutes, examine joints for leakage. Remake leaking joints using new materials and repeat hydrostatic test until no leaks exist.

3. Test conduit as follows:

a. Seal vents and drains and subject conduit to 15 psig for four hours with no loss of pressure. Repair leaks and retest as required.

E. Prepare test and inspection reports.

END OF SECTION

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RIVERSIDE COUNTY REGIONAL MEDICAL CENTER
ED REMODEL
MORENO VALLEY, CALIFORNIA

SECTION 23 2116

HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes special-duty valves and specialties for the following:

1. Hot-water heating piping.
2. Chilled-water piping.
3. Makeup-water piping.
4. Condensate-drain piping.
5. Air-vent piping.
6. Blowdown-drain piping

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
2. Air-control devices.
3. Hydronic specialties.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Hot-Water Heating Piping: 150 psig at 200 deg F.
2. Chilled-Water Piping: 150 psig at 200 deg F.
3. Boiler feed-water piping: 150 psig at 200 deg F.
4. Makeup-Water Piping: 80 psig at 150 deg F.
5. Condensate-Drain Piping: 150 deg F.
6. Air-Vent Piping: 200 deg F.
7. Blowdown-drain piping: 200 deg F.

2.2 VALVES

A. Gate, Globe, Check, Ball, and Butterfly Valves: Comply with requirements specified in Division 23 "General-Duty Valves for HVAC Piping.

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Division 23 "Direct Digital Controls"

C. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.

1. Manufacturers: Subject to compliance with requirements, provide products by the following provide products by one of the following:

a. Amtrol, Inc.
b. Armstrong Pumps, Inc.
c. Bell & Gossett Domestic Pump.
d. Conbraco Industries, Inc.
e. Spence Engineering Company, Inc.
f. Watts Regulator Co.
g. Kunkle, Division of Tyco.
h. Cash-Acme, Division of Reliance

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Low inlet-pressure check valve.
8. Inlet Strainer: stainless steel, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.

10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

D. Diaphragm-Operated Safety Valves: ASME labeled.

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

    a. Amtrol, Inc.
    b. Armstrong Pumps, Inc.
    c. Bell & Gossett Domestic Pump.
    d. Conbraco Industries, Inc.
    e. Spence Engineering Company, Inc.
    f. Watts Regulator Co.
    g. Kunkle, Division of Tyco.
    h. Cash-Acme, Division of Reliance.

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: Stainless steel, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

E. Pressure Independent Dynamic Flow Control Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

    a. Danfoss
    b. Griswold Controls
    c. Delta P Valve

2. Description: Dynamic control valve shall accurately control flow, independent of system pressure fluctuation. Valve is an electronic, dynamic, modulating 2-way pressure independent globe-style body.

    a. Provide integrated pressure regulator; regulator to control pressure across control valve orifice.
    b. Provide regulator incorporating EPDM diaphragm, stainless steel spring and pressure control disc. Pressure control seat shall be brass construction with vulcanized EPDM.
    c. Provide counterbalance of supply pipe pressure to return pipe pressure across diaphragm to prevent diaphragm damage when control valve is closed.
    d. Provide user adjustable maximum flow within valve control range; Adjustment method shall indicate percentage of valve flow range and utilize spring locked method of adjustment.
    e. Regulate internal control valve differential pressure to provide 100% control valve authority.
    f. Shall have linear flow characteristic.
    g. Provide back seated globe design to allow service of packing under pressure without leakage.