

L. Building Automation Systems

1. Introduction

The following Building Automation System (BAS) Standards provide requirements and guidelines for use by the Consultant in the design and construction of Building Automation Systems at the University of Chicago. These systems are comprised of three primary functions: environmental control, utilities metering and lighting.

General Design Requirements

1. Design shall be a fully integrated Building Automation System (BAS), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities.
2. Scope of BAS systems shall meet Owner's Project Requirements.
3. Design of all mechanical and electrical systems, including all BAS systems (HVAC, utility/sub metering, interior/exterior lighting). The University BAS Manager is to review and approve all BAS systems designs.
4. An accepted/approved sequence of operations shall be completed for all HVAC systems. The University BAS Manager is to be consulted and have approved of all final BAS systems designs, including a BAS commissioning plan sign off.
5. Once final BAS scope is defined, the RFP shall be reviewed and approved by the University BAS Manager before going out for bids. BAS manager will review all bids and assist selecting the proper controls vendor.
6. Complete temperature control system to be DDC with electric actuation.
7. Design systems for future flexibility.
8. Prior to start of design, a complete design phase schedule shall be published to incorporate review period and comment resolution period. Each phase shall be complete prior to moving on to the next phase. A set of deliverable including concept presentation, calculations, contents of drawings and specifications shall be defined and presented to the University BAS Manager prior to start of design.
9. The BAS system design shall be approved by the University BAS Manager prior to issue for construction.
10. Any exceptions to the above items must have prior written approval from Facilities Services Project BAS Manager.

Plan and Specification Requirements

1. Consultants shall coordinate all construction documents with other related disciplines. Coordination of all disciplines items shall be done during project design phase and take place within each phase of the project design schedule.
2. All work shall be specified; specifications shall be formatted in the current CSI Master Specification format.
3. All drawings shall be produced using Computer Aided Drafting software, such as AutoCad or Revit.
4. Operations and Maintenance Manuals shall be submitted during construction. Manuals shall be formatted in current CSI Master Specification format. Reviewed O&M Manuals

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- shall be submitted in full prior to FS Operation participation in start-up activities near the end of construction and to be coordinated with Information Resources standards.
5. Record drawings shall be submitted as CAD files and .pdf file format.
 6. Completion of project shall include Operation and Maintenance (O&M) Manuals. Consultant shall outline requirements for Contractor's submission and review with the University.
 7. Plans and specifications shall include warranty and owner training. Warranty shall include materials and labor during first two years operation from substantial completion date or completion of all punch list items, whichever is later.

Energy Conservation Requirements

1. All new mechanical systems shall be designed to conserve energy and shall conform to the University of Chicago's Energy Policy Guidelines. Forms of energy recovery or conservation shall be investigated to maximize energy efficiency on each project.
2. Proposed systems shall meet or exceed the requirements set forth in the City of Chicago's Energy Conservation Code.
3. Refer to Volume III., K. Mechanical Systems
4. Night set back schedules for space unoccupied times shall be incorporated into design.
5. Demand control ventilation shall be incorporated unless specifically demonstrated not to be feasible.
6. Design systems for spaces that need 24 hours per day operations separate from spaces that can utilize night set back. Example, data centers shall be design separate from the building HVAC system.
7. All incoming utilities shall be metered.

System Design Requirements

1. Refer to the Building Design Criteria Matrix for specific building type requirements.
2. A Basis of Design (BOD) narrative shall be submitted at the end of SD phase of design. The document shall identify all design assumptions and the design intent for the mechanical systems. The narrative may include schematic drawings and diagrams to convey the intent. Life Cycle Cost Analysis and estimated utility usage shall be included. The BOD will be updated throughout the design phases of the project to reflect any revisions or re-evaluations of the project.
3. Design shall meet the most stringent of the Chicago Code, ASHRAE, or University of Chicago's Building Design Criteria Matrix conditions and shall meet latest the most stringent ASHRAE's standard 55 Thermal Environmental Conditions for occupant comfort zone or University of Chicago's Matrix temperatures. System sizing must consider tolerance of system components as a whole.
4. The campus operates 24 hrs/7days a week. Construction shall have appropriate isolation for all systems.

2. System Guidelines

a) Building Automation System (BAS)

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1. System to be a fully integrated Building Automation System (BAS), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified.
2. Complete temperature control system to be DDC with electric actuation as specified herein.
3. All wiring, conduit, panels, and accessories for a complete operational system.
4. BAS Contractor shall be responsible for all electrical work associated with the BAS.
 - a. Perform all wiring in accordance with all local and national codes.
 - b. Install all line voltage wiring, concealed or exposed, in conduit in accordance with the division 26 specifications, NEC and local building code.
 - c. Provide a maximum of 50 feet extension of 120 volt, 20 amp circuits and circuit breakers from Emergency power panels for all BAS equipment power. All control panels shall be wired to building central UPS systems. If no central UPS system is provided, a UPS shall be provided for each Supervisory Controller and each Application Controller deemed to be serving a critical system or function. The UPS should be installed with a network card and an automatic bypass.
 - d. Surge transient protection shall be incorporated in design of system to protect electrical components in all DDC Controllers and operator's workstations.
 - e. All low voltage electrical control wiring throughout the building whether exposed or concealed shall be run in conduit in accordance with the division 26 specifications, local building code and the NEC.
 - f. Provide all miscellaneous field device mounting and interconnecting wiring for all mechanical, electrical, and plumbing systems including fuel oil system, emergency generators, chillers, boilers, heat exchangers, water treatment, AC units, condensing units, expansion tanks, VFDs, unit heaters, filtration systems, terminal units, fan coil units, electric heaters, chiller control system, boiler control system, sump pumps, sewage ejector pumps, utility meters and submeters.
 - g. All systems requiring interlock wiring shall be hardwired interlocked and shall not rely on the BAS to operate (e.g. emergency generator to fuel oil pump interlock, emergency generator damper interlock, etc.) Interlock wiring shall be run in separate conduits from BAS associated wiring.
 - h. All wells for water flow metering/monitoring devices, temperature and pressure sensors, flow switches and alarms, as required.
 - i. All installation kits for fluid flow meters, allow service and removal under pressure.
5. Provide open communications system. The system shall be an open architecture with the capabilities to support a multi-vendor environment. To accomplish this effectively, system shall be capable of utilizing industry-standard protocols as follows as well as be able to integrate third-party systems via existing vendor protocols.
 - a. System shall be capable of high speed Ethernet communication using BACnet/IP and TCP/IP protocol for supervisory-level network and BACnet MS/TP for field-level network.
 - b. System shall be capable of BACnet communication according to ANSI/ASHRAE 135-2004.

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- c. System shall be capable of OPC server communications according to OPC Data Access 2.0 and Alarms and Events 1.0.
 - d. All supervisory and field-level controllers shall be BACnet Testing Laboratory (BTL) certified and listed under the appropriate device profile.
 - e. The system shall be capable of supporting both industry-standard and vendor specific protocols to integrate a wide variety of third-party devices and legacy systems.
 - f. All operator interface computer hardware and standard peripherals are to be furnished by the University's ITS Department. If, for any reason, this hardware is furnished by the BAS Contractor, it shall match the University's ITS Department standards exactly and utilize ITS standard images.
6. Provide hardware, software, and wiring to provide communication interfaces with each of the systems listed below.
- a. UPS System
 - b. PDUs and Static Transfer
 - c. ATS Switches
 - d. Computer Room Air Conditioning (CRAC)
 - e. Emergency Generators
 - f. Lighting Control System
 - g. Closed Circuit TV
7. Provide system graphics for each controlled device and/or integrated systems as required by the owner. Origin of information shall be transparent to the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BAS.
8. System should be web based with the user interface software – including graphics - imbedded in each Building Controller. All computers connected physically or virtually to the BAS network shall have access to the web based user interface.
9. Primary DDC panels as follows:
- a. Minimum one (1) BAS system Advanced Application Controller (AAC) panel per each major mechanical system:
 - i. Air Handling Unit
 - ii. Hot Water heat Exchangers and associated pumps
 - iii. Chillers and associated pumps
 - iv. Cooling Towers associated pumps
 - v. Emergency Generator
 - vi. Fuel Oil System
 - b. It shall be acceptable to combine up to three (3) of the following mechanical equipment into one (1) Advanced Application Controller (AAC) panel:
 - i. Exhaust Fans
 - ii. Standalone Supply Fans
 - 1) Package AC Units

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- c. It is acceptable to wire the following systems into any of the Advanced Application Controller (AAC) panels:
 - i. Miscellaneous alarm monitoring (i.e. ATS, leak, temperature, light ...etc.)
 - ii. Miscellaneous equipment (i.e. Unit Heater, Domestic Water Heater, Standalone Dampers ...etc.)
 - d. Motors in motor control centers shall be controlled from the DDC controller associated with HVAC system. It shall not be acceptable to control all motors in a MCC from one DDC controller dedicated to the MCC. The intent of this specification is that the loss of any one DDC controller shall not affect the operation of other HVAC systems, only for the points connected to the DDC controller.
10. Stand-alone Application Specific Controllers (ASCs) for terminal equipment (CAV, FP VAV, and VAV units, and fan coil units).
11. Approved Control System Contractors and Managers
- a. The BAS system shall be furnished, engineered, and installed by one of the factory-authorized branch office of the following approved Control System Contractors and Manufacturers:
 - i. Johnson Controls, Inc.
 - ii. Siemens Building Technologies, Inc.
 - b. Any deviations from the above list must be reviewed and approved by the University's BAS Department Manager.
12. Quality Assurance
- a. The BAS system shall be designed and installed, commissioned and serviced by factory trained personnel. BAS contractor shall have an in-place support facility within 100 miles of the site with technical staff, spare parts inventory and necessary test and diagnostic equipment. The BAS contractor shall provide full time, on site, experienced project manager for this work, responsible for direct supervision of the design, installation, start up and commissioning of the BAS. The Bidder shall be regularly engaged in the installation and maintenance of BAS systems and shall have a minimum of ten (10) years of demonstrated technical expertise and experience in the installation and maintenance of BMS systems similar in size and complexity to this project.
 - b. The BAS contractor shall maintain a service organization consisting of factory trained service personnel and provide a list of 10 projects, similar in size and scope to this project, completed within the last five years.
 - c. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.
 - d. All BAS peer-to-peer building controllers and local user displays shall be UL Listed under Standard UL 916, category PAZX; Standard ULC C100, category UUKL7; and under Standard UL 864, categories UUKL, UDTZ, and QVAX and be so listed at the time of bid. All field level controllers shall comply, at a minimum, with UL Standard UL 916 category PAZX; and be so listed at the time of Bid.

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- e. The BAS peer-to-peer network controllers and local user display shall also comply with the European Electromagnetic Compatibility (EMC) Framework, and bear the C-Tic Mark to show compliance. The purpose of the regulation is to minimize electromagnetic interference between electronic products, which may diminish the performance of electrical products or disrupt essential communications.
- f. DDC peer-to-peer controllers shall be compliant with the European EMC Directive, Standards EN 50081-2 and EN 50082-2, at the Industrial Levels. Additionally the equipment shall be compliant with the European LVD Directive and bear the CE mark in order to show compliance to both directives.
- g. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.
- h. The manufacturer of the building automation system shall provide documentation supporting compliance with ISO-9002 (Model for Quality Assurance in Production, Installation, and Servicing) and ISO-140001 (The application of well-accepted business management principles to the environment). The intent of this specification requirement is to ensure that the products from the manufacturer are delivered through a Quality System and Framework that will assure consistency in the products delivered for this project.

13. 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 design shall comply with current editions of the following codes:
 - 1. National Electric Code (NEC), latest edition
 - 2. ANSI/ASHRAE Standard 135- 2010, BACnet--A Data Communication Protocol for Building Automation and Control Networks
 - 3. City of Chicago Building Code, latest edition

b) Equipment

1. Materials:

- a. All products used in this project installation shall be new and currently manufactured and shall have been applied in similar installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner or Owner's representative. Spare parts shall be available for at least five years after completion of this contract.

2. Communication:

- a. The design of the BAS shall support networking of operator workstations and Building Controllers. The network architecture shall consist of two levels, an Ethernet-based primary network for all operator workstations, servers, and Building DDC controllers along with secondary Field Level Networks (FLN) for terminal equipment application specific controllers.
- b. Access to system data shall not be restricted by the hardware configuration of the BAS system. The hardware configuration of the BAS network shall be totally transparent to the user when accessing data or developing control programs.

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- c. Operator Workstation Communication:
 - i. All color graphic operator workstations shall reside on the Ethernet network and the consoles shall be set up in a client/server configuration.
 - ii. The servers will act as the central database for system graphics and databases to provide consistency throughout all system workstations.
 - iii. The network shall allow concurrent use of multiple BAS software site licenses.
 - iv. Provide two (2) identical servers and a shared hard disk drive array. The second “back-up” server shall function as a hot standby back-up and automatically and immediately take over as the system server on a failure of the primary server. Each server shall be an enterprise level fault tolerant server with redundant processors. Servers shall be located on different floors to maximize redundancy. Server consoles shall not be used as operator workstations.
- d. Management Level Network Communication (MLN)
 - i. All PCs shall simultaneously direct connect to the Ethernet Management Level Network without the use of an interposing device.
 - ii. Operator Workstation shall be capable of simultaneous direct connection and communication with BACnet/IP, OPC and TCP/IP corporate level networks without the use of interposing devices.
 - iii. The Management Level Network shall not impose a maximum constraint on the number of operator workstations.
 - iv. Any controller residing on the Building level networks shall connect to Ethernet network without the use of a PC or a gateway with a hard drive.
 - v. Any PC on the Management Level Network shall have transparent communication with controllers on the building level networks connected via Ethernet.
 - vi. Any break in Ethernet communication from the PC to the controllers on the building level networks shall result in a notification at the PC.
 - vii. The standard client and server workstations on the Management Level Network shall reside on industry standard Ethernet utilizing standard TCP/IP, IEEE 802.3.
 - viii. System software applications will run as a service to allow communication with Building Controllers without the need for user log in. Closing the application or logging off shall not prevent the processing of alarms, network status, panel failures, and trend information.
 - ix. Any break in Ethernet communication between the standard client and server workstations on the Management Level Network shall result in a notification at each workstation.
 - x. Access to the system database shall be available from any standard client workstation on the Management Level Network.
 - xi. Client access to client-server workstation configurations over the Internet network shall be available via Web browser interface.
 - xii. Thin Client access to client-server workstation configurations via Windows Terminal Services shall provide multiple, independent sessions of the workstations software. Terminal Services clients shall have full

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functionality, without the need to install the workstation software on the local hard drive.

- e. Primary Network - Panel to Panel Communication:
 - i. All Building Controllers shall directly reside on the primary BACnet/IP Ethernet network such that communications may be executed directly between Building Controllers, directly between server and Building Controllers on a peer-to-peer basis.
 - ii. Systems that operate via polled response or other types of protocols that rely on a central processor, file server, or similar device to manage panel-to-panel or device-to-device communications shall not be acceptable.
 - iii. All operator interfaces shall have the ability to access all point status and application report data or execute control functions for any and all other devices. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the network data.
 - iv. The primary network shall use BACnet/IP over Ethernet. All devices must:
 - 1. Auto-sense 10/100 Mbps networks.
 - 2. Receive an IP Address from a Dynamic Host Configuration Protocol (DHCP) Server or be configured with a Fixed IP Address.
 - 3. Resolve Name to IP Addresses for devices using a Domain Name Service (DNS) Server on the Ethernet network.
 - 4. Allow MMI access to an individual Primary Network Controller using industry standard Telnet software to view and edit entire Primary Network.
 - v. The primary network shall provide the following minimum performance:
 - 1. Provide high-speed data transfer rates for alarm reporting, report generation from multiple controllers and upload/download efficiency between network devices. System performance shall insure that an alarm occurring at any Building Controller is displayed at any PC workstations, all Building Controllers, and other alarm printers within 15 seconds.
 - 2. Message and alarm buffering to prevent information from being lost.
 - 3. Error detection, correction, and re-transmission to guarantee data integrity.
 - 4. Synchronization of real-time clocks between Building Controllers, including automatic daylight savings time corrections.
 - 5. The primary network shall allow the Building Controllers to access any data from, or send control commands and alarm reports directly to, any other Building Controller or combination of controllers on the network without dependence upon a central or intermediate processing device. Building Controllers shall send alarm reports to multiple operator workstations without dependence upon a central or intermediate processing device. The network shall also allow any Building controller to access,

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- edit, modify, add, delete, back up, restore all system point database and all programs.
 6. The primary network controllers shall back-up and restore their own current database including programs, and points without the requirement for connection to a mass storage device.
 7. The primary network controllers shall provide system-wide wild card point search, command, and access direct from any building controller on the network.
 8. The primary network shall allow the Building Controllers to access on-demand display and reports regarding system-wide information including point names, point status, present value, command priority array, trend information, field panel configuration information.
 9. The primary network shall allow the Building Controllers to be configured system-wide by software based tools, and by direct access from any Building Controller on the network. Proprietary vendor specific software shall not be required for system configuration.
 10. The primary network shall allow the Building Controllers to assign password access and control priorities to each point individually. The logon password (at any PC workstation or portable operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. All other points shall not be displayed at the PC workstation or portable terminal. (e.g. all base building and all tenant points shall be accessible to any base building operators, but only certain base building and tenant points shall be accessible to tenant building operators). Passwords and priorities for every point shall be fully programmable and adjustable.
 11. Devices containing custom programming may reside on the Primary Network.
- f. Secondary Network – Advanced Application Controller (AAC) and Application Specific Controller (ASC) Communication:
- i. Communication over the secondary network shall be BACnet MS/TP protocol.
 - ii. This level communication shall support a family of Advanced Application Controllers for pieces of equipment requiring full programmability and Application Specific Controllers for terminal equipment.
 - iii. The AACs and ASCs shall communicate bi-directionally with the Supervisory network through Supervisory Controllers for transmission of global data.
 - iv. A maximum of 96 terminal equipment controllers may be configured on individual secondary network trunks to insure adequate global data and alarm response times.
- g. Internet Based Communication:

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- i. Web Based Operator Interface
 1. The BAS shall provide a web based graphical interface that allows users to access the BAS data via the Internet, extranet, or Intranet. The interface shall use HTML based ASP pages to send and receive data from the BAS to a web browser.
 2. A web server computer will be supplied. The web server shall use Microsoft's IIS server with Windows 2003 Server, or Windows 2008 Server, or later, and support browser access via Microsoft Internet Explorer 5.0 (or higher), or Navigator Netscape 6.0 (or higher).
 3. All information exchanged over Internet shall be optionally encrypted and secure via SSL (provided by Owner).
 4. Access to the web interface may be password protected. Users' rights and privileges to points and graphics will be the same as those assigned at the BAS workstation. An option will exist to only allow users "read" access via the web browser, while maintaining "command" privileges via the BAS workstation.
 5. The web interface shall not require modification or creation of HTML or ASP pages using an HTML editor. All graphics available at the BAS graphical workstation shall be automatically generated to a web server.
 6. The web based interface shall provide the following functionality to users, based on their access and privilege rights:
 - 1) Logon Screen - allows the user to enter their name, password and domain name for logging into the web server.
 - 2) Alarm Display - a display of current BAS System alarms to which the user has access will be displayed. Users will be able to acknowledge and erase active alarms, and link to additional alarm information including alarm messages. Any alarm acknowledgments initiated through the web interface will be recorded to the BAS System activity log.
 - 3) Graphic Display - Display of system graphics, including animated motion, available in the BAS system workstation will be available for viewing over the web browser. Software that requires the creation of dedicated "web" graphics in order to display the graphics via the browser interface will not be acceptable. A graphic selector list will allow users to select any graphics to which they have access. Graphics displays will automatically refresh with the latest change of values. Users will have the ability to command and override points from the graphic display as determined by their user account rights.
 - 4) Point Details - users will have access to point detail information including operational status, operational

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- priority, physical address, and alarm limits, for point objects to which they have access.
 - 5) Point Commanding - users will be able to override and command points they have access to via the web browser interface. Any commands or overrides initiated via the web browser interface will be written to the BAS system central workstation activity log.
 - 7. The web server licensing options will allow concurrent access by a minimum of five (5) browser connections.
 - 8. Internet connections, ISP services, as well as necessary firewalls or proxy servers shall be provided by the owner as required to support the web access feature.
- ii. Terminal Services Operator Interface
 - iii. Client access to client-server workstation configurations over low-bandwidth network technologies shall be available optionally via Windows Terminal Services or Web browser interface. Remote client access via Windows Terminal Services shall provide multiple, independent sessions of the workstations software – Terminal Services clients shall have workstation software access, without the need to install the workstation software on the local hard drive]
- h. Remote Notification Paging System
- i. Workstations shall be configured to send out messages to numeric pagers, alphanumeric pagers, phones (via text to speech technology), SMS (Simple Messaging Service, text messaging) Devices, and email accounts based on a point's alarm condition.
 - ii. There shall be no limit to the number of points that can be configured for remote notification of alarm conditions and no limit on the number of remote devices which can receive messages from the system.
 - iii. On a per point basis, system shall be configurable to send messages to an individual or group and shall be configurable to send different messages to different remote devices based on alarm message priority level.
 - iv. Remote devices may be scheduled as to when they receive messages from the system to account for operators' work schedules.
 - v. System must be configurable to send messages to an escalation list so that if the first device does not respond, the message is sent on to the next device after a configurable time has elapsed.
 - vi. Message detail shall be configurable on a per user basis.
 - vii. During a "flood" of alarms, remote notification messages shall have the ability to optimize several alarms into an individual remote notification message.
 - viii. Workstation shall have the ability to send manual messages allowing an operator to type in a message to be sent immediately.
 - ix. Workstation shall have a feature to send a heartbeat message to periodically notify users that they have communication with the system.
3. Operator Interface:
- a. Workstation hardware:

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- i. University of Chicago shall provide leased computers for all BAS systems.
- b. Server hardware:
 - i. The University of Chicago shall provide leased server capacity for use to the BAS shop and contractors.
- c. Operator Interface Software:
 - i. Basic Interface Description
 - 1. Operator interface software shall minimize operator training through the use of user-friendly and interactive graphical applications, 30-character English language point identification, on-line help, and industry standard Windows application software. Interface software shall simultaneously communicate with and share data between Ethernet-connected building level networks.
 - 2. Provide a graphical user interface that shall minimize the use of keyboard through the use of a mouse or similar pointing device, with a "point and click" approach to menu selection and a "drag and drop" approach to inter-application navigation.
 - 3. The navigation shall be user friendly by utilizing "forward & back" capability between screens and embedded hyperlinks to open graphics, documents, drawings, etc.
 - 4. Selection of applications within the operator interface software shall be via a graphical toolbar menu – the application toolbar menu shall have the option to be located in a docked position on any of the four sides of the visible desktop space on the workstation display monitor, and the option to automatically hide itself from the visible monitor workspace when not being actively manipulated by the user.
 - 5. The software shall provide a multi-tasking type environment that allows the user to run several applications simultaneously. BAS software shall run on a platform that mirrors the current University of Chicago campus IT&S operating systems standard. System database parameters shall be stored within an object-oriented database. Standard Windows applications shall run simultaneously with the BAS software. The mouse or Alt-Tab keys shall be used to quickly select and switch between multiple applications. The operator shall be able to work in Microsoft Word, Excel, and other Windows based software packages, while concurrently annunciating on-line BAS alarms and monitoring information
 - 6. The software shall provide, as a minimum, the following functionality:
 - 1) Real-time graphical viewing and control of the BAS environment
 - 2) Reporting
 - 3) Scheduling and override of building operations
 - 4) Collection and analysis of historical data

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- 5) Point database editing, storage and downloading of controller databases.
- 6) Utility for combining points into logical Point Groups. The Point Groups shall then be manipulated in Graphics, trend graphs and reports in order to streamline the navigation and usability of the system.
- 7) Alarm reporting, routing, messaging, and acknowledgment
- 8) “Collapsible tree,” dynamic system architecture diagram application:
 - a) Showing the real-time status and definition details of all workstations and devices on a management level network
 - b) Showing the real-time status and definition details of all Building Controllers at the Primary Network.
 - c) Showing the definition details of all application specific controllers
- 9) Definition and construction of dynamic color graphic displays.
- 10) Online, context-sensitive help, including an index, glossary of terms, and the capability to search help via keyword or phrase.
- 11) On-screen access to User Documentation, via online help or PDF-format electronic file.
- 12) Automatic database backup at the operator interface for database changes initiated at Building Controllers.
- 13) Display dynamic trend data graphical plot.
 - a) Must be able to run multiple plots simultaneously
 - b) Each plot must be capable of supporting 10 pts/plot minimum
 - c) Must be able to command points directly off dynamic trend plot application.
 - d) Must be able to plot both real-time and historical trend data
- 14) Program editing
- 15) Transfer trend data to 3rd party spreadsheet software
 - a) Scheduling reports
 - b) Operator Activity Log
 - c) Open communications via OPC Server
 - d) Open communications via BACnet Client & Server
7. Enhanced Functionality:
 - 1) Provide functionality such that any of the following may be performed simultaneously on-line, and in any combination, via adjustable user-sized windows. Operator shall be able to drag and drop information between the

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- following applications, reducing the number of steps to perform a desired function (e.g., Click on a point on the alarm screen and drag it to the dynamic trend graph application to initiate a dynamic trend on the desired point):
- a) Dynamic color graphics application
 - b) Alarm management application
 - c) Scheduling application
 - d) Dynamic trend graph data plotter application
 - e) Dynamic system architecture diagram application
 - f) Control Program and Point database editing applications
 - g) Reporting applications
- 2) Report and alarm printing shall be accomplished via Windows Print Manager, allowing use of network printers.
8. Security: Operator-specific password access protection shall be provided to allow the administrator/manager to limit users' workstation control, display and data base manipulation capabilities as deemed appropriate for each user, based upon an assigned password. Operator privileges shall "follow" the operator to any workstation logged onto the University of Chicago BAS VLAN network. The "BAS Shop" shall be able to grant discrete levels of access and privileges, per user, for each point, graphic, report, schedule, and BAS workstation application. And each BAS user account shall use a Windows Operating System user account as a foundation.
 9. The operator interface software shall also include an application to track the actions of each individual operator, such as alarm acknowledgement, point commanding, schedule overriding, database editing, and logon/logoff. The application shall list each of the actions in a tabular format, and shall have sorting capabilities based on parameters such as ascending or descending time of the action, or name of the object on which the action was performed. The application shall also allow querying based on object name, operator, action, or time range.
 10. Dynamic Color Graphics application shall include the following:
 - 1) Must include graphic editing and modifying capabilities
 - 2) A library of standard control application graphics and symbols must be included
 - 3) Must be able to command points directly off graphics application
 - 4) Graphic display shall include the ability to depict real-time point values dynamically with animation, picture/frame control, symbol association, or dynamic informational text-blocks

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- 5) Navigation through various graphic screens shall be optionally achieved through a hierarchical “tree” structure
 - 6) Graphics viewing shall include zoom capabilities
 - 7) Graphics shall be capable of displaying the status of points that have been overridden by a field HAND switch, for points that have been designed to provide a field HAND override capability.
 - 8) Advanced linking within the Graphics application shall provide the ability to navigate to outside documents (e.g., .doc, .pdf, .xls, etc.), Internet web addresses, e-mail, external programs, and other workstation applications, directly from the Graphics application window with a mouse-click on a customizable link symbol.
11. Reports shall be generated on demand or via pre-defined schedule, and directed to CRT displays, printers or file. As a minimum, the system shall allow the user to easily obtain the following types of reports:
- 1) A general listing of all or selected points in the network
 - 2) List of all points currently in alarm
 - 3) List of all points currently in override status
 - 4) List of all disabled points
 - 5) List of all points currently locked out
 - 6) List of user accounts and access levels
 - 7) List all weekly schedules and events
 - 8) List of holiday programming
 - 9) List of control limits and deadbands
 - 10) Custom reports from 3rd party software
 - 11) System diagnostic reports including, list of Building panels on line and communicating, status of all Building terminal unit device points
 - 12) List of programs
 - 13) List of point definitions
 - 14) List of logical point groups (Please see point grouping table for examples)
 - 15) List of alarm strategy definitions (Please see alarm nomenclature table)
 - 16) List of Building Control panels
 - 17) Point totalization report
 - 18) Point Trend data listings
 - 19) Initial Values report
 - 20) User activity report
12. Scheduling and override
- 1) Provide a calendar type format for simplification of time and date scheduling and overrides of building operations. Schedule definitions reside in the PC workstation and in the Building Controller to ensure time equipment scheduling when PC is off-line, PC is not required to

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- execute time scheduling. Provide override access through menu selection, graphical mouse action or function key. Provide the following capabilities as a minimum:
- a) Weekly schedules
 - b) Zone schedules
 - c) Event schedules – an event consists of logical combinations of equipment and/or zones
 - d) Report schedules
 - e) Ability to schedule for a minimum of up to ten (10) years in advance.
- 2) Additionally, the scheduling application shall:
- a) Provide filtering capabilities of schedules, based on name, time, frequency, and schedule type (event, zone, report)
 - b) Provide sorting capabilities of schedules, based on name, time and type of schedule (zone, event, report)
 - c) Provide searching capabilities of schedules based on name – with wildcarding options
13. Collection and Analysis of Historical Data
- 1) Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals (up to four time-based definitions per point) or change of value, both of which shall be user-definable. Trend data shall be collected stored on hard disk for future diagnostics and reporting. Automatic Trend collection may be scheduled at regular intervals through the same scheduling interface as used for scheduling of zones, events, and reports. Additionally, trend data may be archived to network drives or removable disk media for future retrieval.
 - 2) Trend data reports shall be provided to allow the user to view all trended point data. Reports may be customized to include individual points or predefined groups of selected points. Provide additional functionality to allow predefined groups of up to 250 trended points to be easily transferred on-line to Microsoft Excel. BAS contractor shall provide custom designed spreadsheet reports for use by the owner to track energy usage and cost, equipment run times, equipment efficiency, and/or building environmental conditions. BAS contractor shall provide setup of custom reports including creation of data format templates for monthly or weekly reports.
 - 3) Provide additional functionality that allows the user to view real-time trend data on trend graphical plot displays. A minimum of ten points may be plotted, of either real-

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time or historical data. The dynamic graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the display and take "snapshots" of plot screens to be stored on the workstation disk for future recall and analysis. Exact point values may be viewed and the graphs may be printed. A minimum of ten (10) dynamic graphs shall run simultaneously. Operator shall be able to command points directly on the trend plot by double clicking on the point. Operator shall be able to zoom in on a specific time range within a plot. The dynamic trend plotting application shall support the following types of graphs, with option to graph in 3D: line graph, area graph, curve graph, area-curve graph, step graph, and scatter graph. Each graph may be customized by the user, for graph type, graph text, titles, line styles and weight, colors, and configurable x- and y-axes.

14. Dynamic Color Graphic Displays
 - 1) Capability to create color graphic floor plan displays and system schematics for each piece of mechanical equipment, including, but not limited to, air handling units, chilled water systems, hot water boiler systems, and room level terminal units.
 - 2) The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection, point alarm association, or text-based commands. Graphics software shall permit the importing of Autocad or scanned pictures for use in the system.
 - 3) Dynamic temperature values, humidity values, flow values and status indication shall be shown in their actual respective locations within the system schematics or graphic floor plan displays, and shall automatically update to represent current conditions without operator intervention and without pre-defined screen refresh rates.
 - a) Provide the user the ability to display real-time point values by animated motion or custom picture control visual representation. Animation shall depict movement of mechanical equipment, or air or fluid flow. Picture Control shall depict various positions in relation to assigned point values or ranges. A library (set) of animation and picture control symbols shall be included within the operator interface software's graphics application. Animation shall reflect, ON or OFF conditions, and shall also be optionally

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- configurable for up to five rates of animation speed.
- b) Sizable analog bars shall be available for monitor and control of analog values; high and low alarm limit settings shall be displayed on the analog scale. The user shall be able to "click and drag" the pointer to change the setpoint.
- c) Provide the user the ability to display blocks of point data by defined point groups; alarm conditions shall be displayed by flashing point blocks.
- d) Equipment state or values can be changed by clicking on the associated point block or graphic symbol and selecting the new state (on/off) or setpoint.
- e) State text for digital points can be user-defined up to eight characters.
- 4) Colors shall be used to indicate status and change as the status of the equipment changes. The state colors shall be user definable.
- 5) Advanced linking within the Graphics application shall provide the ability to navigate to outside documents (e.g., .doc, .pdf, .xls, etc.), Internet web addresses, e-mail, external programs, and other workstation applications, directly from the Graphics application window with a mouse-click on a customizable link symbol.
- 6) The Windows environment of the PC operator workstation shall allow the user to simultaneously view several applications at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
- 7) A template library of HVAC application and automation symbols shall be provided including fans, valves, motors, chillers, AHU systems, standard ductwork diagrams and laboratory symbols. The BAS shop shall have the ability to add custom symbols to the template library. The clipart library shall include a minimum of 400 application symbols. In addition, a library consisting of a minimum of 700 graphic background templates shall be provided.
- 8) The Graphics application shall include a set of standard Terminal Equipment controller application-specific background graphic templates. Templates shall provide the automatic display of a selected Terminal Equipment controller's control values and parameters, without the need to create separate and individual graphic files for each controller.

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15. System Configuration & Definition

- 1) A “Collapsible tree,” dynamic system architecture diagram/display application of the site-specific BAS architecture showing status of controllers, PC workstations and networks shall be provided. This application shall include the ability to add and configure workstations, Building Controllers, as well as 3rd-party integrated components. Symbols/Icons representing the system architecture components shall be user-configurable and customizable, and a library of customized icons representing 3rd-party integration solutions shall be included. This application shall also include the functionality for real-time display, configuration and diagnostics connections to Building Controllers.
- 2) Network wide control strategies shall not be restricted to a single Building Controller, but shall be able to include data from any and all other network panels to allow the development of Global control strategies.
- 3) Provide automatic backup and restore of all Building controller databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate Building Controller. Changes made at the user-interface of Building Controllers shall be automatically uploaded to the workstation, ensuring system continuity.
- 4) System configuration, programming, editing, graphics generation shall be performed on-line.
- 5) Point database configuration shall be available to the user within a dedicated point database editor application included in the operator interface software. The editor shall allow the user to create, view existing, modify, copy, and delete points from the database.
- 6) The point editor shall have the capability to assign “informational text” to points as necessary to provide critical information about the equipment.
- 7) The point editor shall also allow the user to configure the alarm management strategy for each point. The editor shall provide the option for editing the point database in an online or offline mode with the Building Controllers.
- 8) The operator interface software shall also provide the capability to perform bulk modification of point definition attributes to a single or multiple user-selected points. This function shall allow the user to choose the properties to copy from a selected point to another point

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- or set of points. The selectable attributes shall include, but are not limited to, Alarm management definitions and Trend definitions.
- 9) Control program configuration shall be available to the user within a dedicated control program editor application included in the operator interface software. The editor shall allow for creation, modification and deletion of control programs. The editor shall include a programming assistance feature that interactively guides the user through parameters required to generate a control program. The editor shall also include the ability to automatically compile the program to ensure its compatibility with the Building Controllers. The editor shall provide the option for editing the control programs in an online or offline mode, and also the ability to selectively enable or disable the live program execution within the Building Controllers.
16. Alarm Management
- 1) Alarm Routing shall allow the user to send alarm notification to selected printers or account location(s) based on time of day, alarm severity, or point type.
 - 2) Alarm Notification shall be presented to each workstation in a tabular format application, and shall include the following information for each alarm point: name, value, alarm time & date, alarm status, priority, acknowledgement information, and alarm count. Each alarm point or priority shall have the ability to sound a discrete audible notification.
 - 3) Alarm Display shall have the ability to list & sort the alarms based on alarm status, point name, ascending or descending alarm time.
 - 4) Directly from the Alarm Display, the user shall have the ability to acknowledge, silence the alarm sound, print, or erase each alarm. The interface shall also have the option to inhibit the erasing of active acknowledged alarms, until they have returned to normal status. The user shall also have the ability to command, launch an associated graphic or trended graphical plot, or run a report on a selected alarm point directly on the Alarm Display.
 - 5) Each alarm point shall have a direct link from the Alarm Display to further user-defined point informational data. The user shall have the ability to also associate real-time electronic annotations or notes to each alarm.
 - 6) Alarm messages shall be customizable for each point, or each alarm priority level, to display detailed instructions to the user regarding actions to take in the event of an alarm. Alarm messages shall also have the optional ability

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- to individually enunciate on the workstation display via a separate pop-up window, automatically being generated as the associated alarm condition occurs. The system shall have the ability to modify the priority text based on operator preference.
- 7) Alarm Display application shall allow workstation operators to send and receive real-time messages to each other, for purposes of coordinating Alarm and BAS system management.
4. Building Controller Software
- a. General:
- i. Furnish the following applications software to form a complete operating system for building and energy management as described in this specification.
 - ii. The software programs specified in this Section shall be provided as an integral part of Building Controllers and shall not be dependent upon any higher level computer or another controller for execution.
 - iii. The Building Controller Software shall be capable of BACnet communications. The BACnet Building Controller (B-BC) shall have demonstrated interoperability during at least one BTL Interoperability Workshop and shall substantially conform to BACnet Building Controller device profile as specified in ANSI/ASHRAE Standard 135-2010.
 - iv. Building Controllers shall have the ability to perform energy management routines including but not limited to time of day scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides, start stop time optimization, automatic daylight savings time switch over, night setback control, enthalpy switch over, peak demand limiting, temperature-compensated duty cycling, heating / cooling interlock, supply temperature reset, priority load shedding, and power failure restart.
 - v. The Building Controllers shall have the ability to perform the following pre tested control algorithms:
 1. Two position control
 2. Proportional control
 3. Proportional plus integral control
 4. Proportional, integral, plus derivative control
 5. Automatic tuning of control loops
 6. Model-Free Adaptive Control
 - vi. Each Building Controller shall be provided with an interactive HELP function to assist operators using POT's and remote connected operators.
- b. System Security
- i. User access shall be secured using individual security passwords and user names.
 - ii. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager/owner. Any access that

- exceeds the level originally specified by the owner needs approval by the BAS Manager.
- iii. User Log On / Log Off attempts shall be recorded.
- iv. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.
- v. Use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security in the field panel.
- c. User Defined Control Applications:
 - i. Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.
 - ii. It shall be possible to use any system measured point data or status, any system calculated data, a result from any process, or any user-defined constant in any controller in the system.
 - iii. Any process shall be able to issue commands to points in any and all other controllers in the system.
 - iv. Processes shall be able to generate operator messages and advisories to other operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or pager.
 - v. Controller shall provide a HELP function key, providing enhanced context sensitive on-line help with task-oriented information from the user manual.
- d. Alarm Management:
 - i. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each Network Controller shall perform distributed, independent alarm analysis, minimize network traffic and prevent alarms from being lost. At no time shall the Network Controllers ability to report alarms be affected by either operator or activity at a PC workstation, local I/O device or communications with other panels on the network.
 - ii. Conditional alarming shall allow generation of alarms based upon user defined multiple criteria.
 - iii. An Alarm “shelving” feature shall be provided to disable alarms during testing. (Pull the Plug, etc.).
 - iv. Binary Alarms. Each binary object shall be set to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
 - v. Analog Alarms. Each analog object shall have both high and low alarm limits. Alarming must be able to be automatically and manually disabled.
 - vi. All alarm or point change reports shall include the point's user defined language description and the time and date of occurrence.
 - vii. Alarm reports and messages shall be routed to user-defined list of operator workstations, or other devices based on time and other

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- conditions. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display graphics.
 - viii. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store an alarm message to more fully describe the alarm condition or direct operator response.
 - ix. Each Network Controller shall be capable of storing a library of at least 50 alarm messages. Each message may be assignable to any number of points in the Controller.
 - x. Operator-selected alarms shall be capable of initiating a call to a remote operator device.
- e. Scheduling:
 - i. Provide a comprehensive menu driven program to automatically start and stop designated multiple objects or events in the system according to a stored time.
 - ii. Schedules shall reside in the building controller and shall not rely on external processing or network.
 - iii. It shall be possible to define a group of objects as a custom event (i.e. meeting, athletic activity, etc.). Events can then be scheduled to operate all necessary equipment automatically.
 - iv. For points assigned to one common load group, it shall be possible to assign variable time delays between each successive start and/or stop within that group.
 - v. The operator shall be able to define the following information:
 - 1. Time, day
 - 2. Commands such as on, off, auto, etc.
 - 3. Time delays between successive commands.
 - 4. There shall be provisions for manual overriding of each schedule by an authorized operator.
 - vi. All new fan systems shall have a default operational schedule of:
 - a. Occupied 6:00 am and Unoccupied 9:00 pm.
 - vii. It shall be possible to schedule calendar-based events up to one year in advance based on the following:
 - 1. Weekly Schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop, and night economizer. When a group of objects are scheduled together as an Event, provide the capability to adjust the start and stop times for each member.
 - 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 is executed, it will be discarded and replaced by the standard schedule for that day of the week.
- f. Temperature-compensated duty cycling.
 - i. The DCCP (Duty Cycle Control Program) shall periodically stop and start loads according to various patterns.

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- ii. The loads shall be cycled such that there is a net reduction in both the electrical demands and the energy consumed.
- g. Automatic Daylight Savings Time Switchover: The system shall provide automatic time adjustment for switching to/from Daylight Savings Time.
- h. Night setback control. The system shall provide the ability to automatically adjust setpoints for night control.
- i. Enthalpy switchover (economizer). The Building Controller Software shall control the position of the air handler relief, return, and outside air dampers. If the outside air enthalpy falls below changeover set point the BCS will modulate the dampers to provide 100 percent outside air. The user will be able to quickly changeover to an economizer system based on dry bulb temperature and will be able to override the economizer cycle and return to minimum outside air operation at any time.
- j. Loop Control. A Model-Free Adaptive Control algorithm or alternatively a PID (proportional-integral-derivative) closed-loop control algorithm with direct or reverse action and anti-windup shall be supplied. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, set point, and weighting parameters shall be user-selectable.
- k. Sequencing. Provide application software based upon the sequences of operation specified to properly sequence equipment.
- l. Staggered Start:
 - iii. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started, along with the time delay between starts, shall be user definable.
 - iv. Upon the resumption of power, each Building Controller shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.
- m. Totalization:
 - i. Run-Time Totalization. Building Controllers shall automatically accumulate and store run-time hours for all digital input and output points. A high runtime alarm shall be assigned, if required, by the operator.
 - ii. Consumption totalization. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for all analog and digital pulse input type points.
 - iii. Event totalization. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for all points. The event totalization feature shall be able to store the records associated with events before reset.
- n. Data Collection:
 - i. A variety of historical data collection utilities shall be provided to manually or automatically sample, store, and display system data for all points.
 - ii. Building Controllers shall store point history data for selected analog and digital inputs and outputs:

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1. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building Controllers point group.
- iii. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either user-defined interval, manual command or when the trend buffers are full. All trend data shall be available for use in 3rd party personal computer applications.
- iv. Loop Tuning. Building Controllers shall also provide high resolution sampling capability for verification of DDC control loop performance. Documented evidence of tuned control loop performance shall be provided on a <monthly, seasonal, quarterly, annual> period.
 1. For Model-Free Adaptive Control loops, evidence of tuned control loop performance shall be provided via graphical plots or trended data logs. Graphical plots shall minimally include depictions of setpoint, process variable (output), and control variable (e.g., temperature). Other parameters that may influence loop control shall also be included in the plot (e.g., fan on/off, mixed-air temp).
 2. For PID control loops, operator-initiated automatic and manual loop tuning algorithms shall be provided for all operator-selected PID control loops. Evidence of tuned control loop performance shall be provided via graphical plots or trended data logs for all loops.
 - 1) In automatic mode, the controller shall perform a step response test with a minimum one-second resolution, evaluate the trend data, calculate the new PID gains and input these values into the selected LOOP statement.
 - 2) Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.
5. Building Controllers
 - a. Building Controllers shall be at least 32 bit, multi-tasking, multi-user, real-time 100 MHz digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers. Controller size shall be sufficient to fully meet the requirements of this specification and the attached point list.
 - b. Each Building Controller shall have sufficient memory, a minimum of 24 megabyte, to support its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, operator I/O, and dial-up communications.
 - c. Building Controllers shall have an integral real-time clock.
 - d. Each Building Controller shall support firmware upgrades without the need to change hardware.

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- e. Each Building Controller shall support:
 - i. Monitoring of industry standard analog and digital inputs, without the addition of equipment outside the Building Controller cabinet.
 - ii. Monitoring of industry standard analog and digital outputs, without the addition of equipment outside the Building Controller cabinet.
- f. Spare Point Capacity. Each Building Controller shall have a minimum of 10 percent spare point capacity.
 - i. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than one spare of each implemented I/O type.
 - ii. Provide all processors, power supplies, and communication controllers so that the implementation of adding a point to the spare point location only requires the addition of the appropriate:
 - 1. Expansion modules
 - 2. Sensor/actuator
 - 3. Field wiring/tubing.
- g. Serial Communication. Building Controllers shall provide at least one data communication port for operation of operator I/O devices such as industry standard printers, operator terminals, and portable laptop operator's terminals. Building Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected printers or terminals. A USB port shall alternatively be available to support local HMI tools connection.
- h. Self-Diagnostics. Each Building Controller shall continuously perform self diagnostics, communication diagnosis, and diagnosis of all panel components. The Building Controller shall provide both local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication for any system.
- i. Power loss. In the event of the loss of power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 100 hours.
- j. Environment.
 - i. Controller hardware shall be suitable for the anticipated ambient conditions for most mechanical spaces.
 - ii. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
 - iii. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
- k. Immunity to power and noise.
 - i. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
 - ii. 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).

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- iii. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
 - 1. RF-Conducted Immunity (RFCl) per ENV 50141 (IEC 1000-4-6) at 3 V
 - 2. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact
 - 3. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500 V signal, 1 kV power
 - 4. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max)
 - iv. Isolation shall be provided at all Building Controller's AC input terminals to suppress induced voltage transients consistent with:
 - 1. IEEE Standard 587 1980
 - 2. UL 864 Supply Line Transients
 - 3. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)
- 6. Advanced Application Controllers (AACs)
 - a. Each Building Controller shall be able to communicate with Advanced Application Controllers (AACs) over the Secondary Network.
 - b. AACs shall be at least 32 bit, multi-tasking, multi-user, real-time 100 MHz digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers. Controller size shall be sufficient to fully meet the requirements of this specification and the attached point list.
 - c. Each AAC shall have sufficient memory, a minimum of 24 megabyte, to support its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, operator I/O, and dial-up communications.
 - d. AACs shall have an integral real-time clock.
 - e. Each AAC shall support firmware upgrades without the need to change hardware.
 - f. Each AAC shall support:
 - i. Monitoring of industry standard analog and digital inputs, without the addition of equipment outside the AAC cabinet.
 - ii. Monitoring of industry standard analog and digital outputs, without the addition of equipment outside the AAC cabinet.
 - g. Spare Point Capacity. Each AAC shall have a minimum of 10 percent spare point capacity.
 - i. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than one spare of each implemented I/O type.
 - ii. Provide all processors, power supplies, and communication controllers so that the implementation of adding a point to the spare point location only requires the addition of the appropriate:
 - 1. Expansion modules
 - 2. Sensor/actuator

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3. Field wiring/tubing.
- h. Serial Communication. AACs shall provide at least one data communication port for operation of operator I/O devices such as industry standard printers, operator terminals, and portable laptop operator's terminals. AACs shall allow temporary use of portable devices without interrupting the normal operation of permanently connected printers or terminals. A USB port shall alternatively be available to support local HMI tools connection.
- i. Self-Diagnostics. Each AAC shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The Building Controller shall provide both local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication for any system.
- j. Power loss. In the event of the loss of power, there shall be an orderly shutdown of all AACs to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 100 hours.
- k. Environment.
 - i. Controller hardware shall be suitable for the anticipated ambient conditions for most mechanical spaces.
 - ii. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
 - iii. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
- l. Immunity to power and noise.
 - i. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
 - ii. 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).
 - iii. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
 1. RF-Conducted Immunity (RFCI) per ENV 50141 (IEC 1000-4-6) at 3 V
 2. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact
 3. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500 V signal, 1 kV power
 4. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max)
 - iv. Isolation shall be provided at all AAC's AC input terminals to suppress induced voltage transients consistent with:
 1. IEEE Standard 587 1980
 2. UL 864 Supply Line Transients
 3. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-1)

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7. Application Specific Controllers (ASC)

a. General:

- i. Each Building Controller shall be able to communicate with application specific controllers (ASCs) over the Secondary Network to control terminal equipment only.
- ii. The use of Secondary Network controllers with custom program applications to control AHU's, water systems, etc. is not acceptable.
- iii. Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor-based, multi-tasking, real-time digital control processor.
- iv. Each ASC shall include all point inputs and outputs necessary to perform the specified control sequences. The ASC shall accept input and provide output signals that comply with industry standards. Controllers utilizing proprietary control signals shall not be acceptable. Outputs utilized either for two-state, modulating floating, or proportional control, allowing for additional system flexibility.
- v. Space Temperature Sensors. Each controller performing space temperature control shall be provided with a matching room temperature sensor.
 1. Wired Sensor specifications. The sensor may be either RTD or thermistor type providing the following.
 - 1) Accuracy: + .5 F
 - 2) Operating Range: 35 to 115 F
 - 3) Set Point Adjustment Range: 55 to 95 F
 - 4) Calibration Adjustments: None required
 - 5) Installation: Up to 100 ft. from controller
 - 6) Auxiliary Communications Port: as required
 - 7) Local LCD Temperature Display: as required
 - 8) Set Point Adjustment Dial as required
 - 9) Occupancy Override Switch as required
 2. Set Point Modes:
 - 1) Independent Heating, Cooling
 - 2) Night Setback-Heating
 - 3) Night Setback-Cooling
 3. LCD Display. Interactive, two- line liquid crystal display shall allow the operator to query and modify operating parameters of the local room terminal unit from the room sensor. The display shall indicate the space temperature and associated ASC point when not being used to query or modify operating parameters.
 4. Set Point Adjustment. The set point adjustment feature shall allow for modification of the temperature set point by the building occupants and operators. Set point adjustment may be locked out, overridden, or limited as to time or temperature through software by an authorized operator at any central workstation, Building Controller, room sensor two-line display, or via the portable operator's terminal.

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5. Override Switch. An override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant and enabled by building operators. The override shall be limited to two (2) hours (adjustable.) The override function may be locked out, overridden, or limited through software by an authorized operator at the operator interface, Building Controller, room sensor two-line display or via the portable operator's terminal.
 6. Space temperature sensors located in “public” spaces – corridors, entry ways, lobbies, libraries, classrooms, lecture halls, toilet rooms, bathrooms, etc. – are to be provided without display, with setpoint adjustment allowing adjustment within a pre-determined range set by the authorized facility operator, and with override switch which can be enabled or disabled on individual basis by the authorized facility operator. The University and authorized facility operator have the option of modifying individual sensor types and/or functionality. Coordinate with the University staff and authorized facility operator prior to the installation of the space temperature sensors.
 7. Space temperature sensors located in “private” spaces – private offices, open office areas, laboratory spaces, conference rooms, etc. – are to be provided with LCD display, with setpoint adjustment allowing adjustment within a pre-determined range set by the authorized facility operator, and with override switch which can be enabled or disabled on individual basis by the authorized facility operator. The University and authorized facility operator have the option of modifying individual sensor types and/or functionality. Coordinate with the University staff and authorized facility operator prior to the installation of the space temperature sensors.
 8. Provide discharge air temperature sensors on all VAV and constant volume terminal air units.
- vi. Communication. Each controller shall perform its primary control function independent of other Secondary Network communication, or if Secondary Network communication is interrupted. Reversion to a fail-safe mode of operation during Secondary Network interruption is not acceptable.
 - vii. Control Algorithms. The controller shall receive its real-time data from the Building Controller time clock to insure Secondary Network continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) gains for all applications. All PID gains and biases shall be field-adjustable by the user via room sensor LCD or the portable operator's terminal as specified herein. Controllers that incorporate proportional and integral (PI) control algorithms only shall not be acceptable.
 - viii. Control Applications. Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified

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- to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of all applications are not acceptable.
- ix. Calibration. Each controller shall include provisions for manual and automatic calibration of the differential pressure transducer in order to maintain stable control and insuring against drift over time.
 - 1. Manual calibration may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Calibration of the transducer at the controller location shall not be necessary
 - 2. Calibration shall be accomplished by stroking the terminal unit damper actuator to a 0% position so that a 0 CFM air volume reading is sensed. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa.
 - 3. Calibration shall be accomplished by zeroing out the pressure sensor and holding damper at last known position until calibration is complete. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa.
 - x. Memory.
 - 1. Provide each ASC with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM, or minimum of 72-hour battery backup shall be provided. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration.
 - 2. Upon replacement, new ASCs shall recover control function and site specific defaults automatically and resume normal operation.
 - xi. Power Supply. The ASCs shall be powered from a 24 VAC source and shall function normally under an operating range of 18 to 28 VAC, allowing for power source fluctuations and voltage drops. Power supply for the ASC must be rated at a minimum of 125% of ASC power consumption and shall be of the fused or current limiting type. The controls contractor shall provide 24 VAC power to the terminal units by utilizing:
 - 1. The existing line voltage power trunk and installing separate isolation transformers for each controller
 - 2. Dedicated line voltage power source and isolation transformers at a central location and installing 24VAC power trunk to supply multiple ASCs in the area.
 - xii. Environment. The controllers shall function normally under ambient conditions of 32 to 122 F (0 to 50 C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the circuit board assembly.

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- xiii. Immunity to noise. Operation shall be protected against electrical noise of 5-120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
 - xiv. Manufacturer Installed Controls.
 - 1. The controls manufacturer shall furnish ASC and actuator for factory mounting to equipment manufacturer.
 - 2. For VAV terminals where applicable, equipment manufacturer shall provide and install flow-cross sensor, 24 VAC transformer, controls enclosure, fan relay, SCR and factory install, wire and tube ASC controller and actuator.
 - 3. Fan powered VAV terminals shall be equipped with a fan speed controller and relay to change summer and winter speed set point.
8. Input/Output Interface:
- a. Hardwired inputs and outputs may tie into the system through building or application specific controllers.
 - b. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no damage to the controller.
 - c. 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 the effects of contact bounce and noise. Binary inputs shall sense “dry contact” closure without external power (other than that provided by the controller) being applied.
 - d. Pulse accumulation input objects. This type of object shall conform to all the requirements of binary input objects and also accept up to 10 pulses per second for pulse accumulation.
 - e. Analog inputs shall allow the monitoring of low-voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with—and field configurable to—commonly available sensing devices.
 - f. Binary outputs shall provide for On/Off operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on building and custom application controllers shall have three-position (On/Off/Auto) override switches and status lights. Outputs shall be selectable for either normally open or normally closed operation.
 - g. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC, 4 to 20 mA or 0-20 PSI signal as required to provide proper control of the output device. Analog outputs on building or custom application controllers shall have status lights and a two-position (AUTO/MANUAL) switch and manually adjustable potentiometer for manual override. Analog outputs shall not exhibit a drift of greater than 0.4% of range per year.
 - h. Tri-State Outputs. Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal unit control applications (VAV terminal units, duct-mounted heating coils, zone dampers,

- radiation, etc.). Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.
- i. 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.
9. Panel-Mount Uninterruptible Power Supplies
 - a. Building Controller and critical systems field controllers should be on distributed building UPS power. If building UPS power is not available, provide separate UPS's per controller/control panel as described below.
 - b. Provide industrial style DIN-rail mounted uninterruptible power supply module in enclosure, to support BAS controllers and control panels where UPS input power is specified for those controllers and panels.
 10. Tower (or Rack-mounted) Uninterruptible Power Supplies
 - a. Provide uninterruptible power supplies (UPSs) to protect Building Controllers and "critical system" field controllers against power failure, power sag, power surge, under-voltage, over-voltage, line noise, frequency variation, switching transients, and harmonic distortion.
 - b. UPSs shall be tower type with LCD display/interface, rated for 700-3000 VA, be >95% efficient, and include battery backup.
 - c. Features shall include hot-swappable batteries and built-in external maintenance bypass, providing line power to the protected equipment during periods when the UPS is out of service for maintenance, repair, or replacement.
 - d. UPS shall be equipped with communication card enabling connectivity via Ethernet IP protocol to be monitored directly by the ITS Department. [Option: Modbus RTU protocol to enable communication with and monitoring by the BAS system]
 - e. Basis of design product: Eaton model 9130 with communication card option.
 11. Power Supplies and Line Filtering
 - a. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in both primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
 - b. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand a 150% current overload for at least three seconds without trip-out or failure.
 - i. 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.
 - ii. Line voltage units shall be UL recognized and CSA approved.
 - c. Power line filtering and surge protection.
 - i. Provide transient voltage and surge suppression for all workstations, network controllers and other critical panels either internally or as an

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external component. Surge protection shall have the following at a minimum:

1. Dielectric strength of 1000 volts minimum
2. Response time of 10 nanoseconds or less
3. Transverse mode noise attenuation of 65 dB or greater
4. Common mode noise attenuation of 150 dB or better at 40 Hz to 100 Hz.
5. Hot swappable batteries
6. Automatic voltage regulation
7. Automatic bypass
8. Energy efficient design
9. Remote on/off
10. Web/SNMP enabled

12. Auxiliary Control Devices

a. General

i. Specified in this section are the following hard wired input/output devices connected to the Building Controller or ASC.

1. All Automatic Dampers, Valves, Actuators
2. Airflow Measuring Stations (serial data communication also)
3. Binary Temperature Devices
4. Temperature Sensors
5. Dew Point/Humidity Sensors
6. Pressure Sensors
7. Refrigerant Monitor System
8. Analog Water Level Sensors
9. Water Leak Detection Systems
10. Audio/Visual Alarm Units
11. Fuel Oil Meters
12. In-Line Flanged Electromagnetic Flow Meters for Hydronic Measurements
13. Energy BTU Meters
14. Vortex Shedding Flow Meters
15. In-Line Makeup Water, Blowdown, and Condensate Meters
16. Indoor Air Quality (CO₂) Sensors
17. Relays
18. Override Timers
19. Current Transformers
20. Voltage Transmitters
21. Voltage Transformers
22. Power Monitors
23. Current Switches
24. Pressure Electric Switches
25. Electro-pneumatic Transducers
26. Local Control panels
27. Room Pressure Monitor
28. User Interface Touch Screen Display
29. Differential Pressure Monitor

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30. Local User Display
- ii. Specified in this section are the following devices connected to the BAS using serial communication.
 1. Water BTU Meters
 2. Mass Flow Meters
 3. Variable Frequency Drives (VFD)
 4. Air Flow Measuring Stations
 5. Boilers/Boiler Controls Panels
 6. Chillers/Chiller Control Panels
 7. Power Monitors
 8. Room Pressure Monitors
 9. Utility Meters
 10. Lighting Control Panels
- b. All Automatic Dampers, Valves, Actuators
 - i. Dampers:
 1. All automatic dampers furnished by this Contractor for modulating control shall be of the proportioning type with opposed or parallel blades depending on the application or as shown on the drawings; dampers for two position action may be of the parallel blade type.
 2. Automatic dampers shall be manufactured by TAMCO or Ruskin and shall meet the requirements detailed below.
 3. All dampers for outdoor air service to be equal to TAMCO Series 9000 aluminum and have the following features:
 - 1) Frames shall be 4" deep x 1" and no less than .080" in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.
 - 2) Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.
 - 3) Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.
 - 4) Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved.
 - 5) Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16" aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.
 - 6) Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc

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- plated steel to provide positive connection to blades and linkage.
- 7) Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.
 - 8) Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).
 - 9) Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.
 - 10) Dampers shall be made to size required without blanking off free area.
 - 11) Dampers shall be available with either opposed blade action or parallel blade action.
 - 12) Dampers shall be available as “flanged to duct” mounting type.
 - 13) Installation of dampers must be in accordance with manufacturer’s installation guidelines provided with each damper shipment.
 - 14) Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer’s installation guidelines).
4. Dampers for all other applications to be equal to TAMCO Series 1500 Ultra Low Leakage Air Foil Aluminum and have the following features:
- 1) Frames shall be 4” deep x 1” and no less than .080” in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.
 - 2) Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.
 - 3) Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.
 - 4) Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved.
 - 5) Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16” aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.

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- 6) Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc plated steel to provide positive connection to blades and linkage.
 - 7) Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.
 - 8) Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).
 - 9) Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.
 - 10) Dampers shall be made to size required without blanking off free area.
 - 11) Dampers shall be available with either opposed blade action or parallel blade action.
 - 12) Dampers shall be available as "flanged to duct" mounting type.
 - 13) Installation of dampers must be in accordance with manufacturer's installation guidelines provided with each damper shipment.
 - 14) Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer's installation guidelines).
5. Automatic dampers (modulating) shall be designed for face velocity that varies from 1,200 fpm to 2,000 fpm in most cases as approved by the design engineer. Dampers to be selected by the supplier with blade shaft lengths that prevent torsion that will create a leakage of more than 2 percent of the rated leakage capacity. Beyond that point, the dampers shall be broken into multiple sections. Field supplied mullions are required on large dampers exceeding 200 square feet.
 6. Individual damper section actuators are preferred unless access to actuators is difficult and then jack shafting is acceptable. ECC to note that drive shafts between dampers of different air paths (i.e., outdoor air and return air or return air and exhaust air) is not acceptable. Jack shafting between sections is permitted when such shafting is designed to accommodate and eliminate the effects of torsion.
 7. ECC to note that free access to all actuators is the responsibility of the ECC.
 8. Each damper shall be equipped with an individual damper operator of the size and style required for the service intended.

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9. Actuators to be designed for modulating control with spring return to the fail "safe" position. Actuators to be low voltage with 100% surplus torque (submittals to incorporate calculations to prove 100 percent closure under 4.0" wg status pressure differential for modulating service and 2.0" wg for two position application).
 10. Terminal box/AFCV damper actuators to be low voltage, non-spring return, incremental control with 200 percent torque. All control actuators to utilize auto zero program to insure total accuracy of damper actuator. The feature to be activated during periods of low or no occupancy.
 11. Pneumatic damper actuators to be piston type of the size and style to meet application. All modulating dampers to be equipped with pilot positioners to make the full power of the actuator available as well as to allow the operating range and starting point of the actuator to be field adjusted.
- ii. Control Valves:
1. Manufacturer: Manufactured, brand labeled or distributed by Belimo, Johnson Controls, Inc., or Siemens
 2. Control valve actuators:
 - 1) Size for valve close off at 150 percent of total system (head) pressure for two-way valves and 100 percent of pressure differential across the valve or 100 percent of total system (pump) head differential pressure for three-way valves.
 - 2) Coupling: Directly couple and mount to valve stem and shaft ISO style direct-coupled mounting pad.
 - 3) Shall meet all the requirements of 2.1.E Electronic Actuators.
 3. Control valves:
 - 1) Factory fabricated of type, body material and pressure class based on maximum pressure and temperature rating of piping system unless otherwise indicated.
 - 2) Sizing:
 - a) Two-position: Line size or size using a pressure differential of 1 psi.
 - b) Two-way modulating: 5 psid or twice the load pressure drop, whichever is more.
 - c) Three-way modulating: Twice the load pressure drop, but not more than 5 psid.
 - 3) Sizing (steam):
 - a) Two-position: Line size or sized using 10% of inlet gauge pressure.
 - b) Modulating: 15 psig or less inlet steam pressure, the pressure drop shall be 80% of inlet gauge pressure. Higher than 15 psig inlet steam pressure, the pressure drop shall be 42% of the inlet absolute pressure.

- 4) Close-off pressure rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system head pressure for two-way valves and 150 percent of the design pressure differential across the three-way valves. **[Combination of actuator and trim shall provide minimum close-off pressure rating of 100 psid.]**
- 5) The control valve assembly shall be provided and delivered from a single manufacturer as a complete assembly.
4. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditioned (except as noted).
5. Pressure independent control valves:
 - 1) NPS 2 and smaller: Forged brass body rated at no less than 400 psi, chrome plated brass ball and stem, female NPT union ends, dual EPDM lubricated O-rings and a brass Tefzel characterizing disc.
 - 2) NPS 2-1/2 through 6: GG25 cast iron body according to ANSI Class 125, Standard Class B, stainless steel ball and blowout proof stem, flange to match ANSI 125 with a dual EPDM O-ring packing design, PTFE seats and a stainless steel flow characterizing disc.
 - 3) Accuracy: The control valves shall accurately control the flow from 0 to 100% full rated flow with an operating pressure differential range of 5 to 50 psi differential across the valve with a valve body accuracy of $\pm 5\%$ variance due to different pressure fluctuation or $\pm 10\%$ total assembly error incorporating differential pressure fluctuation, manufacturing tolerances and valve hysteresis.
 - 4) Flow characteristics: Equal percentage characteristics.
 - 5) All actuators shall be capable of being electronically programmed in the field by use of external computer software or a dedicated handheld tool for the adjustment of flow. Programming using actuator mounted switches or multi-turn actuators are not acceptable.
6. Characterized control valves:
 - 1) NPS 2 and smaller: Nickel plated forged brass body rated at no less than 400 psi, stainless steel ball and blowout proof stem may be female NPT, sweat connection or pressure connect end fittings with a dual EPDM O-ring packing design, fiberglass reinforced Teflon seat or graphite reinforced PTFE seats and a flow characterizing disc.
 - 2) NPS 2-1/2 through 3: GG25 cast iron body according to ANSI Class 125, Standard Class B, stainless steel ball and blowout proof stem, flange to match ANSI 125 with a dual EPDM O-ring package design, PTFE seats and a stainless steel flow characterizing disc.

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- 3) For steam applications, NPS 1 and smaller: Nickel plated forged brass body rated at no less than 600 psi, stainless steel ball and blowout proof stem, female NPT end fittings with a dual EPDM O-ring packing design, fiberglass reinforced PTFE Teflon seats and a PTFE Teflon flow characterizing disc.
 - a) Flow characteristics: Equal percentage characteristics.
- 4) Globe valves shall have the following characteristics:
 - a) NPS 2 and smaller: ANSI Class 250 bronze body, stainless steel stem, brass plug, bronze seat and a TFE packing.
 - b) NPS 2-1/2 and larger: ANSI Class [125][250] cast iron body, stainless steel stem, bronze plug, bronze seat and a TFE V-ring packing.
 - c) Flow characteristics: Two-way valves shall have equal percentage characteristics. Three-way valves shall have linear characteristics.
 - d) Two and three way globe valves shall be used only if characterized control valves do not fit the sizing criteria or application.
- 5) For steam applications, globe valves shall have the following characteristics:
 - a) NPS 2 and smaller: ANSI Class 250 bronze body, stainless steel seat, stem and plug and a TFE packing.
 - b) NPS 2-1/2 and larger: ANSI Class [125][250] cast iron body, stainless steel seat, stem and plug and a TFE V-ring packing.
 - c) Flow characteristics: Linear or equal percentage characteristics.
7. Butterfly valves – resilient seat:
 - 1) NPS 2 and 12: Valve body shall be full lugged cast iron 200 psig body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize an internal spine. The shaft shall be supported at four locations by RPTFE bushings.
 - 2) NPS 14 and larger: Valve body shall be full lugged cast iron 150 psig body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize a dual pin method to prevent the disc from settling onto the linear. The shaft shall be supported at four locations by RPTFE bushings.
 - 3) Sizing:
 - a) Two position: Line size or size using a pressure differential of 1 psi.
 - b) Modulating: [3 psig][5 psig] or twice the load pressure drop, whichever is more. Size for the design flow with the disc in a 60 degree open position and a design velocity not-to-exceed 12 feet per second.

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- 4) Close off pressure rating:
 - a) NPS 2-12" 200 psi bubble tight shutoff.
 - b) NPS 14 and larger: 150 psi bubble tight shutoff.
8. Butterfly valves – high performance:
 - 1) Valve body shall be full lugged carbon steel ANSI Class [150][300] body with a 316 stainless steel disc without a nylon coating, RTFE seat and be ANSI Class 150/300 flange standards. Blowout proof shaft shall be 17-4 ph stainless steel and shall be supported at four locations by glass backed TFE bushings. Valve packing shall be Chevron TFE and shall include fully adjustable packing flange and separable packing gland. Valve body shall have long stem design to allow for 2" insulation (minimum). Valve face-to-face dimensions shall comply with API 609 and MSS-SP-68. Valve assembly shall be completely assembled and tested, ready for installation.
 - 2) Sizing:
 - a) Two position: Line size or size using a pressure differential of 1 psi.
 - b) Modulating: [3 psig][5 psig] or twice the load pressure drop, whichever is more. Size for the design flow with the disc in a 60 degree open position and a design velocity not-to-exceed 12 feet per second.
 - 3) Flow characteristics: Modified equal percentage, unidirectional.
 - 4) Close off pressure rating: [150][285] psi bubble tight shutoff.
 - 5) Media temperature range: ANSI Class [150][300] limitations.
 - 6) Max differential pressure: 285 psi at 100 deg. F for ANSI 150 (725 psi at 100 deg. F. for ANSI 300).
9. Zone valves (on/off two position applications):
 - 1) NPS 1 and smaller: Forged brass body rated at no less than 300 psi, stainless steel stems, female, NPT union or sweat with a stainless steel stem or EPDM seals.
 - 2) The manufacturer shall warrant all components for a period of 2 years from the date of production.
- iii. Electronic Actuators:
 1. Manufactured, brand labeled or distributed by Belimo, Johnson Controls, Inc., or Siemens.
 2. Size for torque required for damper seal at load conditions.
 3. Coupling: V-bolt dual nut clamp with a V-shaped, toothed cradle.
 4. Mounting: Actuators shall be direct shaft mount type. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
 5. Overload protected electronically throughout rotation.
 6. Fail safe operation: Mechanical, spring return mechanism.
[Electronic fail safe shall incorporate a visual indication of the fail safe status on the face of the actuator. The power fail position shall be field adjustable between 0 to 100% in 10

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deg. F increments. The electronic fail safe shall have a 2 second (adjustable) operational delay.]

7. Power requirements (spring return): 24 VAC, maximum 15 VA at 24 VAC or 8 W at 24 VDC.
 8. Proportional actuators shall be fully programmable through an EEPROM without the use of actuator mounted switches.
 9. Temperature rating: -22 deg. F to +122 deg. F.
 10. Housing: Minimum requirement NEMA Type 2/IP54 mounted in any orientation. NEMA 4/4X (IP67) required for outdoor applications.
 11. Agency listings: ISO 9001 or UL.
 12. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.
 13. All damper actuators used on equipment introducing outdoor air shall be furnished with mechanical spring return mechanism as indicated in “fail safe operation” above.
 14. All actuators shall have external adjustable stops to limit the travel in either direction and a gear release to allow manual positioning.
 15. Actuators shall be provided with position feedback signal (2-10 VDC or 4-20 mA) where indicated on HPE drawings. Feedback signal shall be independent of the input signal and shall provide true position indication.
 16. Actuators on chilled water supply and return isolation valves (that isolate building from campus chilled water supply) shall be equipped with end switches positively indicating, through the building BAS system, the valves have been closed for the season.
- iv. Industrial Actuators (Only to be used with Butterfly Valves – Resilient Seat and Butterfly Valves – High Performance):
1. Manufacturer, brand labeled or distributed by Belimo, Johnson Controls, Inc., or Siemens
 2. The combination of valve and actuator shall meet the close-off requirements as specified in the “Butterfly Valves” portion of this Specification.
 3. Coupling: ISO 5211 mounting standards.
 4. Overload protection: A self-resetting thermal switch embedded in the motor.
 5. Manual override: Actuator shall be equipped with a hand wheel or shaft for manual override to permit operation of the actuator in the event of an electrical power failure.
 6. Power requirements: **[24 VAC][120 VAC]** 1 PH.
 7. Auxiliary switches: 2 SPDT rated 3A at 250 VAC.
 8. Temperature rating: -22 deg. F to +150 deg. F.
 9. Housing: Minimum requirement NEMA Type 4X/IP67 with an industrial quality coating. Actuator shall have an internal heater

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- to prevent condensation within the housing. A visual indication beacon shall indicate position status of the device.
- 10. Agency listing: ISO, UL.
- 11. The manufacturer shall warrant for 2 years from the date of production.
- c. Air Flow Measuring Stations
 - i. Duct-mounted stations shall be installed by the Sheet Metal Contractor while fan inlet station installation responsibility shall be by this Contractor.
 - ii. Sizing and physical location of stations shall be the responsibility of this Contractor. ECC to insure that sufficient distance is available both upstream and downstream such that turbulence is not a factor in the velocity pressure measurement. Sizing shall insure that the minimum velocity across the station affords accuracy of measurement and the design engineer shall be notified within 30 days of contract award if any modifications are required to the field ductwork.
 - iii. ECC to insure that a proper access door upstream of the station is provided in the ductwork such that the inlet face of the unit may be cleaned as necessary.
 - iv. Thermal Dispersion Air Flow Measurement:
 - 1. Air volume measurement system to consist of multiple sensors designed to average velocity using thermal dispersion principles. Sensor probes shall be factory calibrated to NIST² traceable standards. Sensor probes to be Type 6063 gold anodized aluminum or Type 316 SS. Depending on the application, probes may be duct-mounted or fan-inlet type. System to be designed to be totally independent of temperature, density, and humidity. Tek-Air or Ebtron
 - 2. The quantity of sensing tubes shall conform to manufacturer's requirements for spacing based on the specified accuracy and the actual inlet and outlet conditions.
 - 3. Unit to be accurate to 2.0% of reading between 50 fpm and 5,000 fpm.
 - 4. Output Interface:
 - a. Airflow and temperature outputs to be 4-20 mA.
 - b. 10 Base-T Ethernet Output for full duplex communication - field selectable for BACnet Ethernet, BACnet IP, Modbus TCP or TCP/IP
 - c. Programmable alarm can be configured for user-defined High or Low Limit or transmitter/probe fault conditions
- d. Binary Temperature Devices
 - i. Line-voltage space thermostat:
 - 1. Line-voltage thermostats shall be bimetal-actuated, snap acting SPDT contact, enclosed, UL listed for electrical rating. The thermostat cover shall provide exposed set point adjustment

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knob. The thermostat shall operate within the 55°F to 85°F setpoint range, with 2°F maximum differential.

ii. Low-temperature safety thermostat:

1. Low-temperature safety thermostats shall be manually reset, line voltage with maximum 23'-0" flexible sensing elements responsible to lowest temperature along entire length. Furnish minimum two (2) wired in series on the discharge side of the first hydronic coils (i.e., a 4-section coil requires eight low limit thermostats wired in series). Contractor to note that the operating head of such instruments shall be shielded from conditions whereby it could be activated by low temperature. Clarify location of low limits with the Engineer during submittal review if HPE Sheets illustrate a location other than the discharge side of the first hydronic coil.
2. All flexible averaging sensors shall be attached by wire ties to a suspended wire or insulated cable to prevent sensor contact with metal or other unit components.
3. Install flexible sensors across all coils at a maximum of 6" from the bottom of the bottom coil and a minimum of 7" diameter to turn the sensor. Install the detector with a maximum free distance of 12" between each pass.
4. Staggered coils shall utilize multiple sensors. Each sensor shall cover one section of the staggered coil. Sensing elements shall be a minimum of 17' long.
5. All flexible sensors shall be protected at point of penetration of unit via a section of poly tubing to prevent contact of the sensor and the unit.
6. Mount detector within 6" of the face of the coil unless noted otherwise. For staggered coil banks, this requirement applies for each half of the bank
7. ECC to note that when any low-temperature safety controls are above an elevation 7'-0" above floor level or otherwise inaccessible, they shall employ automatic reset and shall be wired to an auxiliary control panel of a 5'-0" elevation. The control panel with piano hinged door shall utilize a latching reset relay for each individual low limit control which insures that the fan is de-energized even as the low limit resets automatically. The panel face shall utilize a red alarm pilot light that remains lit until the 10 second time delay reset relay momentary contact switch is activated. An LED inside the panel shall indicate which of low limits has signaled the alarm.

iii. Aquastat:

1. Strap-on type thermostats shall be provided for low or high temperature limit service on hot water or steam condensate pipes. The thermostats shall be UL listed, with a liquid-filled bulb type sensing element and capillary tubing. The thermostat shall

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- operate within the 20°F to 120°F, or 100°F to 240°F, setpoint range, with an adjustable 6°F differential.
2. The low-limit thermostat shall be automatic reset, snap acting SPDT type with concealed set point adjustment.
- e. Temperature Sensors.
- i. Provide the following instrumentation as required by the monitoring, control and optimization functions. All temperature sensor shall use platinum or nickel RTD elements only, silicon elements are not acceptable. All control signals shall be via a 4-20 mA loop. For critical system applications, only temperature transmitters will be accepted. RTDs and transmitters are acceptable for non-critical applications.
 - ii. Room Temperature:
 1. Temperature monitoring range +40/+90 F (+40/120 F for high temp alarms)
 2. Output signal 4-20 mA, 0-10VDC, 1k ohm
 3. Installation adjustments none required
 4. Calibration adjustments zero & span
 5. Factory calibration point 70 deg F
 6. Accuracy at calibration point +0.5 F
 - iii. Liquid Immersion Temperature
 1. Temperature monitoring range +20/+120 F or +70/+220 F
 2. Output signal 4-20 mA, 0-10VDC, (only)
 3. Installation adjustment none required
 4. Calibration adjustments zero & span
 5. Factory calibration point 70 deg F
 6. Accuracy at calibration point +0.5 F
 - iv. Duct (Single Point) Temperature
 1. Temperature monitoring range +20/+120 F
 2. Output signal 4-20 mA, 0-10VDC, 1k ohm
 3. Installation adjustments none required
 4. Calibration adjustments zero & span
 5. Factory calibration point 70 deg F
 6. Accuracy at calibration point +0.5 F
 - v. Duct (Averaging) Temperature
 1. Temperature monitoring range +20/+120 F
 2. Output signal 4 - 20 mA, 0-10VDC, 1k ohm
 3. Installation adjustments none required
 4. Calibration adjustments zero & span
 5. Factory calibration point 70 deg F
 6. Accuracy at calibration point +0.5 F
 - vi. Outside Air Temperature
 1. Temperature monitoring range -50/+122
 2. Output signal 4-20 mA, 0-10VDC, 1k ohm
 3. Installation adjustments none required
 4. Calibration adjustments zero & span
 5. Factory calibration point 70 deg F
 6. Accuracy at calibration point +0.5 F

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7. The University employs two Central Weather stations. Outdoor air temperature and humidity values should be communicated from the central weather station (primary) nearest the building affected by these specifications. Should the primary weather station fail or lose communication, the outdoor air temperature and humidity values shall be communicated from the backup (secondary) central weather station. Should the secondary weather station fail, lose communication, or if the BAS network fail, the local building BAS network shall use the outdoor air sensor installed for that building (if applicable). If there a local sensor is not connected or available, the building BAS system shall utilize the last communicated outdoor air temperature and humidity values until the communication with the primary weather station is restored.
- 8.
- f. Dew Point/Humidity Sensors
 - i. Outside Air Dew Point Temperature
 1. Dew point monitoring range -40/+115 F DP, 12% to 99% RH
 2. Output signal 4-20 mA
 3. Calibration adjustments zero & span
 4. Factory calibration point 70 F
 5. Accuracy at calibration point +2.0 Fdp
 6. The University employs two Central Weather stations. Outdoor air temperature and humidity values should be communicated from the central weather station (primary) nearest the building affected by these specifications. Should the primary weather station fail or lose communication, the outdoor air temperature and humidity values shall be communicated from the backup (secondary) central weather station. Should the secondary weather station fail, lose communication, or if the BAS network fail, the local building BAS network shall use the outdoor air sensor installed for that building (if applicable). If there a local sensor is not connected or available, the building BAS system shall utilize the last communicated outdoor air temperature and humidity values until the communication with the primary weather station is restored.
 - 7.
 - ii. Room/duct Relative Humidity
 1. Sensor Humidity range 0 to 100%
 2. Operating temperature 15 F to +170 F
 3. Accuracy +2% RH
 4. Sensing element Capacitive sensor
 5. Output signal 4-20 mA DC
 6. Installation adjustments zero & span
 7. Operating temperature 15 F to +170 F
 8. Voltage requirement 12-36 VDC
- g. Differential Pressure Sensors

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- iii. General Air and Water Pressure Sensor Requirements:
 - 1. Pressure sensors shall be constructed to withstand 100% pressure over-range without damage and to hold calibrated accuracy when subject to a momentary 40% over-range input.
 - 2. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
 - 3. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and Owner permanent easy-to-use connection.
 - 4. Provide a minimum of a NEMA 1 housing for the transmitter. Locate transmitters in accessible local control panels wherever possible.
 - 5. Provide a two year warranty for each transmitter. Replace all transmitters found to be defective at no cost to the Owner during the warranty period.
- iv. Water Differential Pressure Applications
 - 1. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
 - 2. The differential pressure transmitter shall have non-interactive zero and span adjustments adjustable from the outside cover and meet the following performance specifications:
 - 1) Maximum differential pressure range 1 to 100 psid (1 to 100 psi. Select range appropriate for system application.
 - 2) Reference Accuracy: $\pm 0.5\%$ of full span (includes non-linearity, hysteresis, and repeatability).
 - 3) Transmitter shall be temperature compensated.
 - 3. Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
 - 4. Acceptable Manufacturers: Rosemount Model 3051.
- v. Pump Differential Pressure Applications
 - 1. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure sensing points.
 - 2. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage. Pressure transmitters shall be constructed to withstand 500% pressure over-range without bursting.
 - 3. The differential pressure transmitter shall have dip-switch selectable operating range adjustments, adjustable from inside the cover. The differential pressure transmitter shall have push-button zero adjustment, resettable from inside the cover.

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4. The differential pressure transmitter shall meet the following performance specifications:
 - 1) Maximum differential pressure range 1 to 250 psid 2 to 250 psi. Select range appropriate for system application.
 - 2) Reference Accuracy: $\pm 1.0\%$ of full span (includes non-linearity, hysteresis, and repeatability).
 - 3) Transmitter shall be temperature compensated.
5. The differential pressure transmitter shall be remotely mounted at the process. The differential pressure transmitter and electronics shall be enclosed in a NEMA 4 enclosure.
6. The differential pressure transmitter shall have a LCD display for local indication of; high port pressure, low port pressure, and differential pressure.
7. The transmitter shall be installed with high and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
8. The differential pressure transmitter shall have a 5 year warranty.
9. Acceptable Manufacturers: Veris Industries PW2 Series, or approved equivalent.
- vi. Building/Space Differential Air Pressure Applications (± 0.25 " WC Critical Applications)
 1. The differential pressure transmitter shall use variable capacitance technology with digital compensation and transmit a linear 0-10 VDC output in response to variation of differential pressure. Pressure transmitter shall be NIST traceable.
 2. Accuracy: $\pm 0.5\%$ of span, including non-linearity, hysteresis, non-repeatability, zero offset and span setting errors.
 3. Long-term stability: $< 0.25\%$ per year
 4. Mounting: DIN rail or standard panel mounting options
 5. Provide shielded static pressure probe at each end of space differential pressure sensor locations. Probe shall have multiple sensing ports, impulse suppression chamber and airflow shielding. Provide suitable probe for indoor & outdoor locations.
 6. Acceptable Manufacturers: Ashcroft CXLdp, Vaisala PDT10x series, or approved equivalent.
- vii. Building/Space Differential Air Pressure Applications (± 0.25 " WC Non-Critical Applications)
 1. The differential pressure transmitter shall use variable capacitance technology with stainless steel micor-tig welded sensor and tensioned stainless steel diaphragm and transmit a linear 0-5 VDC or 4-20 mA output in response to variation of differential pressure.
 2. Accuracy: $\pm 2.25\%$ of span, including non-linearity, hysteresis, non-repeatability, zero offset and span setting errors.
 3. Long-term stability: 0.5% per year
 4. Mounting: DIN rail or standard panel mounting options
 5. Acceptable Manufacturers: Setra 264 series, or approved

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- equivalent.
- viii. Duct Differential Air Pressure Applications (0" to 5" WC (0 to 175) psi)
 - 1. The differential pressure transmitter shall use variable capacitance technology with digital compensation and transmit a linear 0-5 VDC or 4-20 mA output in response to variation of differential pressure.
 - 2. Accuracy: $\pm 0.5\%$ of span, including non-linearity, hysteresis, non-repeatability, zero offset and span setting errors.
 - 3. Long-term stability: $< 0.5\%$ per year
 - 4. Mounting: DIN rail or standard panel mounting options
 - 5. Acceptable Manufacturers: Ashcroft CXLdp, Vaisala PDT10x series, or approved equivalent
 - h. Analog Water Level Sensors
 - i. Furnish and install full height, analog level sensors for each location as specified. Sensor shall provide 4-20ma signal in proportion to basin water level. Provide waterproof enclosure and mounting hardware as required. Sensor shall be Drexel Brook or equal.
 - i. Refrigerant Monitor System
 - ii. The unit shall meet or exceed all requirements of ANSI/ASHRAE 15 plus all local, state, and national codes.
 - iii. The refrigerant monitor shall be housed in a NEMA-4 wall mount enclosure as assembled by manufacturer. Detection of refrigerant vapor concentration shall be refrigerant specific and include circulation of ambient air through a non-dispersing infrared energy cell. Electro-chemical sensing technology employing depletion sensors or short term life sensors, which deplete as a normal part of their operation or storage shelf life, shall not be acceptable.
 - iv. Unit range of sensing shall be 0-100 parts per million (ppm) for refrigerant R-123 and/or 0-1000 ppm for all other refrigerants. Concentrations of refrigerant in the ambient air space will be displayed as PPM on the face of the monitor. The monitoring device shall indicate threshold violation via a status panel readout and remote alarm signaling.
 - 1. Horn / Strobe / Signage
 - 1) Refrigerant leak detection system shall include an audible and visual alarm, located directly outside of each door to the machinery room.
 - 2) Visual alarm shall consist of a flashing yellow light placed directly over the machinery room doors with a sign that states:
 - a) DANGER – DO NOT ENTER WHEN LIGHT IS FLASHING
 - b) PELIGRO – NO ENTRAR CUANDO LA LUZ ESTE
 - v. Sequential sampling and multi-point monitoring shall be employed where airflow currents and/or room size prohibit a representative sample from one sensing point. The system shall have add-on sample point expansion modules available for present configuration and future expansion.

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- vi. Unit to utilize three levels of dry contact alarms to afford the following:
 - 1. Level 1: 25 percent contamination (to energize local strobe light and audible alarm).
 - 2. Level 2: 50 percent contamination (to energize remote alarms and area ventilating process).
 - 3. Level 3: 100 percent contamination (to shut down all chillers in Chiller Room).
- vii. The monitor shall incorporate dry contact relays for each alarm level and a malfunction relay. An analog 4-20ma signal, and an RS-485 digital output shall also be standard equipment.
- j. Water Leak Detection System
 - i. General:
 - 1. Furnish and install a complete water detection system for each area specified. The system shall include electronic alarm and locating modules, sensing cable, graphic maps and all auxiliary equipment. The system shall simultaneously detect the presence of water at any point along the cables length, sound an alarm and pinpoint the distance to the leak. The sensing cable shall be of such construction that no metallic parts shall be exposed to the environment. The system shall provide preconnectorized sensing cable and components. The system shall be UL listed and FM approved.
 - 2. The system shall be as manufactured by Raychem Corporation or equal.
 - 3. Locating leak detection panel (TTB-FA)
 - 4. The alarm and locator module, TTB-FA, shall monitor up to a maximum of 1000 feet of sensing cable. The alarm module shall indicate that water has contacted the sensing cable by sounding an audible alarm, actuating an output relay, sending a proportional 4-20 mA signal to the BAS and displaying the distance from the start of the sensing cable to the start of the first contact with water. The location of the first water contact shall be retained on the display until the cable is dry and the module is updated.
 - 5. The alarm module shall be capable of detecting the presence of a 1 inch leak any where along the cable with a repeatability of +/- 1%.
 - 6. The alarm module shall continuously monitor the sensing cables and interconnecting cables for continuity. Any break in the cable shall generate an audible alarm, activate an output relay and activate a "continuity" LED on the face of the module.
 - 7. The alarm module shall have LED's indicating "power" (green), "alarm" (red) and "continuity" (yellow). The module shall be equipped with exposed test, reset and silence buttons. All other functions shall require key access.
 - 8. The alarm module shall be powered by Emergency power.

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9. The module enclosure shall be a minimum of 16 gauge steel, flush mounting type.
- ii. Single point leak detector
 1. The alarm module, TTC, shall monitor up to a maximum of 50 feet of sensing cable. The alarm module shall indicate that water has contacted the sensing cable by sounding an audible alarm and actuating an output relay. The relay shall be remain activated until the cable is dry and the module is reset.
 2. The alarm module shall be capable of detecting the presence of a 1 inch leak anywhere along the cable with a repeatability of +/- 1%.
 3. The alarm module shall continuously monitor the sensing cables and interconnecting cables for continuity. Any break in the cable shall generate an audible alarm, activate an output relay and activate a "continuity" LED on the face of the module.
 4. The alarm module shall have LED's indicating "power" (green), "alarm" (red) and "continuity" (yellow).
 5. The alarm module shall be powered by Emergency power.
 6. The module shall be mounted in an field equipment cabinet.
- iii. Water sensing cable
 1. The water sensing cable (IT-1000) shall detect the presence of water and pinpoint its location. The cable shall consist of four wires: Two sensor wires, a continuity wire and a return wire. All four wires shall be coated and insulated with a fluoropolymer and wound helically around a fluoropolymer core. the cable shall have a breaking strength, including connectors, of at least 70 pounds, per ASTM D-638. The cable shall have an abrasion resistance of >65 cycles, per UL 719.
 2. The sensing cable shall offer distributed sensing with the ability to detect the location of water at any point along the length of the cable. The cable shall be flexible, and carry less than 24VDC under normal conditions.
 3. The system shall not alarm when in contact with any metallic equipment such as drip pans, floor tile supports, conduit, etc.
 4. The cable shall be available in modular, preconnectorized lengths of 5, 10, 15, 25 and 50 feet. Field splicing shall not be acceptable.
 5. The cable shall be UL 910 rated and plenum rated per NEC 725-2(b).
 6. Provide two sets of test instrumentation to owner.
- iv. Jumper cable
 1. Jumper cable shall be used where leak detection cable is not required but continuity is required (in raceways between alarm module and floor surface, etc.). The jumper cable shall be plenum rated and jacketed with fluoropolymer materials, per NEC 725-2(b). The jumper cable shall consist of four different colors (Y, B, R, G), insulated 18 AWG wires and shall be available in preconnectorized lengths of 5, 10, 15, 25 and 50 feet.

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- v. Accessories
 - 1. Provide all end connectors, leader cables, hold down clips, caution tags, spray adhesive (3M 90M) as required.
- vi. Graphic display map
 - 1. Provide a graphic display map for each room served. The map shall be a 1/8 in = 1.0 ft scaled drawing of the area served, indicating actual equipment locations, floor tile and other points of reference. The actual cable routing shall be clearly marked on the map with actual scaled distances every 10 feet.
 - 2. An dynamic graphic display, equivalent to the aforementioned map, shall be duplicated on the BAS operator workstation. The area in alarm (within 5 feet) shall blink in red until the alarm is cleared.
- vii. Performance
 - 1. A maximum wetted area of 2 inches of cable, at any point along the entire length of cable, shall activate an alarm.
 - 2. The system shall be continuously monitored for continuity. The loss of continuity shall cause an alarm within 5 seconds.
 - 3. The cable shall be capable of being cleaned with a clean dry cloth, in place.
 - 4. The cable shall dry and reset the module immediately upon removal from free water. No shaking, wiping or mechanical action shall be required.
- viii. Installation
 - 1. All system components shall be installed in accordance with the manufacturer's recommendations. The manufacturer shall provide necessary installer training and supervision as required.
 - 2. The cable shall be installed on clean, dry finished surfaces only (coordinate access and schedule installation as required) after the possibility of physical damage has been eliminated. The cable shall be fastened to the surface it is monitoring every 4 feet with hold down clips and spray mastic adhesive. Hold down clip installation shall be subject to spot checks during commissioning. If any clip fails, all other clips shall be re-attached and retested, at no additional cost.
 - 3. The system shall be commissioned prior to acceptance. Submit a test procedure for approval.
- ix. Warranty
 - 1. All equipment shall be warranted to the same extent as the BAS system, or per the manufacturer's warranty, whichever is greater.
- k. Audio/Visual Alarm Units
 - i. Provide 1" x 3" translucent illuminated rectangular alarm light ("BAS Alarm"), sonalert horn (hidden), silence switch with stainless steel cover plate to match desk surface. When any BAS alarm occurs (as coordinated with facilities personnel), the alarm light shall flash once per second (adjustable) and the horn shall sound. When the silence switch is

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- pushed, the horn will silence and the pilot light shall light continuously until alarm is cleared.
 - ii. The BAS shall monitor the alarm light, horn and silence switch status.
 - iii. Provide 1/8 inch high engraved and painted lettering for operational instructions as required by the owner on the cover plate.
 - l. Fuel Oil Meters
 - i. Provide fuel oil flow meter on fuel oil supply for each duplex fuel oil pump set. Meters shall be contacting head type approved for use in fuel oil systems. Monitor total accumulated flow, current flow, monthly total flow, and yearly total flow for each duplex pump set and jockey pump specified or shown.
 - ii. Meter shall be intrinsically safe, explosion proof with a minimum resolution of 10 gallons with GPM range appropriate for application.
 - m. In-Line Flanged Electromagnetic Flow Meters for Hydronic Measurements - CHW, HHW, CW, DW:
 - i. Provide an In-line flanged Electromagnetic Flow Meter complete with integral or remote electronics module. The electronics module shall include a backlit graphic display and external keypad. The principle of operation shall be based of Faraday's Law of Electromagnetic Induction.
 - ii. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations. Connections to the piping shall be ANSI class 150 flanges (*ANSI class 300 where required*). For installations in non-metallic pipe, install grounding rings between flanges. The installing contractor is responsible for providing suitable mating flanges and any required reducer/expander.
 - iii. The flow tube shall be epoxy coated steel; the sensing electrodes shall be 316SS; the liner shall be polypropylene or ebonite for low temperature service, PTFE for hot water service (266 F maximum).
 - iv. Each flow meter shall be individually wet-calibrated and accurate to within $\pm 0.2\%$ of reading from 1.6 to 33 feet per second velocity. A certificate of calibration shall be provided with each flow meter.
 - v. Output signals shall be 4-20 mA and programmable pulse. The flow meter shall be capable of measuring bi-directional flow. Each flow meter shall be factory programmed for its specific application, and shall be re-programmable using the integral keypad on the electronics module (no special interface device or computer required).
 - vi. Coordinate manufacturer's recommended installation requirements with piping contractor to ensure proper installation.
 - vii. Each flow meter shall be covered by the manufacturer's two-year warranty.
 - viii. In-line flanged Electromagnetic Flow Meter shall be ONICON Incorporated Model F-3200, Siemens Sitrans Model MAG 6000, or as approved by the Engineer and/or BAS Department Manager.
 - n. Energy BTU Meters
 - i. The entire Energy BTU Measurement System shall be built and calibrated by a single manufacturer and shall consist of a flow meter, two

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- temperature sensors, a BTU meter, temperature thermowells, and all required mechanical installation hardware. The BTU meter and associated sensors and flow meter shall be installed in accordance with the manufacturer's installation guide.
- ii. The BTU meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy Total, Energy Rate, Flow Rate, Supply Temperature and Return Temperature. Output signals shall be either serial network (protocol conforming to BACnet[®] MS/TP, BACnet/IP, LONWORKS[®], JCI-N2, MODBUS RTU, MODBUS TCP, or Siemens-P1) and/or via individual analog and pulse outputs.
 - iii. Each BTU meter shall be factory programmed and tagged for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required).
 - iv. Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within $\pm 0.15^{\circ}\text{F}$ (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).
 - v. A certificate of NIST traceable calibration shall be provided with each system.
 - vi. Coordinate manufacturer's recommended installation requirements with piping contractor to ensure proper installation.
 - vii. Flow meter shall be in accordance with "In-Line Flanged Electromagnetic Flow Meters for Hydronic Measurements" paragraph above.
 - viii. All equipment shall be covered by the manufacturer's two year warranty.
 - ix. Energy BTU Measurement System shall be ONICON Incorporated System-10 BTU Meter, or as approved by the Engineer.
 - x. Provide isolation valve kit to allow removal and servicing of meter while system is operating.
 - xi. All devices associated with the BTU meters serving the chilled water and ice storage system shall be suitable for the extreme environmental conditions. The devices shall properly operate with the specified accuracy and shall not be affected by the media, or by the environment that includes but not limited to low temperatures (10 Deg F), temperature fluctuations and condensation. Control panel enclosures and electronics shall meet the aforementioned requirements or located strategically to ensure proper operation.
- o. Vortex-Shedding Flow Meters - Mass Flowmeter for Saturated Steam
- i. Furnish and install a Sierra Instruments InnovaMass 240 VTP Model Vortex Mass Flow Meter complete with integral density compensation to provide direct mass steam flow output. The flow meter shall calculate mass flow corrected for density with real time calculations based on temperature measured by an integral 1000 ohm platinum RTD. Mass

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flow inferred from specified steam pressure or calculated externally to the flow meter will not be acceptable. The flow meter shall measure mass flow rate, volumetric flow rate, temperature, pressure, and fluid density. The flow meter shall be sized by the manufacturer for each specific application and installed according to manufacturer's recommendations. Provide a flow straightener, if required to meet the manufacturer's minimum upstream straight pipe run requirement. Provide lateral and horizontal supports as required to minimize vibration at the meter location. The manufacturer shall provide a certificate of calibration for each meter. The flow meter shall be programmed by the manufacturer for each specific application and shall be ready to use upon delivery. Mass flow accuracy shall be within $\pm 1.5\%$ of actual reading over a 30:1 range, including all errors associated with velocity measurement, temperature and/or pressure measurement, and density compensation. Volumetric flow accuracy shall be within $\pm 1.0\%$ of actual reading over a 30:1 range, including all errors associated with velocity measurement, temperature and/or pressure measurement, and density compensation. The meter shall be provided with ANSI class 150 or class 300 flanges as required to meet system requirements. The maximum operating temperature shall be 750 deg F. The flow meter body shall be constructed of 300 series stainless steel and include a weather-tight NEMA-4 aluminum electronics enclosure. The meter shall display steam mass flow rate and mass flow total with an integral LCD display and support field programming of all parameters. The meter shall also have integral diagnostics to verify installation conditions and the proper operation of the meter. The meter shall provide a loop-powered 4-20 mA output signal calibrated in direct mass flow rate units for connection to the Central Control System. In addition, an integral pulse output for steam mass flow totalization shall be provided. All outputs shall be linear with mass flow rate.

- ii. Coordinate manufacturer's recommended installation requirements with piping contractor to ensure proper installation.
- iii. Coordinate location to provide proper straight run of pipe, pipe size, etc.
- iv. Power 24VDC power supply as required from Emergency source.
- v. BAS system shall monitor mass flow rate, volumetric flow rate, total mass, temperature, pressure, and fluid density data via a serial network conforming to one of the following protocols: BACnet MS/TP, HART, MODBUS RTU .
- p. In-Line Makeup Water, Blowdown, and Condensate Meters:
 - i. Provide an industrial-grade, field-calibratable, in-line turbine flow meter complete with integral electronics and flow computer. There will be an option for a local or remote backlit LCD display rate of flow in gallons per minute (gpm).
 - ii. Wetted materials:
 - 1. Housing: 316 Stainless Steel
 - 2. Bearings: Ceramic
 - 3. Shaft: Tungsten Carbide

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4. Rotor: PVDF
5. Rings: 316 Stainless Steel
- iii. The measurable flow range shall be 1 – 200 gpm with an accuracy of $\pm 1.5\%$ or better. Operating temperature range shall be 0° F to +140° F with computer. Pressure rating of 1,500 psi.
- iv. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation, straight pipe recommendations, and upstream filtering requirements. Connections to the piping shall be NPT or ISO (female). For installations in non-metallic pipe, install grounding rings between fittings. The installing contractor is responsible for providing suitable mating flanges or fittings and any required reducer/expander.
- v. Flow computer shall communicate instantaneous (or batch) rate of flow (which is resettable) and cumulative flow (which is non-resettable).
- vi. Meter shall be powered by lithium batteries with option for direct power connection. Batteries will have 5-year battery life.
- vii. Meter shall be the G2 model manufactured by Great Plain Industries, or approved equivalent.
- q. Indoor Air Quality (CO2) Sensors
 - i. Provide indoor air quality sensors to monitor Carbon Dioxide (CO2) levels.
 - ii. The sensors shall utilize single-beam, dual-wavelength, non-dispersive infrared technology.
 - iii. The units shall be wall or duct mounted type as indicated on plans and in the sequence of operation.
 - iv. Wall mounted sensors shall be provided with white plastic cover, with optional LCD display.
 - v. Duct mounted sensors shall be provided with LCD display in a dust proof plastic housing with transparent cover.
 - vi. The sensor shall meet the following requirements:
 1. Operating voltage: 24 VAC/DC
 2. Accuracy: $\pm 2\%$ of range + 2% reading
 3. Power consumption: <2.5W
 4. CO2 measuring range: 0 – 2000 ppm
 5. Tolerance: +/- 100 ppm
 6. Output: 4-20mA, 0 – 10 VDC
 7. Calibration: every 5 years recommended
 8. Long-term Stability: $<\pm 5\%$ of range/5 years
 9. Response time: 1 minute
 - vii. The sensors shall be model: Vaisala GM20 Series.
- r. Relays.
 - i. Control relays shall be UL listed plug-in type with dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
 - ii. Time delay relays shall be UL listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable $\pm 200\%$ (minimum) from set point shown on plans. Contact rating, configuration, and coil voltage

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- shall be suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.
 - iii. Where required, provide “delay on break” relays where the output remains energized for the pre-determined time delay after the input has been de-energized. Reclosing the input switch during timing resets the time delay. Loss of input voltage resets the time delay as well as the output.
- s. Override Timers.
 - i. Override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless otherwise specified. Timer shall be suitable for flush mounting on control panel face and located on local control panels or where shown.
 - ii. Current transmitters.
 - iii. AC current transmitters shall be the self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4 to 20 mA two-wire output. Unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A full scale, with internal zero and span adjustment and $\pm 1\%$ full-scale accuracy at 500 ohm maximum burden.
 - iv. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA Recognized.
 - v. Unit shall be split-core type for clamp-on installation on existing wiring.
- t. Current Transformers.
 - i. AC current transformers shall be UL/CSA Recognized and completely encased (except for terminals) in approved plastic material.
 - ii. Transformers shall be available in various current ratios and shall be selected for $\pm 1\%$ accuracy at 5 A full-scale output.
 - iii. Transformers shall be fixed-core or split-core type for installation on new or existing wiring, respectively.
- u. Voltage Transmitters.
 - i. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4 to 20 mA output with zero and span adjustment.
 - ii. 2 Ranges shall include 100 to 130 VAC, 200 to 250 VAC, 250 to 330 VAC, and 400 to 600 VAC full-scale, adjustable, with $\pm 1\%$ full-scale accuracy with 500 ohm maximum burden.
 - iii. Transmitters shall be UL/CSA Recognized at 600 VAC rating and meet or exceed ANSI/ISA S50.1 requirements.
- v. Voltage Transformers.
 - i. AC voltage transformers shall be UL/CSA Recognized, 600 VAC rated, complete with built-in fuse protection.
 - ii. Transformers shall be suitable for ambient temperatures of 4°C to 55°C (40°F to 130°F) and shall provide $\pm 0.5\%$ accuracy at 24 VAC and a 5 VA load.
 - iii. Windings (except for terminals) shall be completely enclosed with metal or plastic material.
- w. Power Monitors.

- i. Power monitors shall be the three-phase type furnished with three-phase disconnect/shorting switch assembly, UL Listed voltage transformers, and UL Listed split-core current transformers.
 - ii. They shall provide a selectable rate pulse output for kWh reading and a 4 to 20 mA output for kW reading. They shall operate with 5 A current inputs with a maximum error of $\pm 2\%$ at 1.0 power factor or $\pm 2.5\%$ at 0.5 power factor.
- x. Current Switches.
 - i. Current-operated switches shall be self-powered, solid-state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system.
- y. Pressure-Electric (Pe) Switches.
 - i. Shall be metal or neoprene diaphragm actuated, operating pressure rated 0-175 kPa (0-25 psig), with calibrated scale set point range of 14-125 kPa (2-18 psig) minimum, UL listed.
 - ii. 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.
 - iii. Shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
 - iv. Shall have a permanent indicating gauge on each pneumatic signal line to PE switches.
- z. Electro-Pneumatic (E/P) Transducers.
 - i. Electronic/pneumatic transducer shall provide a proportional 20 to 100 kPa (3 to 15 psig) output signal from either a 4 to 20 mA or 0 to 10 VDC analog control input.
 - ii. E/P transducer shall be equipped with the following features:
 - 1. Separate span and zero adjustments
 - 2. Manual output adjustments
 - iii. Pressure gauge assembly d. Feedback loop control
 - iv. Air consumption of 0.05 L/s (0.1 scfm) at mid-range
- aa. Local Control Panels.
 - i. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable sub panels. A single key shall be common to all field panels and sub panels.
 - ii. 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.
 - iii. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.
- bb. Room Pressure Monitor:
 - i. General:

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1. The room pressure monitor shall be CRC-RPM model as manufactured by Critical Room Control (CRC).
2. CRC-RPM1: Monitor the pressure of one pressure relationship.
3. CRC-RPM2: Monitor the pressure of two pressure relationships.
4. The room pressure monitor shall be capable of monitoring up to two (2) differential pressure relationships. Each monitor shall have its own controller capable of standalone operation. Each monitor is capable of both visual and audible alarms. Each monitor will use direct pressure measurement utilizing industrial quality differential pressure transducer technology. Pressure sensing technology shall be a dead ended non-metallic silicon diaphragm that does not allow air/gas to pass from controlled space to reference. The monitor shall be capable of displaying pressure to 0.0001" WC.
 - 1) Implied pressure measurement systems utilizing thermal hot wire or thermal mass air velocity measurement are not acceptable.
5. Each monitor shall have an easy to navigate microprocessor based controller with full color touch screen interface. Minimum touch screen size to be 4.0". Screen shall be capable of displaying multiple colors at the same time. Monitor shall not be limited to single screen size and shall be available in multiple sizes depending on application. All settings and programming shall be made via simple touch screen or communication network. The monitor shall have a full color LED TFT/WQVGA touch screen with a minimum resolution of 480 X 272 (WQVGA), 16 bit (65,535) color depth and sunlight viewable. Panel shall have a minimum brightness rating of 350 cdm for clear indication in all lighting environments. Each monitor shall incorporate a high speed microprocessor based controller, designed for critical environment control applications.
6. The monitor shall have easy to navigate screens that clearly give the user description of any changes that are being made.
 - 1) Displays that simply change the back lighting for color or use LED indicators are not acceptable.
 - 2) Monitors that use keypads and layered menus are not acceptable.
7. Display shall be user programmable with graphics and verbiage included with monitor. Monitor shall store all settings in a non-volatile memory. Monitor will allow user to continually display or hide room differential pressure. Main screen shall be solely reserved for critical information and not display programming or

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menu information. Monitor settings shall be accessed via dual password protected touch screen. Main display shall allow user to select from at least three (3) colors. Monitor shall include automated room changeover including timed clearing and cleaning modes. The monitor shall display the values and setpoints of at least eight (8) auxiliary points in addition to differential pressure. The monitor shall include both visual and audible alarming of both differential pressure and auxiliary points. The monitor shall be field configurable to allow or not allow user to make adjustments setpoints.

8. The monitor shall include at least five (5) modes. Modes shall allow for user to enter customizable naming. Monitor shall display user defined precautions. Precautions shall be field customizable.

9. Monitor shall be recess or surface mounted. Supply voltage shall be 24 VDC.

- 1) Monitors using single or multiple line LCD alphanumeric character displays, LED indicators or backlit screens are not acceptable. Touch pads and layered programming menus are not acceptable.

10. Screen is capable of wipe down cleaning and water spray and dust resistant meeting (IP-54).

ii. Mounting:

1. Monitors shall be mounted outside of controlled space at locations shown on the prints. The monitors shall be mounted in locations that are easily visible and accessible by staff.
2. The room monitor shall be available in both recessed and surface mounting configurations.
3. The monitors shall not require penetration into the wall for mounting. The monitor shall not extend more than 0.75" from the wall.
4. Monitors that require differential pressure lines to be run down the wall to monitor must be copper or stainless steel to eliminate kinking.

iii. Room monitor:

1. The monitor shall use clear unambiguous screen and verbiage to indicate monitor modes and alarms. The main display shall clearly indicate the current status of up to two (2) pressure relationships. The main screen shall allow user to display or not display actual differential pressure. The ability to show and hide actual differential pressure readout shall be accessed from the main

screen without having to reconfigure monitor. The monitor shall display the current user defined precautions without having to reconfigure monitor. The monitor shall display current user defined precautions for entering the space. All pressure relationships and associated differential pressure relationships must be clearly displayed at all times.

2. Monitor shall allow the user to select the background color for the main screen.

- 1) The monitors that change main screen or scroll to display additional relationships are not acceptable. Actual pressure readout must be able to be accessed from the main screen without having to reconfigure monitor.

iv. Modes:

1. The monitor shall have a minimum of five (5) user defined modes. Each mode shall be capable of field configuration and naming. The monitor shall include automated sequences and timing features for procedures and room changeover.
2. Naming of the modes shall be field configurable through the touch screen interface. The modes shall include functionality associated with:

- 1) Isolation/pressure controlled.
- 2) Isolation alarming.
- 3) Occupied non-isolation.
- 4) Clearing of space.
- 5) And cleaning.

3. Mode change shall include optional password protection.
4. All modes shall be capable of automating proper procedures. The modes shall include user selectable timed procedures and staff interaction functions.

- 1) Monitors that allow users to select from fixed verbiage or banners that are not coupled to proper sequencing or logic are not acceptable. All mode changes shall be able to be password protected. Each mode will have unique parameters and screen graphics clearly indicating changed status. Mode and condition of space shall be made with single user change and not require user to make changes to multiple parameters.
- 2) Monitors that do not offer automated function of clearing, cleaning and room changeover are not acceptable.

v. Precautions:

1. The monitor/controller shall include precautions that can be displayed during occupied modes. Precautions shall be selected and automated with modes. The user selected precaution shall be clearly shown on the main screen. The monitor shall be capable of not showing any precautions if current conditions do not require any special safety requirements. Precautions shall be automated with current mode selected.
2. Changes to precautions shall include optional password protection.
 - 1) Monitors that do not integrate and/or automate displaying precautions with mode selection or require user to reconfigure or manual key in verbiage are not acceptable.

vi. More information:

1. Each monitor shall have a dedicated screen capable of displaying up to eight (8) network points. The “more information” screen shall be accessible from the main screen.
2. Each point shall be field configurable for type/name i.e. “temperature, humidity, air change rate, etc.” Each point shall be field configurable to engineering units i.e. °F, °C, WC, etc.”
3. Each point shall allow user to select the appropriate resolution to be displayed. Each point shall:
 - 1) Display status of point.
 - 2) Include audible and visual alarming of point.
 - 3) Display or not display set point.
 - 4) Allow or not allow user to make set point change.

vii. Pressure sensing:

1. The room pressure monitor shall be capable of monitoring up to two (2) differential pressure relationships. The monitor pressure sensing shall continuously monitor bi-directional room pressure and the associated referenced space. Each monitor will use direct pressure measurement utilizing industrial quality differential pressure transducer technology. Pressure sensing technology shall be a dead ended non-metallic diaphragm that does not allow air/gas to pass from controlled space to reference space. Pressure measurement shall use a variable capacitance sensor. Each sensor shall be digitally compensated using an application specific integrated circuit (ASIC).

2. Pressure sensor shall not be limited to monitor and field removable. The pressure sensor shall be capable of replacement without removing monitor. The pressure sensor shall be capable of changing ranges without removing monitor. Pressure sensing operation shall be indicated by integral LED power/status light.
3. Pressure sensor shall be individually calibrated for installed and scheduled range.
4. The room pressure sensing shall be factory calibrated with NIST traceable standards.
 - 1) Implied pressure measurement systems utilizing thermal hot wire, thermal mass air velocity measurement, metallic diaphragm or non-dead ended are not acceptable.
 - 2) Pressure sensors that catalogue accuracy based on larger transducer ranges will not be accepted.
 - 3) Monitor suppliers with pressure sensing integral to monitor shall include one (1) monitor/sensor for every five (5) monitors required for project.

viii. Accuracy:

1. Sensing accuracy shall be $\pm 0.4\%$ or $\pm 0.8\%$ full scale including the effects of non-linearity, non-repeatability, hysteresis, zero offset and span setting errors.
 - 1) All monitors must supply differential pressure sensor accuracy statements that include the effects of non-linearity, hysteresis, non-repeatability, zero offset and span setting errors.
 - 2) Accuracy statement and claims that use the (RSS) root sum squares of non-linearity (BFSL), non-repeatability and hysteresis or exclude zero offset and span setting errors are not acceptable.
2. Stability: Stability per year shall $\leq 0.25\%$ per year.
3. Overpressure limits: Minimum proof pressure of 15 psi and minimum.
4. Burst pressure limits: Minimum burst pressure of 25 psi.
5. Available pressure ranges: The monitor shall support the following pressure ranges:
 - 1) 0/0.1, 0/0.25, 0/0.5, 0/0.75, 0/1.0, 0/2.0, 0/2.5, 0/3.0, 0/5.0, 0/10.0, 25.0.
 - 2) Compound: ± 0.1 , ± 0.25 , ± 0.5 , ± 1.0 , ± 2.0 , ± 5.0 , ± 10.0 .

ix. Pressure sensor setup:

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1. The monitor shall be field configurable to accept multiple signal inputs. The monitor shall accept a hardwired analog signal or network signal.
 2. The monitor shall be field configurable to accept multiple pressure ranges. The monitor shall be capable of accepting multiple input signals of (4-20mA, 0-5V or 0-10V). The monitor shall allow the users to zero calibrate pressure without removing monitor or accessing pressure transducer. Zero function shall be accomplished via room monitor touch screen. The monitor shall display offset of zero calibration. The offset shall be directly field configurable without calibration function.
 3. The monitor shall be able to display in inches of water (“WC) or Pascal’s (pa).
- x. Alarms (audible and visual):
1. Audible alarms:
 - 1) The monitor shall include at least three (3) distinct alarm sounds. Alarms shall include:
 - a) Pressure alarm.
 - b) Remote alarm.
 - c) More info auxiliary alarm.
 - 2) Pressure: The monitor shall include both high and low alarms. Both high and low alarms shall be individually configurable. The monitor shall allow for disabling the audible alarm. The monitor shall allow for programmable audible alarm time delay. The monitor shall be capable of locally and remotely acknowledging the audible alarm. The monitor shall include an acknowledgement time out feature. The acknowledgement time out features silences the audible alarm for user defined time, if alarm condition is not cleared after acknowledgement time period has expired the audible alarm will rest. The acknowledge time out feature shall allow for field configurable time delay or can be disabled. Audible alarm shall be indicated with unique icon appearing on the screen. The alarm icon shall also indicate when alarm has been acknowledged.
 - 3) More information: Audible alarms shall be configurable for each of the eight (8) “more info” points. Alarms shall be able to be locally and remotely silenced. When silenced, the monitor shall visually indicate that the alarm has been silenced. When point being displayed does not have any alarm parameters, the indicator shall be grey. When

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audible alarm has been acknowledged, the indicator will show that alarm has been acknowledged.

2. Visual alarms:

1) Pressure: The monitor shall at all times display current condition and alarm status of all pressure relationships being monitored. If monitor is configured for two pressure relationships, both relationships must be clearly displayed at all times. All pressure alarms must be clearly displayed whenever in pressurized mode. When pressure is not being maintained and inside the timed audible delay period, the monitor screen shall display “loss of pressure” and change indication to amber. The monitor shall include a unique “loss of pressure” icon and verbiage indicating that the differential pressure is outside of designated pressure ranges. When pressure is outside of alarm pressure range and audible delay is not active or delay has elapsed, the monitor shall display “pressure alarm” and change indication to red. The monitor shall include a unique alarm icon and verbiage indicating that the differential pressure is outside of designated pressure ranges. Whenever “loss of pressure” or “pressure alarm” conditions are present, the monitor shall also prompt user to check door.

- a) Monitors that change main screen or scroll to display additional relationships and alarms are not acceptable.
- b) Monitor/controllers that do not specifically indicate status or rely on ambiguous verbiage similar to “caution” are not acceptable.

2) More information: Each point shown on the “More Info” screen shall have individual indication for current point status. When no alarm is present, the status indicator shall be green. When in alarm status, indicator shall be red. When point being displayed does not have any alarm parameters, the indicator shall be grey. When audible alarm has been acknowledged, the indicator shall show that alarm has been acknowledged.

xi. Door contact (optional):

- 1. The monitor shall be capable of supporting multiple door contacts. The door contact shall be stand alone or integral to pressure control logic and sequencing.

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2. The monitor shall support surface mount, recessed mount, overhead door, plunger, disconnect and magnet style door contacts.
3. Door contact shall be field configurable to allow the user option to “freeze” the monitor pressure control PI loop.
4. Door control logic to include:
 - 1) Door closed and pressure is lost: Monitor to bypass “loss of pressure” mode and go directly “pressure alarm” mode.
 - 2) Door open and pressure is lost: Monitor indicates “loss of pressure” mode for alarm delay period. When alarm delay has timed out the monitor will go to “pressure alarm” mode.

xii. Monitor inputs and outputs:

1. The monitor shall have minimum of the following inputs and outputs:
 - 1) Analog inputs: Four (4) analog inputs.
 - 2) Analog outputs: Four (4) analog outputs.
 - 3) Digital inputs: Four (4) digital inputs.
 - 4) Digital contacts: Four (4) digital contacts (relay).
2. The monitor shall include onboard power isolation.
3. The monitor shall include LED light indicators that monitor is powered and working properly.
4. The monitor shall include on board power supply including:
 - 1) 10 vdc.
 - 2) 5 vdc.
 - 3) Power circuit for 4-20mA.

xiii. Power isolation:

1. The monitor shall be powered by 24 VAC. The pressure monitor shall be internally isolated and not require external isolation transformers.
 - 1) Monitors that require isolated power supplies shall be responsible for providing proper isolation transformers with hinged enclosure and manual disconnect. The cost for installing isolated power supplies shall be included in monitor price.

xiv. Network communication:

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1. The monitor shall have an RS-485 serial network interface that supports native BACnet MS/TP. The monitor shall also support Modbus, N2 and Lon with optional card.
2. All network configurations shall be made without removing monitor from the wall or mounting location.
3. All network parameters shall be digitally set via touch screen interface. The monitor network shall be field configurable from the touch screen administrative menu.
4. The monitor shall support baud rates of 9600, 19200, 38400, 56200, 76800 and 115200.
5. The monitor shall support instance ID's of a minimum 1-4,000,000.

xv. Analog communication:

1. The monitor shall be capable of communicating via non-network analog points.
2. A minimum of four (4) relays shall be available for pressure alarm indication.
3. The monitor shall be able to send analog signal of mode change between multiple monitors without the use of a communication network.
4. The monitor shall be able to send and receive analog differential pressures between unlimited monitor/controllers in a daisy chain configuration without the use of a communication network.
5. The monitor shall be able to send analog signal and/or relay contacts for communication with remote monitoring station without the use of a communication network.
 - 1) Monitors that require differential pressure and alarms to be passed to remote monitor and between multiple monitors shall be required to run redundant independent communication networks.

xvi. Password protection:

1. Monitor shall have at least two layers of passwords:
 - 1) Staff password shall allow access to daily functions and mode selection.
 - 2) Administrative password shall allow access to engineering and monitor configuration screens.
2. The staff password shall be able to be deactivated.
3. Staff password shall be able to be changed from the administrative menu.

4. The monitor shall have a unique password for staff use and a separate unique password for the accessing the administrative menu.
 - 1) Monitors that give access to menus while unit is in operation or do not offer separate passwords for staff and administrative functions will not be accepted.
 - 2) All menus shall be hidden from view and only appear when screen is touched. Monitors that only use a single level of password protection are not acceptable.

xvii. Time out feature:

1. The monitor shall have a time out feature. This feature shall return the monitor to the main screen after inactivity (field configurable).

xviii. Watchdog function:

1. The monitor shall continuously monitor its own operation to ensure that it is operating properly. The monitor shall be capable of resetting itself to clear any errors before notification.

xix. Diagnostic screen:

1. The monitor shall graphically show all analog and digital inputs and outputs.
2. Analog inputs shall be shown on a bar indicating 0-100% of full signal.
3. The diagnostic screen shall allow for testing of parameters and system checkout without removal of monitor.
4. Digital inputs shall be indicated as red or green as follows:
 - 1) Open verbiage with green indication.
 - 2) Shut verbiage with red indication.
5. Analog outputs shall be able to be controlled from this screen. The user shall be able to move the outputs from 0-100% signal. The monitor shall send same signal of field components.
6. Allows the user to open and close controller relays as follows:
 - 1) Open verbiage with gray indication.
 - 2) Shut verbiage with red indication.
 - 3) Monitors that do not have I/O diagnostics shall include costs for factory representative on site for any troubleshooting that may be related to I/O for installed locations.

cc. User Interface Touch Screen Display:

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i. General:

1. The room user interface shall be CRC-Multiview Model as manufactured by Critical Room Control (CRC).
2. The Multiview shall be capable of displaying up to six (6) fully configurable environmental point values, room status or mode selection graphical icons. Graphical icons shall be displayed in up to seven (7) different arrangements. Each icon shall be configurable to include the point's title, current value, set point, status and/or mode. Multiview shall be able to display any combination of graphical icons on the same screen.
3. Multiview points shall include individual alarm parameters for each point. The Multiview shall be capable of displaying current point values, set points, point status, mode and alarm parameters. Multiview shall allow for user to make set point, status or mode changes. Each monitor is capable of both visual and audible alarms. Each Multiview monitor will support direct and network capabilities. The Multiview graphical icons shall be individually color configurable.
4. Each Multiview shall have an easy to navigate microprocessor based controller with full color touch screen interface. Minimum touch screen size to be 7.0". Screen shall be capable of displaying multiple colors at the same time. Monitor/controller shall not be limited to single screen size and shall be available in multiple sizes depending on application. All settings and programming shall be made via simple touch screen or communication network. All settings and programming shall be made via simple touch screen or communication network. The monitor shall have a full color LED TFT / WQVGA touch display with a minimum resolution of 800 X 480 (WVGA), 18 bit (262,144) color depth, and sunlight viewable. Panel shall have a minimum brightness rating of 400cdm for clear indication in all lighting environments. Each Monitor shall incorporate a high speed microprocessor based controller, designed for critical environment control applications.
5. Each monitor shall be capable of accepting point information via direct analog signal or from network communication.
6. The monitor shall have easy to navigate screens that clearly give the user description of any changes that are being made:
 - 1) Displays that simply change the back lighting for color or use LED indicators are not acceptable.
 - 2) Monitors that use keypads and layered menus are not acceptable.
7. Display shall be user programmable with graphics and verbiage included with monitor. The Multiview shall store all settings in non volatile memory. The Multiview shall allow the user to

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continually display up to six (6) user configurable point values, point status or modes. Main screen shall be solely reserved for critical information and not display programming or menu information. Multiview shall be accessed via optional password protected touch screen. The Multiview shall include both visual and audible alarming. The Multiview shall be field configurable to allow or not allow user to make adjustments set points, current status and mode change.

8. Monitor shall be recess or surfacemounted. Supply voltage shall be 24 VAC/DC.
9. Monitor shall be recess or surface mounted. Supply voltage shall be 24 VAC/DC.

ii. Mounting:

1. The Multiview shall be mounted at locations shown on the prints. The Multiview shall be mounted in locations that are easily visible and accessible by staff.
2. The Multiview shall be available in both recessed and surface mounting configurations.
3. The Multiview shall not require penetration into the wall for mounting. The monitor shall not extend more than 0.75” from the wall.
4. Controller shall be mounted remote from the monitor. All control wiring shall be connected to the controller located remote from monitor.

iii. Multiview value points:

1. The Multiview shall use clear unambiguous screen and verbiage to indicate current values and alarms. The main screen shall display up to six (6) graphical icons. The monitor shall be field configurable to support between 1-6 graphical icons. Each point on the main screen shall display points and associated set points. Each point shall be configurable to allow or not allow user to adjust set point. Each point's status shall be indicated by color background. If a room goes into alarm, its background will turn red, an audible alarm will sound, and a alarm icon will appear. A user can silence the audible alarm by via a “Silence Alarm” button located on each graphical icon. If a user acknowledges / silences a room's audible alarm, that room's background will remain red until the alarm condition changes to normal. Each value point shall be configurable as an analog or network input/output.

iv. Multiview list/status points:

1. The Multiview shall use clear and unambiguous screen and verbiage to indicate a list of user selectable status points. The main screen shall display up to six (6) graphical icons. The monitor shall be field configurable to support between 1-6 graphical icons. Points shall be fully configurable to change modes, indicate alarms, perform control sequencing etc. The Multiview shall be configurable for up to thirty (30) status points. Each graphical icon list shall allow the user to indicate visual and audible alarms based on selection. A user can silence the audible alarm by via a “Silence Alarm” button located on each graphical icon. Each list point shall color configurable. Each value point shall be configurable as an analog or network input/output.
- v. Multiview mode points:
1. The Multiview shall use clear and unambiguous screen and verbiage to indicate a list of user selectable status points. Each graphical icon shall be field configurable to allow up to 1-5 user defined modes. The Multiview shall be configurable for up to thirty (30) modes. Points shall indicate alarms, perform control sequencing etc. Each graphical icon list shall allow the user to indicate visual and audible alarms based on selection. A user can silence the audible alarm via a “Silence Alarm” button located on each graphical icon. Each mode shall be color coded and field configurable. Each mode point shall be configurable as an analog or network input/output.
- vi. Alarms:
1. The Multiview shall have both audible and visual alarm thresholds:
 - 1) Alarm range high and low shall be active when point values exceed the alarm parameters. The background color of the point shall change and indicate alarm condition. A user can silence the audible alarm by via a “silence alarm” button located on each graphical icon.
 2. The Multiview shall include both high and low alarms. Both high and low alarms shall be individually configurable.
 3. The Multiview shall allow for disabling the audible alarm. The Multiview shall allow for programmable audible alarm time delay. The Multiview shall be capable of locally and remotely acknowledging the audible alarm. Audible alarm shall be indicated with unique icon appearing on the main screen graphical icon. The alarm Icon shall also indicate when alarm has been acknowledged.

4. The Multiview shall allow user to set up both audible and visual alarms based on point status. Status alarms shall be field configurable for both color and alarm.
 5. The Multiview shall allow user to set up both audible and visual alarms based on point mode. Status alarms shall be field configurable for both color and alarm.
- vii. Multiview set point change:
 1. The Multiview shall be field configurable to display current set point and allow access to make local changes to set point. Set point change shall be accessed from the main screen graphical icon.
- viii. Multiview status change:
 1. The Multiview shall be field configurable to display current status and allow access to make local changes to status point. Status change shall be accessed from the main screen graphical icon.
- ix. Multiview mode change:
 1. The Multiview shall be field configurable to display current mode and allow access to make local changes to modes. Mode change shall be accessed from the main screen graphical icon.
- x. Controller inputs and outputs:
 1. The monitor/controller shall have minimum of the following inputs and outputs:
 - 1) Analog inputs: Four (4) analog inputs.
 - 2) Analog outputs: Four (4) analog outputs.
 - 3) Digital inputs: Four (4) digital inputs.
 - 4) Digital outputs: Four (4) digital outputs.
 2. The controller shall include on board power isolation.
 3. The controller shall include LED light indicators that controller is powered and working properly.
 4. The controller shall include on board power supply including:
 - 1) 10 vdc.
 - 2) 5 vdc.
 - 3) Power circuit for 4-20 mA.
- xi. Power isolation:

1. The monitor shall be powered by 24VAC/DC. The pressure monitor/controller shall be internally isolated and not require external isolation transformers.

1) Monitors that require isolated power supplies shall be responsible for providing proper isolation transformers with hinged enclosure and manual disconnect. The cost for installing isolated power supplies shall be included in monitor price.

xii. Network communication:

1. The Multiview shall have an RS-485 serial network interface that supports native BACnet MS/TP. The monitor/controller shall also support Modbus, N2 and Lon with optional card.
2. All network configurations shall be made without removing controller from the wall or mounting location.
3. All network parameters shall be digitally set via touch screen interface. The monitor/controller network shall be field configurable from the touch screen administrative menu.
4. The controller/monitor shall support baud rates of 9600, 19200, 38400, 56200 76800 and 115200. The controller/monitor shall support instance ID's of a minimum of 1-4,000,000.

xiii. Analog communication:

1. The monitor/controller shall be capable of communicating via non-network analog points. The monitor/controller shall send analog signals mirroring associated analog inputs.
2. A minimum of four (4) relays shall be available for alarm, status or mode indication.
3. A minimum of four (4) analog outputs shall be configurable for relaying inputs, communicating set point, status or modes.
4. A minimum of four (4) configurable analog inputs. Inputs shall support analog signals from remote sensors and controllers. Inputs can be configured as a value, mode or status input. The inputs shall be configurable to accept multiple voltage inputs.
5. A minimum of four (4) digital inputs shall be available for alarms, status and mode changes from other monitors, relays or controllers.
6. The monitor/controller shall be able send analog signal and/or relay contacts for communication with remote monitoring station without the use of a communication network.

xiv. Password protection:

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1. Monitor/Controller shall have at least one (1) password. The password shall be field configurable. User shall be able to activate or deactivate password protection.
2. The monitor shall have a time out feature. This feature shall return the monitor to the main screen after inactivity (field configurable). After timeout screen will require user to re-enter password to make changes.
 - 1) Monitors that give access to menus while unit is in operation or do not offer separate passwords for staff and administrative functions will not be accepted.
 - 2) All menus shall be hidden from view and only appear when screen is touched.

xv. Watchdog function:

1. The Monitor/controller shall continuously monitor its own operation to ensure that it is operating properly. The monitor/controller shall be capable of resetting itself to clear any errors before notification.

xvi. Diagnostic screen:

1. The monitor/controller shall graphically show all analog and digital inputs and outputs.
2. Analog inputs shall be shown on a bar indicating 0-100% of full signal.
3. The diagnostic screen shall allow for testing of parameters and system checkout without removal of monitor/controller.
4. Digital inputs shall be indicated as red or green as follows:
 - 1) Open verbiage with green indication.
 - 2) Shut verbiage with red indication.
5. Analog outputs shall be able to be controlled from this screen. The user shall be able to move the outputs from 0-100% signal. The controller shall send same signal to field components.
6. Allows the user to open and close controller relays as follows:
 - 1) Open verbiage with gray indication.
 - 2) Shut verbiage with red indication.

dd. Differential Pressure Monitor:

- i. Differential pressure monitor for space pressure differentials in Surgeries, Isolation Rooms, etc., to be TSI Pressura Model #8630-PM with adjustable update to negate rapid alarm change.
- ii. Unit to include alphanumeric digital display of room pressure differential in inches water gage.

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- iii. Alarm to be initiated with an adjustable 20-600 second delay any time the room pressure differential is less than 0.05" wg.
 - iv. The monitor system shall include sensor, digital interface module, transformer, cables, and a Mute menu key to manually deactivate the audible alarm for 5-minute intervals and then require reset for additional deactivation period.
 - v. Differential Pressure Room Pressure Switch equal to TSI Model #8694-7 with Negative-Neutral key switch and alarm status lights. The key switch will deactivate all alarms when in the Neutral position. All alarms will be active when the key switch is in the Negative position.
- ee. Local User Display
 - i. Where specified in the sequence of operation or points list, the controllers on the peer to peer building level network shall have a display and keypad for local interface. A keypad shall be provided for interrogating and commanding points in the controller.
 - ii. The display shall use the same security password and access rights for points in the display as is used in the associated controller.
 - iii. The LCD display shall be a minimum of a 2 line 40 character display.
 - iv. The LCD display shall include the full point name, value (numeric, digital or state text), point priority and alarm status on one screen.
 - v. The LCD shall dynamically update the value, priority, and alarm status for the point being displayed.
 - vi. The display shall be mounted either on the door of the enclosure or remote from the controller.
- 13. Communication and Control Wiring
 - a. General:
 - i. Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 16 unless otherwise noted herein.
 - ii. All insulated wire to be copper conductors, UL labeled for 90°C minimum service.
 - b. Wire Sizing and Insulation
 - i. Wiring shall comply with minimum wire size and insulation based on services listed below:

1.	Service	Minimum Gage/Type	Insulation Class
2.	AC 24V Power	12 Ga Solid	600 Volt
3.	DC 24V Power	10 Ga Solid	600 Volt
4.	Class 1	14 Ga Stranded	600 Volt
5.	Class 2	18 Ga Stranded	300 Volt
6.	Class 3	18 Ga Stranded	300 Volt
 - ii. Provide plenum-rated cable when open cable is permitted in supply or return air plenum where allowed per execution specifications defined in Paragraph 3.07
 - c. Power Wiring:
 - i. 115V power circuit wiring above 100 feet distance shall use minimum 10 gage.

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- ii. 24V control power wiring above 200 feet distance shall use minimum 12 gage.
 - d. Control Wiring:
 - i. Digital Input/output wiring shall use Class 2 twisted pair, insulated.
 - ii. Analog inputs shall use Class 2 twisted shielded pair, insulated and jacketed and require a grounded shield.
 - iii. Actuators with tri-state control shall use 3 conductor with same characteristics
 - e. Communication Wiring
 - i. Ethernet Cable shall be minimum CAT5
 - ii. Secondary level network shall be 18-24 gage, TSP, low capacitance cable
 - f. Approved Cable Manufacturers:
 - i. Wiring from the following manufacturers which meet the above criteria shall be acceptable:
 - 1. Anixter
 - 2. Belden
- 14. Fiber Optic Cable System
 - a. Please refer to the University of Chicago IT Services Standards.
- 15. Data Information/Connection Outlet
 - A. The installation of data information outlets is mandatory for all new and renovated University buildings in order to comply with industry standards and provide the University with a consistent and sustainable infrastructure.
 - B. For those buildings served and supported by the University of Chicago IT Services (ITS), the ITS Department is responsible for installing all fiber optic cables, patch panels, Category 6A Ethernet cables, routers, switches, and network outlets or “drops” – including network data “drops” required for the BAS system. The University’s Project Manager submits a request for the necessary network data “drops” to the ITS Department. After installation, the BAS Department requests activation of respective data “drops” through the ITS Department.
 - C. For buildings not served and supported by the ITS Department, ITS is responsible for installing the fiber optic cable to the building and terminating it at the main patch panel. Beyond that point, the BAS contractor is responsible for furnishing and installing the Category 6A Ethernet cable, network switches and routers, and network data “drops” required for the BAS system. Refer to the University of Chicago IT Services Standards for network hardware requirements. The BAS Contractor shall follow the installation requirements as stated below:
 - 1. Ethernet cable shall be Commscope Uniprise Category 6A, non-plenum, 4-pair cable supporting 10GB/s Ethernet requirements.
 - 2. At the IDF end, the cable will be terminated at a Category 6A RJ45 Uniprise patch panel.
 - 3. Each data outlet shall have two Category 6A cables installed. One white cable and one gray cable.
 - 4. At the data outlet end, the cable will be terminated at Category 6A 8-position 568B/RJ45 jacks, gray in color, and terminated in a 2-port face plate

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5. Horizontal face plate configuration:
 - a. In a 2-port face plate, the “C1” data jack (first, white cable) shall be in the bottom position and the “C2” data jack (second, gray cable) shall be in the top position.
 - b. In a 4-port face plate, the “C1” data jack shall be in the bottom left position, the “C2” data jack shall be in the top left position, the “C3” data jack shall be in the bottom right position, and the “C4” data jack shall be in the top right position.
6. Vertical face plate configuration:
 - a. In a 2-port face plate, the “C1” data jack (first, white cable) shall be in the left position and the “C2” data jack (second, gray cable) shall be in the right position.
 - b. In a 4-port face plate, the “C1” data jack shall be in the top left position, the “C2” data jack shall be in the top right position, the “C3” data jack shall be in the bottom left position, and the “C4” data jack shall be in the bottom right position.
7. All cable will be secured and dressed with Velcro tie-wraps.
8. Do not install compressed, kinked, scored, deformed, or abraded cable. If any cable is, or becomes damaged, replace the entire length of damaged cable.
9. All data outlets shall be serviced with 1” conduit to the basket tray, or pull box via horizontal conduit system. Conduits shall service only one data outlet each. No daisy-chaining or looping between data outlets is allowed.
10. Labeling:
 - a. For vertical face plates, the location labels shall be installed on the top label holder on the face plate.
 - b. For horizontal face plates, the location labels shall be installed on the left label holder on the face plate.
 - c. For vertical face plates, the IDF labels shall be installed on the bottom label holder on the face plate. This label will contain the IDF room number only.
 - d. For horizontal face plates, the location labels shall be installed on the right label holder on the face plate. This label will contain the IDF room number only.

16. References

The Consultant shall comply with the following codes and standards:

- Current City of Chicago Building Code, including mechanical, plumbing, fire protection, and energy codes.
- ASHRAE standards including ASHRAE 55, ASHRAE 62.1, and ASHRAE 90.1
- All state codes
- FM Global Property Loss Prevention Data Sheets and approved products as applicable.

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