SECTION 23 09 50

BUILDING AUTOMATION SYSTEM (BAS) GENERAL

PART 1 - GENERAL

1.01 SECTION INCLUDES

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B. Section 23 09 51 - Building Automation System (BAS) Basic Materials, Interface Devices, and Sensors

C. Section 23 09 53 - BAS Field Panels

D. Section 23 09 54 - BAS Communication Devices

E. Section 23 09 55 - BAS Software and Programming

F. Section 23 09 58 - Sequences of Operation

G. Section 23 09 59 - BAS Commissioning

1.03 DESCRIPTION OF WORK

A. The building automation system (BAS) defined in this specification shall interface with the Delaware's State Network , and shall utilize the BACnet communication requirements as defined by ASHRAE/ANSI 135 (current version and addendum) for all communication.

B. Contractor shall furnish and install a building automation system (BAS). The new BAS shall utilize electronic sensing, microprocessor-based digital control, and electronic actuation of dampers and valves to perform control sequences and functions specified. The BAS for this project will generally consist of monitoring and control of systems listed below. Reference also control drawings, sequences of operation, and points lists.

C. The systems to be controlled under work of this section basically comprise (describe the scope of the project). The HVAC systems being controlled are (describe systems to be controlled). This Section defines the manner and method by which these controls function.

1.04 APPLICATION OF OPEN PROTOCOLS

A. Subject to the detailed requirements provided throughout the specifications, the BAS and digital control and communications components installed, as work of this contract shall be an integrated distributed processing system utilizing BACnet. System components shall communicate using native BACnet in accordance with ASHRAE Standard 135 and current addenda and annexes, including all workstations, all building controllers, and all application specific controllers. Gateways to other communication protocols are not acceptable

1.05 QUALITY ASSURANCE

A. Product Line Demonstrated History: The product line being proposed for the project must have an installed history of demonstrated satisfactory operation for a length of 2 years since date of final completion in at least 10 installations of comparative size and complexity. Submittals shall document this requirement with references.

The following requirement relates to the actual installing contractor.

B. Installer's Qualifications: Firms specializing and experienced in control system installations for not less than 5 years. Firms with experience in BAS installation projects with point counts equal to this project and systems of the same character as this project. If installer is a Value Added Reseller (VAR) of a manufacturer's product, installer must demonstrate at least three years prior experience with that manufacturer's products. Experience starts with awarded Final Completion of previous projects. Submittals must document this experience with references.

C. Installer's Experience with Proposed Product Line: Firms shall have specialized in and be experienced with the installation of the proposed product line for not less than one year from date of final completion on at least 3 projects of similar size and complexity. Submittals shall document this experience with references.

D. Installer's Field Coordinator and Sequence Programmer Qualifications: Individual(s) shall specialize in and be experienced with control system installation for not less than 5 years. Proposed field coordinator shall have experience with the installation of the proposed product line for not less than 2 projects of similar size and complexity. Installer shall submit the names of the proposed individual and at least one alternate for each duty. Submittals shall document this experience with references. The proposed individuals must show proof of the following training:
   1. Product Line Training: Individuals overseeing the installation and configuration of the proposed product line must provide evidence of the most advanced training offered by the Manufacturer on that product line for installation and configuration
   2. Programming Training: Individuals involved with programming the site-specific sequences shall provide evidence of the most advanced programming training offered by the vendor of the programming application offered by the Manufacturer.

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

F. Installer's Response Time and Proximity
   1. Installer must maintain a fully capable service facility within a 45 mile radius of the project site. Service facility shall manage the emergency service dispatches and maintain the inventory of spare parts.
   2. Emergency response times are listed below in this section. Installer must demonstrate the ability to meet the response times.

1.06 CODES AND STANDARDS

A. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
   1. ASHRAE 135: BACnet - A Data Communication Protocol for Building Automation and Control Networks. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. current edition including all related addenda shall apply.

B. Electronics Industries Alliance
   1. EIA-709.1-A-99: Control Network Protocol Specification
   2. EIA-709.3-99: Free-Topology Twisted-Pair Channel Specification

3. EIA-232: Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.
4. EIA-458: Standard Optical Fiber Material Classes and Preferred Sizes
5. EIA-485: Standard for Electrical Characteristics of Generator and Receivers for use in Balanced Digital Multipoint Systems.
6. EIA-472: General and Sectional Specifications for Fiber Optic Cable
7. EIA-475: Generic and Sectional Specifications for Fiber Optic Connectors and all Sectional Specifications
8. EIA-573: Generic and Sectional Specifications for Field Portable Polishing Device for Preparation Optical Fiber and all Sectional Specifications
9. EIA-590: Standard for Physical Location and Protection of Below-Ground Fiber Optic Cable Plant and all Sectional Specifications

C. Underwriters Laboratories
1. UL 916: Energy Management Systems.
The following rating is required only for devices used for smoke control purposes. If these are not intended, delete.
2. UUKL 864: UL Supervised Smoke Control

D. NEMA Compliance
1. NEMA 250: Enclosure for Electrical Equipment
2. NEMA ICS 1: General Standards for Industrial Controls.

E. NFPA Compliance
1. NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems" where applicable to controls and control sequences.
2. NFPA 70 National Electrical Code (NEC)

F. Institute of Electrical and Electronics Engineers (IEEE)
1. IEEE 142: Recommended Practice for Grounding of Industrial and Commercial Power Systems
2. IEEE 802.3: CSMA/CD (Ethernet - Based) LAN
3. IEEE 802.4: Token Bus Working Group (ARCNET - Based) LAN

1.07 DEFINITIONS

A. Advanced Application Controller (AAC): A device with limited resources relative to the Building Controller (BC). It may support a level of programming and may also be intended for application specific applications.

B. Application Protocol Data Unit (APDU): A unit of data specified in an application protocol and consisting of application protocol control information and possible application user data (ISO 9545).

C. Application Specific Controller (ASC): A device with limited resources relative to the Advanced Application Controller (AAC). It may support a level of programming and may also be intended for application-specific applications. .

D. BACnet/BACnet Standard: BACnet communication requirements as defined by ASHRAE/ANSI 135 (Current edition and addendum).

E. BACnet Interoperability Building Blocks (BIBB): A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.

F. Binding: In the general sense, binding refers to the associations or mappings of the sources network variable and their intended opr required destinations.

G. Building Automation System (BAS): The entire integrated management and control system

H. Building Controller (BC): A fully programmable device capable of carrying out a number of tasks including control and monitoring via direct digital control (DDC) of specific systems, acting as a communications router between the controlled devices / equipment and the CSS, and temporary data storage for trend information, time schedules, and alarm data.

I. Change of Value (COV): An event that occurs when a measured or calculated analog value changes by a predefined amount (ASHRAE/ANSI 135 (current version and addendum)).

J. Client: A device that is the requestor of services from a server. A client device makes requests of and receives responses from a server device.

K. Continuous Monitoring: A sampling and recording of a variable based on time or change of state (e.g. trending an analog value, monitoring a binary change of state).

L. Controller or Control Unit (CU): Intelligent stand-alone control device. Controller is a generic reference and shall include BCs, AACs, and ASCs as appropriate.

M. Control Systems Server (CSS): A server class computer(s) that maintains the systems configuration and programming database. This server is located at the State of Delaware's data center in a virtual environment and serves as an access point to BAS.

N. Controlling LAN: High speed, peer-to-peer controller LAN connecting BCs, AACs and ASCs. Refer to System Architecture below.

O. Direct Digital Control (DDC): Microprocessor-based control including Analog/Digital conversion and program logic

P. Functional Profile: A collection of variables required to define a the key parameters for a standard application. As this applies to the HVAC industry, this would include applications like VAV terminal, fan coil units, and the like.

Q. Gateway (GTWY): A device, which contains two or more dissimilar networks/protocols, permitting information exchange between them.

R. Hand Held Device (HHD): Manufacturer's microprocessor based device for direct connection to a Controller.

S. LAN Interface Device (LANID): Device or function used to facilitate communication and sharing of data throughout the BAS

T. Local Area Network (LAN): General term for a network segment within the architecture. Various types and functions of LANs are defined herein.

U. Local Supervisory LAN: Also known as the State's Network: Ethernet-based network connecting Primary Controlling LANs with each other and OWSs and CSSs. See System Architecture below.

V. Master-Slave/Token Passing (MS/TP): Data link protocol as defined by the BACnet standard.

W. Open Database Connectivity (ODBC): An open standard application-programming interface (API) for accessing a database developed. ODBC compliant systems make it possible to access any data from any application, regardless of which database management system (DBMS) is handling the data.

X. Operator Interface (OI): A device used by the operator to manage the BAS including OWSs, POTs, and HHDs.

Y. Operator Workstation (OWS): The user's interface with the BAS system. As the BAS network devices are stand-alone, dedicated OWS is not required for communications to occur. The

OWS can be any computer on the State's Network that has a compatible Web browser.

Z. Point-to-Point (PTP): Serial communication as defined in the BACnet standard.

AA. Portable Operators Terminal (POT): Mobile computer used both for direct connection to a controller as well as network connection.

AB. Protocol Implementation Conformance Statement (PICS): A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device (ASHRAE/ANSI 135 (current version and addendum)).

AC. Router: A device that connects two or more networks at the network layer.

AD. Secondary Controlling LAN: LAN connecting AACs and ASCs, generally lower speed and less reliable than the Controlling LAN. Refer to System Architecture below.

AE. Server : A device that is a provider of services to a client. A client device makes requests of and receives responses from a server device.

AF. Standardized Query Language (SQL): A database computer language designed for managing data in relational database management system (RDBMS). Its scope includes data insert, query, update and delete, schema creation and modification, and data access control.

AG. Smart Device: A control I/O device such as a sensor or actuator that can directly communicate with a controller through the network. This differs from an ASC in that it typically deals only with one variable.

AH. Extensible Markup Language (XML): A specification developed by the World Wide Web Consortium. XML is a pared-down version of SGML, designed especially for Web documents. It is a set of rules for encoding documents in machine-readable form that allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.

1.08 FUNCTIONAL INTENT

A. Throughout Sections 23 09 50 through 23 09 55, the Sequences of Operation, and Section 23 09 59 detailed requirements are specified, some of which indicate a means, method or configuration acceptable to meet that requirement. Contractor may submit products that utilize alternate means, methods, and configurations that meet the functional intent. However these will only be allowed with prior approval.

1.09 SUBMITTALS

A. Submit under provisions of Section 01 30 00 .

B. Electronic Submittals: While all requirements for hard copy submittal apply, control submittals and O&M information shall also be provided in electronic format as follows.
   1. Drawings and Diagrams: Shop drawings shall be provided on electronic media as an AutoCAD (current version) and/or Adobe Portable Document Format file. All 'X reference' and font files must be provided with AutoCAD files.
   2. Other Submittals: All other submittals shall be provided in Adobe Portable Document Format (PDF).

C. Qualifications: Manufacturer, Installer, and Key personnel qualifications as indicated for the appropriate item above.

D. Product Data: Submit manufacturer's technical product data for each control device, panel, and accessory furnished, indicating dimensions, capacities, performance and electrical characteristics, and material finishes. Also include installation and start-up instructions.

E. Shop Drawings: Submit shop drawings for each control system, including a complete drawing for each air handling unit, system, pump, device, etc. with all point descriptors, addresses and point names indicated. Each shop drawing shall contain the following information:
   1. System Architecture and System Layout:
      a. One-line diagram indicating schematic locations of all control units, workstations, LAN interface devices, gateways, etc. Indicate network number, device ID, , instance number, MAC address, drawing reference number, and controller type for each control unit. Indicate media, protocol, baud rate, and type of each LAN. Indicate media, protocol, baud rate, and type of each LAN. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the diagram.
      b. Provide electronic floor plans locating all control units, workstations, LAN interface devices, gateways, etc. Include all network communication wiring routing, power wiring, power originating sources, and low voltage power wiring. Indicate network number, device ID, instance number, MAC address, drawing reference number, and controller type for each control unit. Indicate media, protocol, baud rate, and type of each LAN. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the floor plans. Wiring routing as-built conditions shall be maintained accurately throughout the construction period and the drawing shall be updated to accurately reflect accurate, actual installed conditions.
   2. Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and control devices. Include verbal description of sequence of operation.
   3. All physical points on the schematic flow diagram shall be indicated with names, descriptors, and point addresses identified as listed in the point summary table.
   4. With each schematic, provide a point summary table listing building number and abbreviation, system type, equipment type, full point name, point description, Ethernet backbone network number, network number, device ID, object ID (object type, instance number). See Section 23 09 55 - Part III for additional requirements.
   5. Label each control device with setting or adjustable range of control.
   6. Label each input and output with the appropriate range.
   7. Provide a Bill of Materials with each schematic. Indicate device identification to match schematic and actual field labeling, quantity, actual product ordering number, manufacturer, description, size, voltage range, pressure range, temperature range, etc. as applicable.
   8. With each schematic, provide valve and actuator information including size, Cv, design flow, design pressure drop, manufacturer, model number, close off rating, etc. Indicate normal positions of spring return valves and dampers.
   9. Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring, which are existing, factory-installed and portions to be field-installed.
   10. Details of control panels, including controls, instruments, and labeling shown in plan or elevation indicating the installed locations.
   11. Sheets shall be consecutively numbered.
   12. Each sheet shall have a title indicating the type of information included and the HVAC system controlled.
   13. Table of Contents listing sheet titles and sheet numbers.
   14. Legend and list of abbreviations.
   15. Memory allocation projections.
   16. Submit along with shop drawings but under separate cover calculated and guaranteed system response times of the most heavily loaded LAN in the system.

F. Open Protocol Information
   1. BACnet Systems:
      a. BACnet object description, object ID, and device ID, for each I/O point.
      b. Documentation for any non-standard BACnet objects, properties, or enumerations used detailing their structure, data types, and any associated lists of enumerated values.
      c. Submit PICS indicating the BACnet functionality and configuration of each controller.

G. Framed Control Drawings: Laminated control drawings including system control schematics, sequences of operation and panel termination drawings, shall be provided in panels for major pieces of equipment. Terminal unit drawings shall be located in the central plant equipment panel or mechanical room panel.

H. Control Logic Documentation
   1. Submit control logic program listings (for graphical programming) and logic flow charts (for line type programs) to document the control software of all control units.
   2. Control logic shall be annotated to describe how it accomplishes the sequence of operation. Annotations shall be sufficient to allow an operator to relate each program component (block or line) to corresponding portions of the specified Sequence of Operation.
   3. Include written description of each control sequence.
   4. Include control response, settings, setpoints, throttling ranges, gains, reset schedules, adjustable parameters and limits.
   5. Sheets shall be consecutively numbered.
   6. Each sheet shall have a title indicating the controller designations and the HVAC system controlled.
   7. Include Table of Contents listing sheet titles and sheet numbers
   8. Submit one complete set of programming and operating manuals for all digital controllers concurrently with control logic documentation. This set will count toward the required number of Operation and Maintenance materials specified below and in Section 01 30 00.

I. Operation and Maintenance Materials:
   1. Submit documents under provisions of Section 01 03 00. One copy of the materials shall be delivered directly to the State facilities operation staff, in addition to the copies required by other Sections.
   2. Submit maintenance instructions and spare parts lists for each type of control device, control unit, and accessory.
   3. Submit BAS User's Guides (Operating Manuals) for each controller type .
   4. Submit BAS advanced Programming Manuals for each controller type.
   5. Include all submittals (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) in maintenance manual; in accordance with requirements of Division 1.

J. Controls contractor shall provide the State with all product line technical manuals and technical bulletins, to include new and upgraded products, by the same distribution channel as to dealers or branches. This service will be provided for 5 years as part of the contract price, and will be offered to the State thereafter for the same price as to a dealer or branch.

K. Manufacturers Certificates: For all listed and/or labeled products, provide certificate of conformance.

L. Product Warranty Certificates: submit manufacturers product warranty certificates covering the hardware provided.

1.10 PROJECT RECORD DOCUMENTS

A. Submit documents under provisions of Section 01 30 00.

B. Record copies of product data and control shop drawings updated to reflect the final installed condition.

C. Record copies of approved control logic programming and database on paper and on CD's. Accurately record actual setpoints and settings of controls, final sequence of operation, including changes to programs made after submission and approval of shop drawings and including changes to programs made during specified testing.

D. Record copies of approved project specific graphic software on CDs.

E. Record copies shall include individual floor plans with controller locations with all interconnecting wiring routing including space sensors, LAN wiring, power wiring, low voltage power wiring. Indicate device instance, MAC address and drawing reference number.

F. Provide record riser diagram showing the location of all controllers.

G. Maintain project record documents throughout the warranty period and submit final documents at the end of the warranty period

1.11 SYSTEM ARCHITECTURE

A. The system provided shall incorporate hardware resources sufficient to meet the functional requirements of these Specifications. The Contractor shall include all items not specifically itemized in these Specifications that are necessary to implement, maintain, and operate the system in compliance with the functional intent of these Specifications.

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

C. The system architecture shall consist of the Ethernet-based State Network, and Controlling LANs that support BCs, AACs, ASCs, Operator Workstations (OWS), Smart Devices (SD), and Remote Communication Devices (RCDs) as applicable. The following indicates a functional description of the BAS structure.
   1. State Network: Internet-based network connecting multiple facilities with a central data and application server, accessible via standard web-browser. This is an existing infrastructure and contractor is not required to configure any components of this network. Refer to Section 23 09 54 for requirements. This contractor shall integrate the controlling devices and the CCS together.
   2. Local Supervisory LAN: The Local Supervisory LAN shall be an Ethernet-based, 100 Mbps LAN connecting Primary Control LANs and OWSs. The LAN serves as the inter-BC gateway and OWS-to-BC gateway and communications path. Contractor shall provide this as a dedicated LAN for the control system. LAN shall be IEEE 802.3 Ethernet over Fiber or Category 5 cable with switches and routers that support 100 Mbps throughput. Power-line carrier communication shall not be acceptable for communications. The physical media will be that installed for the IT infrastructure of the facility and as such network drops will be provided under that scope of work to facilitate work of this scope. This network will be 100 Mbps and therefore all network interface cards shall support that speed. The higher level layers of this network shall be BACnet as described below:
      a. BACnet Supervisory LAN: Shall be BACnet/IP as defined in the BACnet standard, and shall share a common network number for the Ethernet backbone, as defined in the BACnet standard. Point/Object naming conventions are specified in 23 09 55 - Part III.
   3. Controlling LAN: High-speed, peer-to-peer communicating LAN used to connect AACs, ASCs and Building Controllers (BCs) and communicate exclusively control information. Acceptable technologies include:
      a. Ethernet (IEEE802.3)
      b. ARCNET (IEEE802.4)

c. Communication to/from building controller (BC) and the control system server (CSS) shall utilize standard TCP/IP, BACnet/IP ports (80and/or 47808)

4. Secondary Controlling LAN : Network used to connect AACs, ASCs or SDs. These can be Master Slave/ Token Passing or polling, in addition to those allowed for Primary Controller LANs. Network speed vs. the number of controllers on the LAN shall be dictated by the response time and trending requirements.

D. Dynamic Data Access: Any data throughout any level of the network shall be available to and accessible by all other devices, Controllers and OWS, whether directly connected or connected remotely.

E. Remote Data Access: The system shall support the following methods of remote access to the building data.

1. Browser-based access: A remote user using a standard browser shall be able to access all control system facilities and graphics with proper authentication. The State shall maintain continuous network connection. The following paradigms are acceptable for browser-based access:
   a. Native Internet-based user interface (HTML, Java, XML, etc.) via a standard freely distributed web browser that does not require a Windows client software installation.

F. The communication speed between the controllers, LAN interface devices, and operator interface devices shall be sufficient to ensure fast system response time under any loading condition. Contractor shall submit guaranteed response times with shop drawings including calculations to support the guarantee. In no case shall delay times between an event, request, or command initiation and its completion be greater than those listed herein. Contractor shall recommend reconfiguring the LAN as necessary to accomplish these performance requirements.:

1. 5 seconds between a Level 1 (critical) alarm occurrence and enunciation at operator workstation.
2. 10 seconds between a Level 2 alarm occurrence and enunciation at operator workstation.
3. 20 seconds between and a Level 3-5 alarm occurrence and enunciation at operator workstation.
4. 10 seconds between an operator command via the operator interface to change a setpoint and the subsequent change in the controller.
5. 5 seconds between an operator command via the operator interface to start/stop a device and the subsequent command to be received at the controller.
6. 10 seconds between a change of value or state of an input and it being updated on the operator interface.
7. 10 seconds between an operator selection of a graphic and it completely painting the screen and updating at least 10 points.

G. Control Systems Server (CSS): A server class computer(s) that maintains the systems configuration and programming database. This server is located at the State of Delaware's data center in a virtual environment and serves as an access point to BAS. It shall hold the backup files of the information downloaded into the individual controllers and as such support uploading and downloading that information directly to/from the controllers. It shall also act as a control information server to non-control system based programs. It shall allow secure multiple-access to the control information. Refer to Section 23 09 52 - BAS Operator Interfaces for its requirements.

H. The Operator Interface shall provide for overall system supervision, graphical user interface, management report generation, alarm annunciation, and remote monitoring. Refer to Section 23 09 52 - BAS Operator Interfaces.

I. The BCs, AACs, ASCs, [and SDs] shall monitor, control, and provide the field interface for all points specified. Each BC, AAC, or ASC shall be capable of performing all specified energy

management functions, and all DDC functions, independent of other BCs, AACs, or ASCs and operator interface devices as more fully specified in Section 23 09 53 - BAS Field Panels.

J. Systems Configuration Database: The system architecture shall support maintaining the systems configuration database on the CSS. User tools provided to the State shall allow configuring, updating, maintaining, etc. current configurations and settings whether they are initiated at the server or the end device.
   1. Database Schema shall be published and provided to the State to facilitate easy access to the data.
   2. Database shall be ODBC compliant.

K. Interruptions or fault at any point on any Primary Controller LAN shall not interrupt communications between other nodes on the network. If a LAN is severed, two separate networks shall be formed and communications within each network shall continue uninterrupted.

L. All line drivers, signal boosters, and signal conditioners etc. shall be provided as necessary for proper data communication.

M. Anytime any controller's database or program is changed in the field, the controller shall be capable of automatically uploading the new data to the CSS.

1.12 WARRANTY MAINTENANCE

A. Contractor shall warrant all products and labor for a period of (insert warranty period) after Substantial Completion.

B. The State reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. The Contractor shall warrant parts and installation work regardless of any such changes made by the State, unless the Contractor provides clear and convincing evidence that a specific problem is the result of such changes to the BAS.

C. At no cost to the State, during the warranty period, the Contractor shall provide maintenance services for software and hardware components as specified below:
   1. Maintenance services shall be provided for all devices and hardware specified in sections 23 09 51 through 23 09 59 . Service all equipment per the manufacturer's recommendations. All devices shall be calibrated within the last month of the warranty period.
   2. Emergency Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following notification by the State to the Contractor.
      a. Response by telephone to any request for service shall be provided within two (2) hours of the State's initial telephone request for service.
      b. In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the State's site within eight (8) hours of the State's initial telephone request for such services, as specified.
   3. Normal Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would not result in property damage or loss of comfort control shall be corrected and repaired following telephonic notification by the State to the Contractor.
      a. Response by telephone to any request for service shall be provided within eight (8) working hours (contractor specified 40 hr per week normal working period) of the State's initial telephone request for service.

b. In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the State's site within three (3) working days of the State's initial telephone request for such services, as specified.

4. Telephonic Request for Service: Contractor shall specify a maximum of three telephone numbers for The State to call in the event of a need for service. At least one of the lines shall be attended at any given time at all times. Alternatively, pagers can be used for technicians trained in system to be serviced. One of the three paged technicians shall respond to every call within 15 minutes.
5. Technical Support: Contractor shall provide technical support by telephone throughout the warranty period.
6. Preventive maintenance shall be provided throughout the warranty period in accordance with the hardware component manufacturer's requirements.

1.13 DELIVERY, STORAGE, AND HANDLING

A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons during shipping, storage and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protect from weather.

1.14 LISTING AND LABELING

A. The BAS and components shall be listed by Underwriters Laboratories (UL 916) as an Energy Management System.

PART 2 - PRODUCTS

2.01 MANUFACTURERS (Pre-Approved by the State)

A. Automated Logic by Radius Systems

B. BuildingLogix / Lynxspring / KMC Controls by Seiberlich Trane

C. Johnson Controls by Modern Controls

D. Substitutions: See Section 01 60 00 - Product Requirements

2.02 MATERIALS AND EQUIPMENT

A. Materials shall be new, the best of their respective kinds without imperfections or blemishes and shall not be damaged in any way. Used equipment shall not used in any way for the permanent installation except where drawings or specs specifically allow existing materials to remain in place.

2.03 UNIFORMITY

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

PART 3 - EXECUTION

3.01 INSPECTION

A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS

A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.

B. Network Connectivity: The BAS contractor shall provide two network connections with Cat-6 cables from the Building Controller to the State's IT network.
   1. The BAS contractor shall terminate one end of the two Cat-6 cables at or around the State's patch panel and make connections to the State's switch with green patch cables, following the instruction of the DFM's IT personnel.
   2. The BAS contractor shall terminate the other end of the two Cat-6 cables near or within the building controller cabinet with dual RJ-45 terminal box and make connection of one cable to the building controller. Note: the second connection is for on-site operator interface through a mobile computer. Exposed cable shall be protected by conduit or wire mold.
   3. The BAS contractor shall label the two network connections BAC-1 and BAC-2 on both ends.

C. Refer to additional requirements in other sections of this specification.

3.03 SURGE PROTECTION

A. The Contractor shall furnish and install any power supply surge protection, filters, etc. as necessary for proper operation and protection of all BCs, AAC/ASCS operator interfaces, printers, routers, gateways and other hardware and interface devices. All equipment shall be capable of handling voltage variations 10% above or below measured nominal value, with no effect on hardware, software, communications, and data storage.

3.04 DEMOLITION AND REUSE OF EXISTING MATERIALS AND EQUIPMENT

A. Contractor shall assume that existing equipment that specifically is indicated to be reused is in good condition and is operable. Contractor, during the course of work, shall inspect these devices and determine if any devices are in need of replacement or repair. Contractor shall prepare an itemized list of suggested repairs/replacement. This repair/replacement will be at the discretion of the State and will be accomplished by expanding this contract.

B. Existing wire, conduit, and control panel cabinets may be reused at the State Project Engineer's discretion, but only if such materials or equipment comply with the applicable specification for new materials and equipment. Such materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service.

C. Where such materials are reused, the contractor's shop drawings shall reflect the existing wiring designation. If existing labeling is illegible or otherwise does not comply with the applicable specification for labeling, wiring runs shall be relabeled in accordance with the requirements specified elsewhere.

D. Existing pneumatic tubing located between the existing BAS panels and the pneumatic operators shall not be reused; however, conduit for such tubing may be reused. All other pneumatic tubing may be reused, but only if such materials comply with the applicable specification for new materials. Materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service. All pneumatic tubing to be reused shall be pressure tested and all leaks shall be repaired. All reused pneumatic tubing shall be purged with dry air or nitrogen.

E. The existing pneumatic main air supply system shall be modified as required and reused to serve existing pneumatic controls that are to remain, and shall be extended as necessary to serve new pneumatic controls. Where existing pneumatic controls are removed, main air piping shall be removed back to the point of connection to the main air supply which remains in use, and shall be capped or plugged.

F. Existing valves and dampers and their operators may be reused only when preapproved by the State. Contractor shall lubricate all damper linkages of dampers being controlled under this project.

G. Other materials and equipment not specifically mentioned herein may be reused only if specifically allowed by indications on the drawings.

H. For HVAC systems which are indicated to receive a new BAS, all existing materials and equipment associated with the existing pneumatic controls and EMCS shall be removed unless otherwise specified or indicated to remain, or unless reused in accordance with the above requirements, except for the following: 1) conduit and electrical boxes (but not wiring within conduit) may remain in place if not reused (leave a pull line); 2) inaccessible pneumatic tubing may remain in place if not reused. Existing materials and equipment to be removed shall be removed subject to the requirements in paragraph “Sequence of Work”. For HVAC systems, which are not to receive a new DDC BAS, the existing pneumatic control system shall remain fully functional.

3.05 SEQUENCE OF WORK For Existing Systems Conversion

A. General: All work involving changeover of control functions from existing pneumatic control system to the new DDC BAS shall be performed in accordance with the following sequence in order to minimize the duration of equipment outages. The following descriptions are intended to indicate the sequence in which the work shall be performed, not to define fully the scope of the work.

B. Install operator's terminal, peripherals, graphic software, and LAN prior to placing any equipment under the control of the new BAS.

C. Work which requires shutting down a pump motor, fan motor, or chiller shall be considered a utility shutdown and shall be subject to the restrictions specified in Division 0.1

D. The following sequence applies to an individually controlled HVAC subsystem, such as an air handling unit. Only one such system shall be placed under manual control (as described below) at any given time.
   1. Install controllers adjacent to (or within) existing control panel. Programming shall be complete (except for loading and debugging) prior to installation. Install all field devices, which do not require interruption of the existing control system.
   2. Install all conduit, wiring, and pneumatic tubing which does not require interruption of the existing control system.
   3. Provide temporary variable pressure type hand pumps at each pneumatically controlled output, for temporary use by The State's maintenance and operation contractor personnel. Schedule this step at least 48 hours in advance with the Building Engineer.
   4. Remove existing controls including wiring, conduit, and tubing (except materials to be reused in accordance with provisions specified elsewhere) which must be removed to facilitate installation of new BAS materials and equipment.
   5. Remove existing digital control system points (if applicable). Install and calibrate remainder of new BAS materials and equipment for this subsystem. Load controller software. Connect controller(s) to LAN.
   6. Perform all field testing and calibration that does not require connection of permanent pneumatic outputs.
   7. Remove temporary hand pumps and install permanent pneumatic output connections. Place the system under the control of the new DDC/BAS equipment. Conclude field testing and submit field testing report prior to placing the next subsystem under temporary manual control. The State shall be given a password with a priority level that allows monitoring (but not control until notification of substantial completion has been approved).
   8. Remove remaining existing pneumatic and digital control system materials and equipment (except materials to be reused in accordance with provisions specified elsewhere). All existing digital controls equipment for those subsystems that have not yet been converted shall remain intact, on-line, and fully functional.

9. Schedule work in The State's occupied spaces 3 days in advance with the State's representative.

3.06 CONTROL POWER SOURCE AND SUPPLY

A. Section 23 09 50 Contractor shall extend all power source wiring required for operation of all equipment and devices provided under Sections 23 09 50 through 23 09 55 and Sequences of Operation.

The following item will have to be customized for each system and project. The consideration is where to power controllers from. For distributed controllers that are associated with one unit, it is convenient to power them along with the system so the controller can take action based on the presence of power. However on large centralized panels, it may be best to put these on the most reliable source of power that serves the equipment being controlled and then provide for individual monitoring of the various system's power sources by the controller. The object here is to make a robust system that does not interpret power failures as device failure and therefore in some instances have to take down the unit for manual acknowledged reset. This can compromise reliability.

B. General requirements for obtaining power include the following:
   1. Obtain power from a source that feeds the equipment being controlled such that both the control component and the equipment are powered from the same panel. Where equipment is powered from a 460V source, obtain power from the electrically most proximate 120v source fed from a common origin.
   2. Where control equipment is located inside a new equipment enclosure, coordinate with the equipment manufacturer and feed the control with the same source as the equipment. If the equipment's control transformer is large enough and of the correct voltage to supply the controls it may be used. If the equipment's control transformer is not large enough or of the correct voltage to supply the controls provide separate transformer
   3. Where a controller controls multiple systems on varying levels of power reliability (normal, emergency, and/or interruptible), the controller shall be powered by the highest level of reliability served. Furthermore, the controller in that condition shall monitor each power type served to determine so logic can assess whether a failure is due to a power loss and respond appropriately. A three-phase monitor into a digital input shall suffice as power monitoring.
   4. Standalone Functionality: Refer to Section 23 09 53.

3.07 BAS STARTUP, COMMISSIONING AND TRAINNING

A. Refer to Section 23 09 59

3.08 SEQUENCE OF OPERATION

A. Refer to Section 23 09 58 - Sequences of Operation

END OF SECTION 23 09 50

SECTION 23 09 51

BAS BASIC MATERIALS, INTERFACE DEVICES, AND SENSORS

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Pneumatic Tubing

B. Wiring

C. Control Valves and Actuators

D. Control Dampers and Actuators

E. Control Panels

F. Sensors

G. Flow Meter

H. Pneumatic Control Components (Gauges, switches, relays, etc.)

I. Electric Control Components (Switches, EP Valves, Thermostats, Relays, Smoke Detectors, etc.)

J. Transducers

K. Air Flow Measuring Stations

L. Current Switches

M. Nameplates

N. Testing Equipment

1.02 RELATED DOCUMENTS

A. Section 23 09 50 - Building Automation System (BAS) General

B. Section 23 09 53 - BAS Field Panels

C. Section 23 09 54 - BAS Communications Devices

D. Section 23 09 55 - BAS Software

E. Section 23 09 58 - Sequences of Operation

F. Section 23 09 59 - BAS Commissioning

1.03 DESCRIPTION OF WORK

A. Refer to Section 23 09 50 for general requirements.

B. Refer to other Division 23 sections for installation of instrument wells, valve bodies, and dampers in mechanical systems; not work of this section.

C. Provide the following electrical work of this section, complying with requirements of Division 26 sections:
   1. Control wiring between field-installed controls, indicating devices, and unit control panels.
   2. Interlock wiring between electrically interlocked devices, sensors, and between a hand or auto position of motor starters as indicated for all mechanical and controls.
   3. Wiring associated with indicating and alarm panels (remote alarm panels) and connections to their associated field devices.

4. All other necessary wiring for fully complete and functional control system as specified.

1.04 WORK BY OTHERS

A. Control Valves furnished under this section shall be installed under the applicable piping section under the direction of Section 23 09 51 Contractor who will be fully responsible for the proper operation of the valve.

B. Control Dampers furnished under this section shall be installed under the applicable air distribution or air handling equipment section under the direction of Section 23 09 51 Contractor who will be fully responsible for the proper operation of the damper

C. Water Pressure Taps, Thermal Wells, Flow Switches, Flow Meters, etc. that will have wet surfaces, shall be installed under the applicable piping Section under the direction of Section 23 09 51 Contractor who will be fully responsible for the proper installation and application.

D. Controlled Equipment Power Wiring shall be furnished and installed under Division 26. Where control involves 120V control devices controlling 120V equipment, Division 26 Contractor shall extend power wiring to the equipment. Section 23 09 51 Contractor shall extend it from the equipment to the control device.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. General: Provide electronic control products in sizes and capacities indicated, consisting of valves, dampers, thermostats, clocks, controllers, sensors, and other components as required for complete installation and reviewed and approved by the State. Except as otherwise indicated, provide manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by manufacturer, and as required for application indicated.

B. Communication Wiring: All wiring shall be in accordance with National Electrical Codes and Division 26 of this specification.
   1. Contractor shall supply all communication wiring between Building Controllers, Routers, Gateways, AAC's, ASC's and local and remote peripherals (e.g., operator workstations, printers, and modems).
   2. Local Supervisory LAN: For any portions of this network required under this section of the specification, contractor shall use Fiber or Category 6 of standard TIA/EIA (100/1000BaseT). Network shall be run with no splices and separate from any wiring over thirty (30) volts.
   3. Primary and Secondary Controller LANs: Communication wiring shall be individually 100% shielded pairs per manufacturers recommendations for distances installed, with overall PVC cover, Class 2, plenum-rated run with no splices and separate from any wiring over thirty (30) volts. Shield shall be terminated and wiring shall be grounded as recommended by BC manufacturer.

C. Signal Wiring: Contractor shall run all signal wiring in accordance with National Electric Codes and Division 26 of this Specification.
   1. Signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, etc. shall be twisted, 100% shielded pair, minimum 18-gauge wire, with PVC cover. Signal wiring shall be run with no splices and separate from any wiring above thirty (30) volts.
   2. Signal wiring shield shall be grounded at controller end only unless otherwise recommended by the controller manufacturer.

D. Low Voltage Analog Output Wiring: Contractor shall run all low voltage control wiring in accordance with National Electric Codes and Division 16 of this Specification.

1. Low voltage control wiring shall be minimum 16-gauge, twisted pair, 100% shielded, with PVC cover, Class 2 plenum-rated. Low voltage control wiring shall be run with no splices separate from any wiring above thirty (30) volts.

E. Control Panels: Provide control panels with suitable brackets for wall mounting for each control system. Locate panel adjacent to systems served.
1. Fabricate panels of 16-gage furniture-grade steel, or 6063-T5 extruded aluminum alloy, totally enclosed on four sides, with hinged door and keyed lock, with manufacturer's standard shop- painted finish and color.
2. Provide UL-listed cabinets for use with line voltage devices.
3. Control panel shall be completely factory wired and piped, and all electrical connections made to a terminal strip. Control panel shall have standard manufacturer's color.
4. All gauges and control components shall be identified by means of nameplates.
5. All control tubing and wiring shall be run neatly and orderly in open slot wiring duct with cover.
6. Complete wiring and tubing termination drawings shall be mounted in or adjacent to panel.

2.02 Control Valves (with Auto-flow Balancing)

A. General: Provide factory fabricated pressure independent characterized control valves with built in flow regulator of type, body material and pressure class indicated. Where type or body material is not indicated, provide selection as determined by manufacturer for installation requirements and pressure class, based on maximum pressure and temperature in piping system. Provide valve size in accordance with scheduled or specified maximum pressure drop across control valve. Control valves shall be equipped with heavy-duty actuators, and with proper close-off rating for each individual application. Minimum close-off rating shall be as scheduled and adequate for each application, and shall generally be considered at dead head rating of the pump.

B. Ball Type
1. Body: Forged Brass, nickel plated; threaded ends.
2. Seat: Reinforced Teflon PTFE
3. Ball: Chrome plated brass
4. Port: Standard or 'V' style.
5. Stem: Chrome plated brass
6. Cold Service Pressure: 400 psi WOG
7. Regulator components: Stainless steel/brass/Delrin 500AF
8. Spring: Stainless Steel

C. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
1. Belimo
2. Substitutions: See Section 01 60 00 - Product Requirements.

2.03 Control Valves

A. General: Provide factory fabricated control valves of type, body material and pressure class indicated. Where type or body material is not indicated, provide selection as determined by manufacturer for installation requirements and pressure class, based on maximum pressure and temperature in piping system. Provide valve size in accordance with scheduled or specified maximum pressure drop across control valve. Control valves shall be equipped with heavy-duty actuators, and with proper close-off rating for each individual application. Minimum close-off rating shall be as scheduled and adequate for each application, and shall generally be considered at dead head rating of the pump.

B. Plug-Type Globe Pattern for Water Service:
   1. Valve Sizing: Where not specifically indicated on the control drawings, modulating valves shall be sized for maximum full flow pressure drop between 50% and 100% of the branch circuit it is controlling unless scheduled otherwise. Two-position valves shall be same size as connecting piping.
   2. Single Seated (Two-way) Valves: Valves shall have equal-percentage characteristic for typical heat exchanger service and linear characteristic for building loop connections to campus systems unless otherwise scheduled on the drawings. Valves shall have cage-type trim, providing seating and guiding surfaces for plug on 'top-and-bottom' guided plugs.
   3. Double Seated (Three-way) Valves: Valves shall have linear characteristic. Valves shall be balanced-plug type, with cage-type trim providing seating and guiding surfaces on 'top-and-bottom' guided plugs.
   4. Temperature Rating: 25°F minimum, 250°F maximum
   5. Body: Bronze, screwed, 250 psi maximum working pressure for 1/2” to 2”; Cast Iron, flanged, 125 psi maximum working pressure for 2-1/2” and larger.
   6. Valve Trim: Bronze; Stem: Polished stainless steel.
   7. Packing: Spring Loaded Teflon or Synthetic Elastomer U-cups, self-adjusting.
   8. Plug: Brass, bronze or stainless steel, Seat: Brass
   9. Disc: Replaceable Composition or Stainless Steel Filled PTFE.
   10. Ambient Operating Temperature Limits: -10 to 150°F (-12.2 to 66 °C)
   11. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
      a. Johnson Controls
      b. Invensys
      c. Warren
      d. Delta
      e. Belimo
      f. Substitutions: See Section 01 60 00 - Product Requirements.

C. Plug-Type Globe Pattern for Steam Service:
   1. Valve Sizing: Where valve size is not specifically indicated on the drawings, size modulating valves for applications of 15 psig or less for 80% of inlet gage pressure unless scheduled otherwise. Modulating valves for applications of greater than 15 psig shall be sized for 42% of inlet absolute pressure unless scheduled otherwise. Two-position valves shall be same size as connecting piping.
   2. Characteristics: Modified equal-percentage characteristics. Cage-type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.
      a. Working Temperature: 250°F minimum for saturated steam applications of 15 psig or less; 366°F minimum for saturated steam applications of greater than 15 psig up to 150 psig.
      b. Body: Bronze, screwed, 250 psig steam working pressure for 1/2” to 2”; Cast Iron, flanged, 100 psig steam working pressure for 2-1/2” and larger for applications of 50 psig or less.
      c. Valve Trim, Plug, Seat and Stem: Polished stainless steel.
      d. Packing: Spring Loaded Teflon.
      e. Disc: Replaceable Composition or Stainless Steel Filled PTFE.
      f. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
         1) Johnson Controls
         2) Invensys
         3) Warren
         4) Delta
         5) Substitutions: See Section 01 60 00 - Product Requirements.

D. Butterfly Type:
   1. Body: Extended neck epoxy coated cast or ductile iron with full lug pattern, ANSI Class 125 or 250 bolt pattern to match specified flanges.
   2. Seat: EPDM, except in loop bypass applications where seat shall be metal to metal
   3. Disc: Bronze or stainless steel, pinned or mechanically locked to shaft
   4. Bearings: Bronze or stainless steel
   5. Shaft: 416 stainless steel
   6. Cold Service Pressure: 175 psi
   7. Close Off: Bubble-tight shutoff to 150 psi
   8. Operation: Valve and actuator operation shall be smooth both seating and unseating. Should more that 2 psi deadband be required to seat/unseat the valve, valve shall be replaced at no cost to the State.
   9. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
      a. Jamesbury WS815
      b. Bray Series 31
      c. Keystone AR2
      d. Dezurik BGS
      e. Belimo
      f. Substitutions: See Section 01 60 00 - Product Requirements.

E. Ball Type
   1. Body: Brass or bronze; one-, two-, or three-piece design; threaded ends.
   2. Seat: Reinforced Teflon
   3. Ball: Stainless steel.
   4. Port: Standard or 'V' style.
   5. Stem: Stainless steel, blow-out proof design, extended to match thickness of insulation.
   6. Cold Service Pressure: 600 psi WOG
   7. Steam working Pressure: 150 psi
   8. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
      a. Conbraco
      b. Worcester
      c. Nibco
      d. Jamesbury
      e. PBM
      f. Delta
      g. Belimo
      h. Substitutions: See Section 01 60 00 - Product Requirements

F. Segmented or Characterized Ball Type
   1. Body: Carbon Steel (ASTM 216), one-piece design with wafer style ends.
   2. Seat: Reinforced Teflon (PTFE).
   3. Ball: Stainless steel ASTM A351
   4. Port: Segmented design with equal-percentage characteristic.
   5. Stem: Stainless steel.
   6. Cold Service Pressure: 200 psi WOG
   7. Cavitation Trim: Provide cavitation trim where indicated and/or required, designed to eliminate cavitation and noise while maintaining an equal percentage characteristic. Trim shall be a series of plates with orifices to break the pressure drop into multi-stages.
   8. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
      a. Jamesbury R-Series
      b. Fisher

c. Belimo
d. Substitutions: See Section 01 60 00 - Product Requirements

2.04 Control Dampers

A. General: Provide factory fabricated automatic control dampers of sizes, velocity and pressure classes as required for smooth, stable, and controllable air flow. Provide parallel or opposed blade dampers as recommended by manufacturers sizing techniques. For dampers located near fan outlets, provide dampers rated for fan outlet velocity and close-off pressure, and recommended by damper manufacturer for fan discharge damper service. Control dampers used for smoke dampers shall comply with UL 555S. Control Dampers used for fire dampers shall comply with UL 555.

B. For general isolation and modulating control service in rectangular ducts at velocities not greater than 1500 fpm (7.62 m/s), differential pressure not greater than 2.5" w.c. (622 Pa):
1. Performance: Test in accordance with AMCA 500.
2. Frames: Galvanized steel, 16-gauge minimum thickness, welded or riveted with corner reinforcement.
3. Blades: Stainless steel in lab exhausts and galvanized steel elsewhere, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 1/2 inch (12.7 mm) shafts with set screws, 16 gauge minimum thickness.
4. Blade Seals: Synthetic elastomer, mechanically attached, field replaceable.
5. Jamb Seals: Stainless steel.
6. Shaft Bearings: Oil impregnated sintered bronze, graphite impregnated nylon sleeve or other molded synthetic sleeve, with thrust washers at bearings.
7. Linkage: Concealed in frame.
8. Linkage Bearings: Oil impregnated sintered bronze or graphite impregnated nylon.
9. Leakage: Less than one percent based on approach velocity of 1500 ft./min. (7.62 m/s) and 1 inches wg. (249Pa).
10. Maximum Pressure Differential: 2.5 inches wg. (622 Pa)
11. Temperature Limits: -40 to 200 °F (-40 to 93 °C).
12. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with intermediate frames and jackshafts appropriate for installation.

C. For general isolation and modulating control service in rectangular ducts at velocities not greater than 4000 fpm (20.3 m/s), differential pressure not greater than 6" w.c. (1493 Pa):
1. Performance: Test in accordance with AMCA 500.
2. Frames: Galvanized steel, 16-gauge minimum thickness, welded or riveted with corner reinforcement.
3. Blades: extruded aluminum hollow airfoil shape, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 1/2 inch (12.7 mm) shafts, 14 gauge minimum extrusion thickness.
4. Blade Seals: Synthetic elastomeric, mechanically attached, field replaceable.
5. Jamb Seals: Stainless steel.
6. Shaft Bearings: Oil impregnated sintered bronze sleeve, graphite impregnated nylon sleeve, molded synthetic sleeve, or stainless steel sleeve, with thrust washers at bearings.
7. Linkage: Concealed in frame.
8. Linkage Bearings: Oil impregnated sintered bronze or graphite impregnated nylon.
9. Leakage: Less than 0.1 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1 inches wg. (249Pa).
10. Maximum Pressure Differential: 6 inches wg. (622 Pa)
11. Temperature Limits: -40 to 200 °F (-40 to 93 °C).

12. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with appropriately intermediate frames, and jackshafts.

D. For general isolation and modulating control service in rectangular ducts at velocities not greater than 4000 fpm, differential pressure not greater than 12" w.c.:
   1. Performance: Test in accordance with AMCA 500.
   2. Frames: Galvanized steel, 12-gauge minimum thickness, welded or riveted with corner reinforcement.
   3. Blades: Extruded aluminum hollow airfoil shape, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 3/4 inch (19 mm) shafts with set screws
   4. Shaft Bearings: Oil impregnated sintered bronze or stainless steel, pressed into frame, with thrust washers at bearings.
   5. Linkage: 10-gauge minimum thickness galvanized steel clevis type crank arms, 3/16" x3/4" (4.76 mm x 19 mm) minimum thickness tie rods.
   6. Linkage Bearings: Oil impregnated sintered bronze or graphite impregnated nylon.
   7. Leakage: Less than 0.2 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1 inches wg. (249Pa) differential pressure.
   8. Maximum Pressure Differential: 12 inches wg. (2984 Pa)
   9. Temperature Limits: -40 to 300 °F (-40 to 149 °C).
   10. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with appropriately intermediate frames, and jackshafts.

E. For general isolation and modulating control service in round ducts up to 40 inches in size at velocities not greater than 2500 fpm (12.7 m/s), differential pressure not greater than 4" w.c. (994 Pa):
   1. Performance: Test in accordance with AMCA 500.
   2. Frames: rolled 12 gauge steel strip for sizes 6 inch and smaller, rolled 14 gauge steel channel for larger sizes, galvanized or aluminum finish.
   3. Blades: Steel construction, 12 gauge minimum thickness for dampers less than 18 inches (457 mm) in size, 10 gauge minimum thickness for larger dampers.
   4. Blade Seals: Full circumference neoprene.
   5. Shaft: ½ inch (12.7 mm) diameter zinc or cadmium plated steel.
   6. Shaft Bearings: Oil impregnated sintered bronze or stainless steel, pressed into frame, with thrust washers at bearings.
   7. Leakage: Less than 0.2 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1 inches wg. (249Pa) differential pressure.
   8. Maximum Pressure Differential: 4 inches wg. (994 Pa)
   9. Temperature Limits: -40 to 300 °F (-40 to 149 °C).

F. For general isolation and modulating control service in round ducts up to 60 inches in size at velocities not greater than 4000 fpm (20.3 m/s), differential pressure not greater than 6" w.c. (1492 Pa):
   1. Performance: Test in accordance with AMCA 500.
   2. Frames: rolled 10-gauge steel channel for sizes 48 inch and smaller, rolled 3/16 inch (4.76 mm) thick steel channel for larger sizes, galvanized or aluminum finish.
   3. Blades: Steel construction, 10-gauge minimum thickness for dampers not greater than 48 inches in size, ¼ inch (6.35 mm) minimum thickness for larger dampers.
   4. Blade stops: ½ inch x ¼ inch (12.7 mm x 6.35 mm) full circumference steel bar.
   5. Blade Seals: Full circumference neoprene.
   6. Shaft: zinc or cadmium plated steel, angle reinforcing as necessary.
   7. Shaft Bearings: Oil impregnated sintered bronze or stainless steel, pressed into frame,

with thrust washers at bearings.

8. Leakage: Less than 0.4 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1 inches wg. (249Pa) differential pressure.
9. Maximum Pressure Differential: 6 inches wg. (1492 Pa)
10. Temperature Limits: -40 to 250 °F (-40 to 121 °C).

2.05 ACTUATORS

A. General: Size actuators and linkages to operate their appropriate dampers or valves with sufficient reserve torque or force to provide smooth modulating action or 2-position action as specified. Select spring-return actuators with manual override to provide positive shut-off of devices as they are applied.

B. Damper Actuators
   1. Ambient Operating Temperature Limits: -10 to 150°F (-12.2 to 66 °C)
   2. Two Position Electric Actuators: Line voltage with spring return
   3. Electronic Actuators: Provide actuators with spring return for two-position (24v), 0-5 Vdc, 0-10 Vdc, 2-10Vdc, 4-20 mA, or PWM input (subject to restrictions) as required. Actuators shall travel full stroke in less than [90] seconds. Actuators shall be designed for a minimum of 60,000 full cycles at full torque and be UL 873 listed. Provide stroke indicator. Actuators shall have positive positioning circuit. Where two actuators are required in parallel or in sequence provide an auxiliary actuator driver. Actuators shall have current limiting motor protection. Actuators shall have manual override where indicated. Modulating actuators for valves shall have minimum rangeability of 40 to 1.
      a. Close-Off Pressure: Provide the minimum torque required, and spring return for fail positioning (unless otherwise specifically indicated) sized for required close-off pressure. Required close-off pressure for two-way water valve applications shall be the shutoff head of associated pump. Required close-off rating of steam valve applications shall be design inlet steam pressure plus 50 percent for low pressure steam, and 10 percent for high pressure steam. Required close-off rating of air damper applications shall be shutoff pressure of associated fan, plus 10 percent.
      b. Acceptable Manufacturers: Subject to compliance with requirements approved manufacturers are as follows:
         1) Belimo
         2) Johnson Controls
         3) Delta
         4) Invensys
         5) Substitutions: See Section 01 60 00 - Product Requirements

C. Quarter-Turn Actuators (for ball and butterfly valves):
   1. Electric
      a. Motor: Suitable for 120 or 240 Volt single-phase power supply. Insulation shall be NEMA Class F or better. Motor shall be rated for 100 percent duty cycle. Motors shall have inherent overload protection.
      b. Gear Train. Motor output shall be directed to a self locking gear drive mechanism. Gears shall be rated for torque input exceeding motor locked rotor torque.
      c. Wiring: Power and control wiring shall be wired to a terminal strip in the actuator enclosure
      d. Failsafe Positioning: Actuators shall be spring return type for failsafe positioning.
      e. Enclosure: Actuator enclosure shall be NEMA-4 rated, and shall have a minimum of two threaded conduit entries. Provide an enclosure heater for actuators located outside of buildings.
      f. Limit Switches: Travel limit switches shall be UL and CSA approved. Switches shall limit actuator in both open and closed positions.
      g. Mechanical Travel Stops: The actuator shall include mechanical travel stops of

stainless steel construction to limit actuator to specific degrees of rotation.

h. Manual Override: Actuators shall have manual actuator override to allow operation of the valve when power is off. For valves 4 inches and smaller the override may be a removable wrench or lever or geared handwheel type. For larger valves, the override shall be a fixed geared handwheel type. An automatic power cut-off switch shall be provided to disconnect power from the motor when the handwheel is engaged for manual operation.

i. Valve Position Indicator: A valve position indicator with arrow and open and closed position marks shall be provided to indicate valve position.

j. Torque Limit Switches: Provide torque limit switches to interrupt motor power when torque limit is exceeded in either direction of rotation.

k. Position Controller: For valves used for modulating control, provide an electronic positioner capable of accepting 4-20 mA, 0-10 Vdc, 2-10 Vdc, and 135 Ohm potentiometer.

l. Ambient Conditions: Actuator shall be designed for operation from -140 to 150 °F ambient temperature with 0 to 100 percent relative humidity.

2.06 GENERAL FIELD DEVICES

A. Provide field devices for input and output of digital (binary) and analog signals into controllers (BCs, AACs, ASCs). Provide signal conditioning for all field devices as recommended by field device manufacturers, and as required for proper operation in the system.

B. It shall be the Contractor's responsibility to assure that all field devices are compatible with controller hardware and software.

C. Field devices specified herein are generally 'two-wire' type transmitters, with power for the device to be supplied from the respective controller. If the controller provided is not equipped to provide this power, or is not designed to work with 'two-wire' type transmitters, or if field device is to serve as input to more than one controller, or where the length of wire to the controller will unacceptably affect the accuracy, the Contractor shall provide 'four-wire' type equal transmitter and necessary regulated DC power supply or 120 VAC power supply, as required.

D. For field devices specified hereinafter that require signal conditioners, signal boosters, signal repeaters, or other devices for proper interface to controllers, Contractor shall furnish and install proper device, including 120V power as required. Such devices shall have accuracy equal to, or better than, the accuracy listed for respective field devices.

E. Accuracy: As stated in this Section, accuracy shall include combined effects of nonlinearity, nonrepeatability and hysteresis.

2.07 TEMPERATURE SENSORS (TS)

A. Sensor range: When matched with A/D converter of BC, AAC/ASC, or SD, sensor range shall provide a resolution of no worse than 0.3°F (0.16 °C) (unless noted otherwise). Where thermistors are used, the stability shall be better than 0.25°F over 5 years.

B. Matched Sensors: The following applications shall require matched sensors:
   1. Building Loop Connections: Provide matched loop and building supply sensors where control sequence requires controlling to a temperature rise (differential).
   2. Hydronic Temperature Difference Calculations: Provide matched supply and return temperature sensors where the pair is used for calculating temperature difference for use in load calculations or sequencing such as across chillers and plants.
   3. Air Handling Unit Sequencing: Provide matched pair for the cooling and heating coil leaving sensors where the sequence includes calculating an offset from the supply air setpoint to maintain a leaving heating coil temperature.

C. Room Temperature Sensor: Shall be an element contained within a ventilated cover, suitable for

wall mounting. Provide insulated base. Following sensing elements are acceptable:

1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.4°F accuracy at calibration point.
2. Provide setpoint adjustment where indicated. The setpoint adjustment shall be a warmer/cooler indication that shall be scalable via the BAS.
3. Provide an occupancy override button on the room sensor enclosure where indicated. This shall be a momentary contact closure
4. Provide current temperature indication via an LCD or LED readout where indicated.

D. Single-Point Duct Temperature Sensor: Shall consist of sensing element, junction box for wiring connections and gasket to prevent air leakage or vibration noise. Temperature range as required for resolution indicated in paragraph A. Sensor probe shall be 304 stainless steel.
   1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.2°F accuracy at calibration point

E. Averaging Duct Temperature Sensor: Shall consist of an averaging element, junction box for wiring connections and gasket to prevent air leakage. Provide sensor lengths and quantities to result in one lineal foot of sensing element for each three square feet of cooling coil/duct face area. Temperature range as required for resolution indicated in paragraph A.
   1. Sensing element shall be platinum RTD, or thermistor, +/- 0.2°F accuracy at calibration point.

F. Liquid immersion temperature sensor shall include [brass] thermowell, sensor and connection head for wiring connections. Temperature range shall be as required for resolution of 0.15°F.
   1. Sensing element (chilled water/glycol systems) shall be platinum RTD +/- 0.2°F accuracy at calibration point. Temperature range shall be as required for resolution of 0.15°F.
   2. Sensing element (other systems) shall be platinum RTD, thermistor, or integrated circuit, +/- 0.4°F accuracy at calibration point. Temperature range shall be as required for resolution of 0.3°F.

G. Pipe Surface-Mount Temperature Sensor: Shall include metal junction box and clamps and shall be suitable for sensing pipe surface temperature and installation under insulation. Provide thermally conductive paste at pipe contact point. Temperature range shall be as require for resolution indicated in paragraph A.
   1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.4°F accuracy at calibration point.

H. Outside air sensors shall consist of a sensor, sun shield, utility box, and watertight gasket to prevent water seepage. Temperature range shall be as require for resolution indicated in Paragraph A
   1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.4°F accuracy at calibration point.

2.08 Temperature Transmitters

A. Where required by Controller, or where wiring runs are over 50 feet, sensors as specified above may be matched with transmitters outputting 4-20 mA linearly across the specified temperature range. Transmitters shall have zero and span adjustments, an accuracy of 0.1°F when applied to the sensor range.

2.09 HUMIDITY TRANSMITTERS

A. Units shall be suitable for duct, wall (room) or outdoor mounting. Unit shall be two-wire transmitter utilizing bulk polymer resistance change or thin film capacitance change humidity sensor. Unit shall produce linear continuous output of 4-20 mA for percent relative humidity (% RH). A combination temperature and humidity sensor may be used for zone level monitoring. Sensors shall have the following minimum performance and application criteria:

1. Input Range: 0 to 100% RH.
2. Accuracy(% RH): +/- 2% (when used for enthalpy calculation, dewpoint calculation or humidifier control) or +/- 3% (monitoring only) between 20-90% RH at 77°F, including hysteresis, linearity, and repeatability.
3. Sensor Operating Range: As required by application
4. Long Term Stability: Less than 1% drift per year.

B. Acceptable Manufacturers: Units shall be Vaisala HM Series, General Eastern, Microline, or Hy-Cal HT Series. Substitutions shall be allowed per Division 1.

2.10 DIFFERENTIAL PRESSURE TRANSMITTERS (DP)

A. General Purpose - Water: Two-wire transmitter, 4-20 mA output with zero and span adjustments. Plus or minus 0.5% overall accuracy, 450 psig (3103 KPa) maximum static pressure rating, 200 psid maximum overpressure rating for 6 through 60 psid range, 450 psid for 100 through 300 psid range. Acceptable units shall be Kele & Associates Model 360 C. Substitutions shall be allowed per Division 1.

B. Industrial Application, Liquid, Steam and Gas:
1. General: Two-wire smart DP cell type transmitter, 4-20 mA or 1-5 Vdc user-selectable linear or square root output, adjustable span and zero, stainless steel wetted parts.
2. Environmental limits: -40 to 250 °F (-40 to 121°C), 0 to 100% RH..
3. Accuracy: less than 0.1 percent of span.
4. Output Damping: Time constant user selectable from 0 to 36 seconds.
5. Vibration Effect: Less than ±0.1% of upper range limit from 15 to 2000 Hz in any axis relative to pipe mounted process conditions.
6. Electrical Enclosure: NEMA-4, -4X, -7, -9.
7. Approvals: FM, CSA.
8. Acceptable Manufacturers: Rosemount Inc. 3051 Series, Foxboro, Johnson-Yokagawa, Setra, or Mamac. Substitutions shall be allowed per Division 1.

C. General Purpose Low Pressure Air: Generally for use in static measurement of duct pressure or constant volume air velocity pressure measurement where the range is applicable.
1. General: Loop powered two-wire differential capacitance cell-type transmitter.
2. Output: two wire 4-20 mA output with zero adjustment.
3. Overall Accuracy: Plus or minus 1%.
4. Minimum Range: 0.1 in. w.c.
5. Maximum Range: 10 inches w.c.
6. Housing: Polymer housing suitable for surface mounting.
7. Acceptable Manufacturers: Modus T30. Substitutions shall be allowed per Division 1.
8. Static Sensing Element: Pitot-type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.
9. Range: Select for specified setpoint to be between 25% and 75% full-scale.

D. General Purpose Low Pressure/Low Differential Air: Generally for use in static measurement of space pressure or constant volume air velocity pressure measurement where the range is applicable.
1. General: Loop powered, two-wire differential capacitance cell type transmitter.
2. Output: Two-wire 4-20 mA output with zero adjustment.
3. Overall Accuracy: Plus or minus 1%.
4. Minimum Range: 0 in. w.c.
5. Maximum Range: 0.1, 0.25, or 0.5 inches w.c.
6. Housing: Polymer housing suitable for surface mounting.
7. Acceptable Manufacturers: Modus T30. Substitutions shall be allowed per Division 1.
8. Static Sensing Element: Pitot-type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.

9. Range: Select for specified setpoint to be between 25% and 75% full-scale.

E. VAV Velocity Pressure: Generally for use in variable volume air velocity pressure measurement where the range is applicable.
   1. General: Loop powered two-wire differential capacitance cell type transmitter.
   2. Output: Two-wire, 4-20 mA output with zero adjustment.
   3. Overall Accuracy: Plus or minus 0.25%
   4. Minimum Range: 0 in. w.c.
   5. Maximum Range: 1 inch w.c.
   6. Housing: Polymer housing suitable for surface mounting.
   7. Acceptable Manufacturers: Setra. Substitutions shall be allowed per Division 1.
   8. Range: Select for minimum range that will accept the maximum velocity pressure expected.

2.11 Valve Bypass for Differential Pressure Sensors

A. Provide a five valve bypass kit for protection of DP sensors where the static on the pipe can cause on over pressure when connected to one port with the other at atmospheric pressure. Kit shall include high and low pressure isolation valves, high and low pressure vent valves, and a bypass valve contained in a NEMA-1 enclosure.

2.12 DIFFERENTIAL PRESSURE SWITCHES (DPS)

A. General Service - Air: Diaphragm with adjustable setpoint and differential and snap acting form C contacts rated for the application. Provide manufacturer's recommended static pressure sensing tips and connecting tubing

B. General Service - Water: Diaphragm with adjustable setpoint, 2 psig or adjustable differential, and snap-acting Form C contacts rated for the application. 60 psid minimum pressure differential range. 0°F to 160°F operating temperature range.

2.13 PRESSURE SWITCHES (PS)

A. Diaphragm or bourdon tube with adjustable setpoint and differential and snap-acting Form C contacts rated for the application. Pressure switches shall be capable of withstanding 150% of rated pressure.

B. Acceptable Manufacturers: Square D, ITT Neo-Dyn, ASCO, Penn, Honeywell, and Johnson Controls. Substitutions shall be allowed per Division 1.

2.14 TRANSDUCERS

A. Standard Capacity Electronic-to-Pneumatic (E-P) Transducers: E-P transducers shall be Voltage-to-Pneumatic (V-P) type, Current-to-Pneumatic (I-P) type, [and Pulse Width Modulated-to-Pneumatic (PWM-P) type]:
   1. Electrical Power Supply: 24 Vac or 24 Vdc.
   2. Pneumatic Air Supply: 30 psig (2.07 bar) maximum.
   3. Air Capacity: 1100 scim @ 20 psig (300 cm3/sec @ 1.4 bar).
   4. Air Consumption: Zero at steady state.
   5. Output Span: 0-20 psig (0-1.4 bar).
   6. Input: 4-20 mA, 0-5 Vdc, 1-5 Vdc, 0-10 Vdc, 2-10 Vdc, 0-15 Vdc, or 3-15 Vdc input. [Pulse width modulated or tri-state input shall be allowed].
   7. Pulse Width Modulated and Tri-state Input Time Base: Dip switch selectable
   8. Enclosure: Polymer designed for surface or panel mount.
   9. Air Connections: ¼" (6.35 mm) barbed.
   10. Failure Mode on Power Loss: Non-failsafe transducers shall have no output air loss. Failsafe transducers shall exhaust output upon power loss.

11. Acceptable Manufacturers: RE Technologies Model UCP-522. Substitutions shall be allowed per Division 1.

B. Binary to Analog Transducers ([Pulse Width Modulating] or Tri-State-to-Voltage or -Current):
   1. Adjustable zero and span.
   2. Failure Mode on Power Loss: Shall be provided with memory feature to allow the transducer to return to last value on power failure.
   3. Accuracy: ± 1% of span
   4. Output Span: 4-20 mA, 0-5 Vdc, 1-5 Vdc, 0-10Vdc, 2-10Vdc, 0-15Vdc, 3-15Vdc
   5. Input: 4-20 mA, pulse width modulated or tri-state input.
   6. Pulse Width Modulated] and Tri-state Input Time Base: Dip switch selectable.
   7. Enclosure: Polymer designed for surface or panel mount.
   8. Failure Mode on Power Loss: Non-failsafe transducers shall have no output air loss. Failsafe transducers shall exhaust output upon power loss.
   9. Acceptable Manufacturers: RE Technologies Model PWA Series. Substitutions shall be allowed per Division 1.

C. Electronic-to Electronic (Voltage or Current to Current or Voltage):
   1. Adjustable zero and span.
   2. Failure Mode on Power Loss: Memory feature to allow the transducer to return to last value on power failure.
   3. Accuracy: ± 1% of span.
   4. Output Span: 4-20 mA, 0-5 Vdc, 1-5 Vdc, 0-10 Vdc, 2-10 Vdc, 0-15 Vdc, 3-15 Vdc.
   5. Input: 0-20 Vdc, 0-20 ma, 0-10 kOhm.
   6. Pulse Width Modulated] and Tri-state Input Time Base: Dip switch selectable
   7. Enclosure: Polymer enclosure designed for surface or panel mount.
   8. Acceptable Manufacturers: RE Technologies Model PWA Series. Substitutions shall be allowed per Division 1.

2.15 Current Switches (CS)

A. Clamp-On or Solid-Core Design Current Operated Switch (for Constant Speed Motor Status Indication)
   1. Range: 1.5 to 150 amps.
   2. Trip Point: Adjustable.
   3. Switch: Solid state, normally open, 1 to 135 Vac or Vdc, 0.3 Amps. Zero off state leakage.
   4. Lower Frequency Limit: 6 Hz.
   5. Trip Indication: LED
   6. Approvals: UL, CSA
   7. Max. Cable Size: 350 MCM
   8. Acceptable Manufacturers: Veris Industries H-708/908; Inc., RE Technologies SCS1150A-LED. Substitutions shall be allowed per Division 1.

B. Clamp-on or Solid-Core Wire Through Current Switch (CS/CR) (for Constant Speed Motors): Same as CS with 24v command relay rated at 5A @ 240 Vac resistive, 3A @ 240 Vac inductive, load control contact power shall be induced from monitored conductor (minimum conductor current required to energize relay 5A, max. rating of 135A). Acceptable Manufacturers shall be Veris Industries, Inc., Model # H938/735; or RE Technologies RCS 1150. Substitutions shall be allowed per Division 1.
   1. Where used for single-phase devices, provide the CS/CR in a self-contained unit in a housing similar with override switch to Kele RIBX. Substitutions shall be allowed per Division 1.

C. Clamp-On Design Current Operated Switch for Variable Speed Motor Status Indication
   1. Range: 1.5 to 135 Amps.

2. Trip Point: Self-calibrating based on VA memory associated with frequency to detect loss of belt with subsequent increase of control output to 60 Hz.
3. Switch: Solid state, normally open, 1 to 135 Vac or Vdc, 0.3 Amps. Zero off state leakage.
4. Frequency Range: 5-75 Hz
5. Trip Indication: LED
6. Approvals: UL, CSA
7. Max. Cable Size: 350 MCM
8. Acceptable Manufacturers: Veris Industries, Inc. H-904. Substitutions shall be allowed per Division 1.

D. Clamp-On Wire Through Current Switch (CS/CR) (for Variable Speed Motors): Same as CS with 24v command relay rated at 5A @ 240 Vac resistive, 3A @ 240 Vac inductive, load control contact power shall be induced from monitored conductor (minimum conductor current required to energize relay 5A, max. rating of 135A). Acceptable manufacturer shall be Veris Industries, Inc., Model # H934. Substitutions shall be allowed per Division 1.

E. Variable Speed Status: Where current switches are used to sense the status for variable speed devices, the CT shall include on-board VA/Hz memory to allow distinction between a belt break and subsequent ramp up to 60 Hz, versus operation at low speed. The belt break scenario shall be indicated as a loss of status and the operation at low speed shall indicate normal status.

2.16 CURRENT TRANSFORMERS (CT)

A. Clamp-On Design Current Transformer (for Motor Current Sensing)
1. Range: 1-10 amps minimum, 20-200 amps maximum
2. Trip Point: Adjustable
3. Output: 0-5 VDC.
4. Accuracy: ±0.2% from 20 to 100 Hz.
5. Acceptable Manufacturers: KELE SA100. Substitutions shall be allowed per Division 1.

2.17 ELECTRIC METER

A. Sub-meter shall be designed for Multifunction Electrical Measurement on 3 phase power systems.
1. Sub-meter shall support 3 element wye, 2.5 element wye, 2 element delta, 4 wire delta systems.
2. The sub-meter shall accept universal voltage input suitable for 120, 220, and 277 power systems.
3. Surge withstand shall conform to IEEE C37.90.1
4. The sub-meter shall be user programmable for voltage range to any PT ratio.
5. The sub-meter shall accept a voltage input range of up to 416 Volts Line to Neutral, and a range of up to 721 Volts Line to Line.
6. Sub-meter shall accept a current reading of up to 11 amps continuous.

B. The sub-meter shall have an accuracy of +/- 0.1% or better for volts and amps, and 0.2% for power and energy functions. The sub-meter shall meet the accuracy requirements of IEC687 (class 0.2%) and ANSI C12.20 (Class 0.2%).
1. The sub-meter shall provide true RMS measurements of voltage, phase to neutral and phase to phase, current, per phase and neutral.
2. The sub-meter shall provide sampling at 400+ samples per cycle on all channel measured readings simultaneously.
3. The sub-meter shall utilize 24 bit Analog to Digital conversion.

C. The sub-meter shall include a three lines, bright red, .56” LED display.
1. The sub-meter shall fit in both DIN 92mm and ANSI C39.1 Round cut-outs.
2. The sub-meter must display a % of Load Bar on the front panel to provide an analog feel.

The % Load bar shall have no less than 10 segments.

3. The sub-meter must have a programmable display, which allows for the following programming functions including automatic scroll, screen selection programming, and energy scaling.

D. Sub-meter shall include virtual measurement upgrade packs, which shall allow user to upgrade in field without removing installed sub-meter.
   1. Two upgrade packs shall be:
      a. Volts, Amps, kW, kVAR, PF, kVA, Freq., kWh, kVAh, kVARh.
      b. Volts, Amps, kW, kVAR, PF, kVA, Freq., kWh, kVAh, kVARh, %THD Monitoring and Limit Exceeded Alarms.
         1) These virtual upgrade packs must be able to be updated without physically removing the installed sub-meter.
         2) Sub-meter shall be a traceable revenue sub-meter, which shall contain a utility grade test pulse, allowing power providers to verify and confirm that the sub-meter is performing to its rated accuracy.

E. The sub-meter shall include two independent communication ports with advanced features.
   1. Port 1 shall provide an optical IrDA port (through the faceplate) which shall allow the unit to be set up and programmed using a PDA or remote laptop without need for a communication cable.
   2. Port 2 shall be selectable for RS485 communication, for 10 base-T Ethernet or for 802.11 Wireless Ethernet.
   3. When in serial mode, the meter shall speak Modbus ASCII, Modbus RTU, or DNP 3.0 protocol up to 57.6K baud.
   4. When in Ethernet mode, the meter shall provide an 802.11 WIFI or an RJ45 Ethernet connection which shall allow the unit to be assigned an IP address and communicate Modbus protocol over Ethernet TCP/IP.
   5. The sub-meter shall have Pocket PC based software available for remote programming and integration.

F. The sub-meter shall provide user configured fixed window or rolling window demand. This shall allow user to set up the particular utility demand profile.
   1. Readings for kW, kVAR, kVA and PF shall be calculated using utility demand features.
   2. All other parameters shall offer max and min capability over the user selectable averaging period.
   3. Voltage shall provide an instantaneous max and min reading, displaying the highest surge and lowest sag seen by the sub-meter.
   4. The meter shall additionally measure accumulated energy in both generating and consuming quadrants with a programmable scaling that allow up to 8 digits of energy resolution.
   5. The meter shall also accumulate positive and negative VAR-hours and VA-hours. All readings shall be stamped with a positive and negative average demand.

G. The sub-meter shall support power supply and support direct wiring from 100 to 400 Volts AC or 100 to 370 Volts DC.
   1. Sub-meter power supply shall accept burden of 10VA max.
   2. The sub-meter shall have a standard 4-year warranty.

H. Sub-meter shall be able to be stored in (-40 to +85) degrees C.
   1. Operating temperature shall be (-30 to +70) degrees C.
   2. NEMA 12 faceplate rating shall be available for the Sub-meter.

I. The following devices are required for each meter assembly:
   1. Meter: Shark 100-S-60-10-V3-WIFI (or pre-approved equal)
   2. Split CT's (3 per Meter): EI-5SP-1200-00 (or pre-approved equal)

a. Field verified amp rating on service prior to ordering CT.
b. CT Short Block: SB-6TC (or pre-approved equal)

2.18 DUAL TECHNOLOGY OCCUPANCY SENSOR

A. Occupancy Sensors shall be dual-technology WattStopper model DT-300 or approved equal.

B. Occupancy Sensors shall be capable of detecting presence in the control area by detecting Doppler shifts in transmitted ultrasound and passive infrared heat changes.

C. Occupancy Sensors shall use patent pending ultrasonic diffusion technology that spreads coverage to a wider area.

D. Occupancy Sensors shall utilize Dual Sensing Verification Principle for coordination between ultrasonic and PIR technologies. Detection verification of both technologies must occur in order to activate lighting systems. Upon verification, detection by either shall hold lighting on.

E. Occupancy Sensors shall have a retrigger feature in which detection by either technology shall retrigger the lighting system on within 5 seconds of being switched off.

F. Occupancy Sensors shall be ceiling mounted with a flat, unobtrusive appearance and provide 360° coverage.

G. Ultrasonic sensing shall be volumetric in coverage with a frequency of 40 KHz. It shall utilize Advanced Signal Processing that automatically adjusts the detection threshold dynamically to compensate for changing levels of activity and airflow throughout controlled space.

H. To avoid false ON activations and to provide immunity to RFI and EMI, Detection Signature Analysis shall be used to examine the frequency, duration, and amplitude of a signal, to respond only to those signals caused by human motion.

I. The PIR technology shall utilize a temperature compensated, dual element sensor and a multi-element Fresnel lens. The lens shall be Poly IR4 material to offer superior performance in the infrared wavelengths and filter short wavelength IR, such as those emitted by the sun and other visible light sources. The lens shall have grooves facing in to avoid dust and residue build up which affects IR reception.

J. Occupancy Sensors shall operate at 24 VDC/VAC (halfwave-rectified) and utilize power relay packs as specified.

K. Occupancy Sensors shall utilize adaptive technology to optimize time delay and sensitivity settings to fit occupant usage patterns. The use of adaptive technology shall be selectable with a DIP switch.

L. Occupancy Sensors shall feature a walk-through mode, where lights turn off 3 minutes after the area is initially occupied if no motion is detected after the first 30 seconds.

M. Occupancy sensors shall have a built-in light level sensor that works from 10 to 300 footcandles.

N. Occupancy sensors shall have a manual-on function that is facilitated by installing a momentary switch.

O. Occupancy Sensors shall have eight occupancy logic options that give the ability to customize control to meet application needs.

P. DT-300 sensor shall have an additional single-pole, double throw isolated relay with normally open, normally closed and common outputs. The isolated relay shall be for use with HVAC control, data logging, and other control options.

Q. Each sensing technology shall have an LED indicator that remains active at all times in order to verify detection within the area to be controlled. The LED can be disabled for applications that

require less sensor visibility.

R. To ensure quality and reliability, sensor shall be manufactured by an ISO 9002 certified manufacturing facility and shall have a defect rate of less than 1/3 of 1%.

S. Sensors shall have standard 5 year warranty and shall be UL and CUL listed.

T. Power Relay Pack for Occupancy Sensor:
1. Power Relay Packs shall be WattStopper model BZ-150 or approved equal.
2. Power Relay Packs shall be self-contained transformer and relay modules measuring 1.75" x 2.75" x 1.5".
3. Power Relay Packs shall have dry contacts capable of switching 20 amp ballast and incandescent loads @ 120 VAC, 60 Hz; 20 amp ballast @ 277 VAC, 60 Hz; 1 hp @ 120-250 VAC, 60Hz.
4. Power Relay Packs shall have primary dual-voltage inputs of 120/277 VAC.
5. Power Relay Packs shall provide 24 VDC, 225 mA output with relay connected.
6. Power Relay Packs shall be capable of parallel wiring without regard to AC phases on primary.
7. Power Relay Packs can be used as a stand-alone, low voltage switches or can be wired to sensors for automatic control.
8. Power Relay Packs shall have hold-ON and hold-OFF inputs for integration with lighting control panels, BMS and other building systems.
9. Power Relay Packs shall have overcurrent protection if the low voltage current drawn exceeds 225 mA. In the event of an overcurrent condition, the low voltage output current shuts down and the LED will blink to indicate a fault condition.
10. Power Relay Packs shall have integral LED to indicate status of relay.
11. Power Relay Packs shall be UL 2043 plenum-rated and shall have low voltage Teflon coated leads, rated for 300 volts.
12. Power Relay Packs shall utilize Zero Crossing Circuitry to protect from the effects of inrush current and increase product longevity.
13. To ensure quality and reliability, Power Relay Packs shall be manufactured by an ISO 9002 certified manufacturing facility and shall have a defect rate of less than 1/3 of 1%.
14. Power Relay Packs shall have a 5 year warranty.
15. Power Relay Packs shall be UL and CUL listed.

2.19 OUTDOOR AIR STATIC PRESSURE SENSING TIP

A. Pressure sensor: Pressure sensing tip shall be designed to minimize the effects of wind and resulting velocity pressure up to 80 mph. Acceptable manufacturers shall be Dwyer A-306. Substitutions shall be allowed per Division 1.

B. Low Air Pressure Surge Dampener: 30-second time constant. Acceptable manufacturer shall be Modus SD030. Substitutions shall be allowed per Division 1.

2.20 CONTINUOUS LEVEL TRANSMITTERS

A. Capacitance Type
1. Provide a loop powered, continuous capacitance type level transmitter with adjustable span and zero.
2. Output: 4-20 mA.
3. Probe: Fluoropolymer coated stainless steel rod or cable. Provide cable probe with end attachment hardware or weight.
4. Electrical Enclosure: NEMA-4, -7.
5. Approvals: UL or CSA.
6. Accuracy: ±1% of calibrated span.
7. Process Connection: MPT or ANSI Flange as required.
8. Acceptable Manufacturers: Drexelbrook, Endress & Hauser. Substitutions shall be allowed

per Division 1.

B. Hydrostatic Pressure
   1. Two wire smart d/p cell type transmitter
   2. 4-20 mA or 1 to 5 volt user selectable linear or square root output
   3. Adjustable span and zero
   4. Stainless steel wetted parts
   5. Environmental limits: -40 to 250 °F (-40 to 121°C), 0 to 100% RH
   6. Accuracy: less than 0.1 percent of span
   7. Output Damping: time constant user selectable from 0 to 36 seconds
   8. Vibration Effect: Less than ±0.1% of upper range limit from 15 to 2000 Hz in any axis relative to pipe mounted process conditions.
   9. Electrical Enclosure: NEMA 4, 4X, 7, 9
   10. Approvals: FM, CSA
   11. Acceptable Manufacturers: Rosemount Inc. 3051 Series, Foxboro, and Johnson-Yokagawa. Substitutions shall be allowed per Division 1.

2.21 INSERTION TYPE TURBINE METER FOR WATER SERVICE

A. Turbine Insertion Flow Meter sensing method shall be impedance sensing (iron magnetic and non-photoelectric), with volumetric accuracy of +/- 2% of reading over middle 80% of operating range, and +/- 4% of reading over the entire operating range. Turbine Insertion Flow Meter shall have maximum operating pressure of 400 psi and maximum operating temperature of 200°F continuous (220°F peak). All wetted metal parts shall be constructed of 316 stainless steel. Flow meter shall meet or exceed all of the accuracy, head loss, flow limits, pressure and material requirements of the AWWA standard C704-70 for the respective pipe or tube size. Analog outputs shall consist of non-interactive zero and span adjustments, a DC linearly of 0.1% of span, voltage output of 0-10 V, and current output of 4-20 mA.
   1. Install in water systems with a minimum of 10 pipe diameters unobstructed flow. [Double turbine insertion required at between 10 and 4 diameters unobstructed flow.]
   2. Acceptable Manufacturers: Onicon Corp. and Hersey. Substitutions shall be allowed per Division 1.

2.22 VORTEX SHEDDING FLOW METER FOR LIQUID, STEAM AND GAS SERVICE:

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

B. Maximum Fluid Temperature: 800 °F (427 °C)

C. Wetted Parts: Stainless Steel

D. Housing: NEMA 4X

E. Turndown: 10:1 minimum.

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

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

H. Acceptable Manufacturers: Foxboro 83 series, Johnson-Yokagawa, and Rosemount. Substitutions shall be allowed per Division 1.

2.23 MAGNETIC FLOW METERS FOR WATER SERVICE

A. Acceptable Manufacturers:
   1. Engineering Measurements Co. (EMCO MAG 3100 with a model MAG 2500 electronic transmitter and display)
   2. Rosemont
   3. Toshiba
   4. Hersey Measurement

5. Yokogawa Industrial Automation
6. Endress & Hauser

B. General Requirements:
1. Sensor shall be a magnetic flow meter, which utilizes Faraday's Law to measure volumetric fluid flow through a pipe.
2. The flow meter shall consist of 2 elements, the sensor and the electronics. The sensor shall generate a measuring signal proportional to the flow velocity in the pipe. The electronics shall convert this EMF into a standard current output.
3. Electronic replacement shall not affect meter accuracy (electronic units are not matched with specific sensors).
   a. Provide a four-wire, externally powered, magnetic type flow transmitter with adjustable span and zero, integrally mounted to flow tube.
   b. Output: 4-20 mA
   c. Flow Tube: Stainless steel
   d. Electrical Enclosure: NEMA 4, 7.
   e. Approvals: UL or CSA.
   f. Stability: 0.1% of rate over six months.
   g. Process Connection: Carbon steel, ANSI 150 LB, size as required.

C. Meter Accuracy:
1. Under the reference conditions of a 68 °F media temperature, a 68 °F ambient temperature, a +/- 1% nominal power supply voltage, 10 diameters up stream and 5 down of straight piping and a fully developed flow profile; the meter must meet the following requirements:
2. +/- 0.8% of reading accuracy in the flow range of 1.65 - 33 ft/sec +/- (0.66/Velocity actual ft/s +0.4)% of reading accuracy in the flow range of 0-1.65 ft/sec.
3. Meter repeatability shall be +/- 0.1% of rate at velocities > 1.65 ft/sec.

D. Calibration: The sensor must be calibrated on an internationally accredited (i.e. NAMAS) flow rig with accuracy better than 0.1%. Calibration shall be traceable to National Institute of Standard and Technology.

E. Construction:
1. The meter piping material shall be AISI 304 stainless steel.
2. The meter flange and enclosure material shall be carbon steel.
3. The external surface of the sensor is to be treated with at least .006 in. (150 µm) of Corrosion resistant two-component paint.
4. The inner meter piping shall be protected with a neoprene liner or similar liner.
5. The electrode material shall be AISI 316 Ti or better.
6. The sensor be ANSI class 150#.

F. Electronics:
1. The sensor shall contain a SENSOR-PROM, storing calibration and factory default settings, i.e. the identification of the sensor and size.
2. An ISO 9001 approved company shall manufacture the sensor and electronics.
3. As standard, the electronics must be installable directly on the sensor or installable (remote) up to 1500 ft from the sensor as a maximum.
4. With local electronics installation, the electronics shall be able to withstand 3 feet water submersion for up to 30 minutes.
5. The electronics shall be compatible with the following power specifications:
   a. 15/230 Vac +10% to 15% 50-60 Hz.
   b. The power consumption must be 10 Watts or less independent of meter size.
   c. The meter electronics shall be able to produce simultaneous scaleable current and frequency/pulse output. The frequency output shall be linearly proportional to flow rate and scaleable from 0-10 kHz. The pulse output shall be scaleable from 50 to 5000 milliseconds duration, suitable for an electromechanical totalizer in engineering units.

d. The electronics must have an internal totalizer for summation of flow.
e. The output of the electronics must be individually, galvanically isolated with an isolation voltage of more than 500 V.

G. Output:
1. The current signal must be either 0-20 mA or 4-20 mA proportional to the flow velocity.
2. The output current signal must accommodate 20% over range without loss in linearity.
3. The electronics shall have an alphanumeric LCD display showing actual flow and totalized flow in engineering units.
4. The display and keyboard must be rotatable so that the display can be viewed regardless of sensor orientation.

H. Error Detection:
1. The electronics must be able to detect the flowing error conditions:
a. Signal connection between electronics and sensor interrupted.
b. Loss of current to the coil circuit.
c. Load on the current output.
d. Defective electronics.
e. Defective sensor.
f. Empty pipe.
g. The electronics must have an Error Log where all error conditions occurring within a period of 180 days are stored.

I. Electronic Replacement Programming:
1. The electronics must be immediately replaceable without the need of cable disconnection or renewed configuration programming.
2. When the supply voltage is applied, the electronics must self configure and display flow without keyboard contact (no programming required).
3. The electronics must be provided with an automatic zero flow setting.
4. The electronics shall be programmable with respect to:
a. User display options and menu
b. Setting data
c. Configuration of outputs
d. Zero 'cut-off' from 0% to 9.9% of maximum flow.
e. For ease of programming, the electronics shall be programmable away from the meter using the meter Sensor-Prom and a 9 V battery.
f. The electronics shall be suitable for operation in an ambient temperature range of -4 °F to 120 °F.

2.24 VENTURI FLOW METER FOR WATER SERVICE

A. Flow Sensing Element: Differential-pressure Venturi-type designed for installation in piping.

B. Construction: Bronze or cadmium plated steel with brass quick connect fittings and attached tag with flow conversion data and rated flow. Ends shall be threaded for 2” and smaller and flanged or welded for larger than 2”.

C. Differential transmitter shall be dual range industrial grade as specified above.

D. Connect differential pressure to venturi and repipe quick connect fittings for measurement. Provide ball valves to isolate quick connects and differential pressure transmitter.

E. Apply Venturi-type flow meters where minimum flow range is no less than 40% of maximum flow.

AE must clearly indicate which flow meters are acceptable for various duties.

2.25 AIRFLOW MEASURING STATIONS (AFMS)

A. Pitot Tube Grids: Provide an array of velocity pressure sensing elements with averaging manifolds and air straightening vanes packaged in a sheet metal casing. Distribute sensing elements in accordance with ASHRAE for traversing ducts. Provide taps to connect tubing from instrumentation. Label AFM with drawing number designation, design flow, velocity pressure, and pressure drop. Application of pitot grids shall be allowed only where minimum expected flow is greater than 30% or maximum flow

B. Hot Wire Grid: Provide an array of hot wire anemometer with air straightening package in a sheet metal casing. Provide averaging circuitry and transmitter to transmit a linear signal proportional to airflow.

C. Vortex Shedding Grid: Provide an array of vortex shedding elements designed to produce stable 'Karmen Vortices' that are linear with air velocity. Provide the electronics to totalize the pulses and output average velocity proportional to an output signal of 4-20ma.
   1. Sensor Accuracy: ±1.5%
   2. Electronics Accuracy: ±0.5%
   3. Range: Select minimum range to accommodate the expected flow range of the project
   4. Temperature Limits: 20-140˚F
   5. Acceptable Manufacturer: Tek-Air Systems Inc. 'Vortek' Model. Ebtron 'Gold Series' Model. Substitutions shall be allowed per Division 1.

2.26 Air Velocity Pressure Sensors (Insertion Type)

A. Single or Multi-Point Averaging (as indicated): Sensing tip shall be for insertion into duct with mounting flange and push on tube connections. Material shall be suitable to the application.

2.27 CO2 Sensors/Transmitters (CO2)

A. CO2 sensors shall use silicon based, diffusion aspirated, infrared single beam, dual-wavelength sensor.

B. Accuracy: ±36ppm at 800 ppm and 68°F.

C. Stability: 5% over 5 years.

D. Output: 4-20 mA, 0-10 Vdc or relay.

E. Mounting: Duct or Wall as indicated.

F. Acceptable Manufacturer: Vaisala, Inc. GMD20 (duct) or GMW20 (wall).

2.28 PNEUMATIC CONTROL COMPONENTS

A. Analog Pressure Gauges: Gauges shall be pneumatic type, minimum 1-1/2" in (38 mm) diameter, with white face and black numerals. Surface-mounted gauges shall have chrome plated trim and be a minimum of 2-1/2" in (64 mm) diameter.

B. Pneumatic Actuated Pressure Switches (PE) (for 30 psig max pressure control systems): Pressure ranges and sensitivity of PEs shall match control system sequence of operation. Switch operation shall be externally adjustable over the operating pressure range (nominal 0-20 psig, 0 to 138 KPa). PE switches shall be SPDT type, rated for the particular application, and shall be UL listed. PE shall be as manufactured by Penn. Substitutions shall be allowed as per Division 1

C. Pilot Positioners: Operating span adjustment range is from 3 to 13 psi (21 to 91 kPa). Positioner shall be furnished with a mounting bracket for attachment directly to the actuator.

2.29 ELECTRIC CONTROL COMPONENTS

A. Limit Switches (LS): Limit switches shall be UL listed, SPDT or DPDT type, with adjustable trim arm. Limit switches shall be as manufactured by Square D, Allen Bradley. Substitutions shall be allowed per Division 1.

B. Electric Solenoid-Operated Pneumatic Valves (EP): EP valves shall be rated for a minimum of 1.5 times their maximum operating static and differential pressure.. Valves shall be ported 2-way, 3-way, or 4-way and shall be normally closed or open as required by the application. EPs shall be sized for minimum pressure drop, and shall be UL and CSA listed. Furnish and install gauges on all inputs of EPs. Furnish an adjustable air pressure regulator on input side of solenoid valves serving actuators operating at greater than 30 psig.
   1. Coil Enclosure: Indoors shall be NEMA-1, Outdoors and NEMA-3, 4, 7, 9.
   2. Fluid Temperature Rating: Valves for compressed air and cold water service shall have 150 °F (66 °C) minimum rating. Valves for hot water or steam service shall have fluid temperature rating higher than the maximum expected fluid temperature.
   3. Acceptable Manufacturers: EP valves shall be as manufactured by ASCO or Parker. Substitutions shall be allowed per Division 1.
   4. Coil Rating: EP valves shall have appropriate voltage coil rated for the application (i.e., 24 VAC, 120 VAC, 24 VDC, etc.).

C. Low Temperature Detector ('Freezestat') (FZ): Low temperature detector shall consist of a 'cold spot' element which responds only to the lowest temperature along any one foot of entire element, minimum bulb size of 1/8" x 20' (3.2mm x 6.1m), junction box for wiring connections and gasket to prevent air leakage or vibration noise, DPST (4 wire, 2 circuit) with manual reset. Temperature range 15 to 55°F (-9.4 to 12.8°C), factory set at 38°F.

D. High Temperature Detectors ('Firestat') (FS): High temperature detector shall consist of 3-pole contacts, a single point sensor, junction box for wiring connections and gasket to prevent air leakage of vibration noise, triple-pole, with manual reset. Temperature range 25 to 215°F (-4 to 102°C).

E. Surface-Mounted Thermostat: Surface-mounted thermostat shall consist of SPDT contacts, operating temperature range of 50 to 150° F (10 to 65°C) , and a minimum 10°F fixed setpoint differential.

F. Low Voltage Wall Thermostat: Wall-mounted thermostat shall consist of SPDT sealed mercury contacts, operating temperature range of 50 to 90°F (10 to 32°C), switch rating of 24 Vac (30 Vac max.), and both manual and automatic fan operation in both the heat and cool modes.

G. Control Relays: All control relays shall be UL listed, with contacts rated for the application, and mounted in minimum NEMA-1 enclosure for indoor locations, NEMA-4 for outdoor locations.
   1. Control relays for use on electrical systems of 120 volts or less shall have, as a minimum, the following:
      a. AC coil pull-in voltage range of +10%, -15% or nominal voltage.
      b. Coil sealed volt-amperes (VA) not greater than four (4) VA.
      c. Silver cadmium Form C (SPDT) contacts in a dustproof enclosure, with 8 or 11 pin type plug.
      d. Pilot light indication of power-to-coil and coil retainer clips.
      e. Coil rated for 50 and 60 Hz service.
      f. Acceptable Manufacturers: Relays shall be Potter Brumfield, Model KRPA. Substitutions shall be allowed per Division 1.
      g. Relays used for across-the-line control (start/stop) of 120V motors, 1/4 HP, and 1/3 HP, shall be rated to break minimum 10 Amps inductive load. Relays shall be IDEC. Substitutions shall be allowed per Division 1.

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

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

I. Control Transformers: Furnish and install control transformers as required. Control transformers shall be machine tool type, and shall be US and CSA listed. Primary and secondary sides shall be fused in accordance with the NEC. Transformer shall be proper size for application, and mounted in minimum NEMA-1 enclosure.
1. Transformers shall be manufactured by Westinghouse, Square 'D', or Jefferson. Substitutions shall be allowed per Division 1.

J. Time Delay Relays (TDR): TDRs shall be capable of on or off delayed functions, with adjustable timing periods, and cycle timing light. Contacts shall be rated for the application with a minimum of two (2) sets of Form C contacts, enclosed in a dustproof enclosure.
1. TDRs shall have silver cadmium contacts with a minimum life span rating of one million operations. TDRs shall have solid state, plug-in type coils with transient suppression devices.
2. TDRs shall be UL and CSA listed, Crouzet type. Substitutions shall be allowed per Division 1.

K. Electric Push Button Switch: Switch shall be momentary contact, oil tight, push button, with number of N.O. and/or N.C. contacts as required. Contacts shall be snap-action type, and rated for minimum 120 Vac operation. Switch shall be 800T type, as manufactured by Allen Bradley. Substitutions shall be allowed per Division 1.

L. Pilot Light: Panel-mounted pilot light shall be NEMA ICS 2 oil tight, transformer type, with screw terminals, push-to-test unit, LED type, rated for 120 VAC. Unit shall be 800T type, as manufactured by Allen-Bradley. Substitutions shall be allowed per Division 1.

M. Alarm Horn: Panel-mounted audible alarm horn shall be continuous tone, 120 Vac Sonalert solid-state electronic signal, as manufactured by Mallory. Substitutions shall be allowed per Division 1.

N. Electric Selector Switch (SS): Switch shall be maintained contact, NEMA ICS 2, oil-tight selector switch with contact arrangement, as required. Contacts shall be rated for minimum 120 Vac operation. Switch shall be 800T type, as manufactured by Allen-Bradley. Substitutions shall be allowed per Division 1.

2.30 REFRIGERANT MONITOR

A. General: Contractor shall provide a refrigerant sensitive infrared-based stationary refrigerant gas leak monitor system designed to continuously measure refrigerants. Refrigerant monitor shall be coordinated to detect refrigerant type on project. The alarm system shall comply with ANSI/ASHRAE 15-2007 and local code requirements.

B. The refrigerant monitor shall be capable of monitoring multiple refrigerant gas compounds at multiple locations in concentrations of 0 PPM to a minimum of 1000 PPM. The Monitor shall have a low range resolution of 1 PPM in the range of 1 PPM through 100 PPM. Readings above 100 PPM must be accurate to within ±5% of reading. Accuracy shall be maintained within ambient environmental ranges of 0ºC. through 50ºC., (32ºF. through 122ºF.) and 5% through 90% relative humidity, non-condensing.

C. The refrigerant monitor shall automatically and continuously monitor the areas through a sample draw type tubular pick up system with an internal pump and filter. The installation of the

monitoring control and the tubing shall be in strict accordance with the manufactures instructions. The location, routing, and final position of the sample tubes shall be submitted to the engineer with all necessary shop drawings and monitor specifications and installation instructions. Tubing size, tubing material, and tube length limitations shall be within the specifications of the monitor manufacture. The location and method of tube support and hangers must be identified on the shop drawings. Each of the sampling tubes shall have end of line filters.

D. The analyzer will be based on infrared detection technology, and will be factory tested and calibrated for the specified refrigerant or refrigerants. Factory certification of the calibrations shall be provided with the O&M manuals. . The analyzer shall provide a menu driven or automatic method of checking both zero, span calibration for each sensor, and allow for adjustment.

E. The monitor shall be equipped with 4 outputs. Three relays shall energize at an adjustable user defined set point based on refrigerant concentration levels. The relay threshold adjustment shall be protected by keyed or password access controls. Adjustments and observations shall be made at the front panel operator interface. The relay threshold values can be viewed without a password. The digital display will continuously display the refrigerant concentration level and alarm status. The fourth output shall indicate a monitor malfunction alarm. The monitor shall also have an analog output that will provide a liner scaled reference to the refrigerant concentration in parts per million. The analog output signal shall be an industry standard DC voltage, or mA current signal.

F. The monitor shall have a NEMA-4 moisture resistant enclosure with a gasketed, hinged front cover. Conduits and tube connections shall be located on the bottom of the enclosure. The enclosure shall have a rust and corrosion resistant finish.

G. The following alarm modes will be provided by the refrigerant monitor:
   1. ALARM LEVEL ONE - Low level of refrigerant concentration at one of the sampling points has detected the presence of a possible refrigerant leak. The initial alarm threshold shall be set to 5 PPM (adj.) and increased if there are nuisance alarms. This alarm level shall be displayed on the refrigerant monitor interface panel, indicating which sensor has triggered the alarm, and the associated concentration of refrigerant in PPM. This event will also send an Alarm Level One signal to the BAS through a digital output from the monitor relay. This alarm will remain active until the refrigerant concentration is reduced below set point.
   2. ALARM LEVEL TWO - This alarm shall indicate that one of the sensors has detected a refrigerant concentration that is approaching dangerous levels in the area being monitored. This alarm shall be set to 25% below the maximum calculated refrigerant level specified in ANSI/ASHRAE 15-1994 and ASHRAE 34-1992. This alarm will be displayed on the monitor interface, and will indicate which of the sensors has caused the alarm, and the highest concentration in PPM. This event will also activate the beacon and audible alarm mounted on the refrigerant monitoring enclosure. This alarm will also be sent to the BAS through the digital output of the relay. In this mode the audible alarm can be silenced, but the beacon shall remain active until the fault is cleared
   3. ALARM LEVEL THREE - This alarm shall be set at the maximum calculated refrigerant level specified in ANSI/ASHRAE 15-1994 and ASHRAE 34-1992 whichever is the lowest concentration. The refrigerant monitor interface will display which sensor has caused the alarm, and the associated concentration in PPM. This event will also activate the beacon and audible alarm mounted on the refrigerant monitoring enclosure. If the audible alarm had been silenced by an earlier alarm, the activation of this level three alarm will cause the audible alarm to be activated again. The relay in the refrigerant monitoring panel shall activate the space ventilation system, and will disable all combustion or flame-producing equipment via hardwired control interlocks. In addition, this event and will de-energize the energy source for any hot surface (850°F or 454°C) located in the space. Interlocks must also be provided to close any normally open doors or openings to the space for proper

ventilation and isolation during this alarm condition. This alarm level will also signal the BAS through the digital output through the same relay. In this mode, the audible alarm can be silenced, but the beacon shall remain active until the fault is cleared.

H. All alarm conditions shall be report to the BAS system as follows:
   1. ALARM LEVEL ONE - The lowest refrigerant alarm level shall detect the presence of refrigerant in low concentrations and energize a relay to signal a low level alarm to the BAS operator terminal(s). The alarm shall display an alarm message stating that there is a potential refrigerant leak in the designated area.
   2. ALARM LEVEL TWO - The second refrigerant level alarm shall be a high refrigerant alarm alert. This alarm shall energize a relay to signal the BAS system indicating a high level alarm on the BAS operator terminal(s). This BAS alarm shall state that high levels of refrigerant have been detected in the designated area.
   3. FAULT ALARM - Reports a high level alarm to the BAS operator terminal(s) that there is a fault in the refrigerant monitoring alarm system.

2.31 SMOKE CONTROL/FIREMAN'S OVERRIDE PANEL

A. Integral enunciator/control panel part of complete engineered and UUKL 864 listed system.

B. Provide clear, laminated graphic schematically representing the building air systems. Status LEDs shall be associated with graphic representations of fans. Override switches shall be provided as required by NFPA 110 to allow override of the fans and dampers applicable to the code requirements.

C. Interface with Fire Alarm System as required to implement the requirements specified in the Sequence of Operations.

2.32 NAMEPLATES

A. Provide engraved phenolic or micarta nameplates for all equipment, components, and field devices furnished. Nameplates shall be 1/8 thick, black, with white center core, and shall be minimum 1" x 3", with minimum 1/4" high block lettering. Nameplates for devices smaller than 1" x 3" shall be attached to adjacent surface.

B. Each nameplate shall identify the function for each device.

2.33 TESTING EQUIPMENT

A. Contractor shall test and calibrate all signaling circuits of all field devices to ascertain that required digital and accurate analog signals are transmitted, received, and displayed at system operator terminals, and make all repairs and recalibrations required to complete test. Contractor shall be responsible for test equipment required to perform these tests and calibrations. Test equipment used for testing and calibration of field devices shall be at least twice as accurate as respective field device (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range).

PART 3 - EXECUTION

3.01 INSPECTION

A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS

A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings. Install electrical components and use electrical products complying with requirements of National Electric Code and all local codes.

B. Control Wiring: The term "control wiring" is defined to include providing of wire, conduit and miscellaneous materials as required for mounting and connection of electric control devices.
   1. Wiring System: Install complete wiring system for electric control systems. Conceal wiring except in mechanical rooms and areas where other conduit and piping are exposed. Installation of wiring shall generally follow building lines. Install in accordance with National Electrical Code and Division 16 of this Specification. Fasten flexible conductors bridging cabinets and doors, neatly along hinge side, and protect against abrasion. Tie and support conductors neatly.
   2. Control Wiring Conductors: Install control wiring conductors, without splices between terminal points, color-coded. Install in neat workmanlike manner, securely fastened. Install in accordance with National Electrical Code and Division 16 of this Specification.
   3. Communication wiring, signal wiring and low voltage control wiring shall be installed separate from any wiring over thirty (30) volts. Signal wiring shield shall be grounded at controller end only, unless otherwise recommended by the controller manufacturer.
   4. All WAN and LAN Communication wiring shield shall be terminated as recommended by controller manufacturer. All WAN and LAN Communication wiring shall be labeled with a network number, device ID at each termination and shall correspond with the WAN and LAN system architecture and floor plan submittals.
   5. Install all control wiring external to panels in electric metallic tubing or raceway. However, communication wiring, signal wiring and low voltage control wiring may be run without conduit in concealed, accessible locations if noise immunity is ensured. Contractor will be fully responsible for noise immunity and rewire in conduit if electrical or RF noise affects performance. Accessible locations are defined as areas inside mechanical equipment enclosures, such as heating and cooling units, instrument panels etc.; in accessible pipe chases with easy access, or suspended ceilings with easy access. Installation of wiring shall generally follow building lines. Run in a neat and orderly fashion, bundled where applicable, and completely suspended (strapped to rigid elements or routed through wiring rings) away from areas of normal access. Tie and support conductors neatly with suitable nylon ties. Conductors shall not be supported by the ceiling system or ceiling support system. Conductors shall be pulled tight and be installed as high as practically possible in ceiling cavities. Wiring shall not be laid on the ceiling or duct. Conductors shall not be installed between the top cord of a joist or beam and the bottom of roof decking. Contractor shall be fully responsible for noise immunity and rewire in conduit if electrical or RF noise affects performance.
   6. Number-code or color-code conductors appropriately for future identification and servicing of control system. Code shall be as indicated on approved installation drawings.

C. Control Valves: Install so that actuators, wiring, and tubing connections are accessible for maintenance. Where possible, install with valve stem axis vertical, with operator side up. Where vertical stem position is not possible, or would result in poor access, valves may be installed with stem horizontal. Do not install valves with stem below horizontal, or down.

D. Freezestats: Install freezestats in a serpentine fashion where shown on drawing. Provide one foot of element for each square foot of coil face area. Where coil face area exceeds required length of element, provide multiple devices, wired in parallel for normally open close on trip application, wired in series for normally closed, open on trip application. Adequately support with coil clips.

E. Averaging Temperature Sensors: Cover no more than two square feet per linear foot of sensor length except where indicated. Generally where flow is sufficiently homogeneous/adequately mixed at sensing location, consult AE for requirements.

   AE must specifically show locations of all flow meters and design in the straight length of duct or pipe required for accurate sensors. This length must be specifically shown on the drawing.

F. Airflow Measuring Stations: Install per manufacturer's recommendations in an unobstructed straight length of duct (except those installations specifically designed for installation in fan inlet). For installations in fan inlets, provide on both inlets of double inlet fans and provide inlet cone adapter as recommended by AFM station manufacturer.

G. Fluid Flow Sensors: Install per manufacturer's recommendations in an unobstructed straight length of pipe.

H. Relative Humidity Sensors: Provide element guard as recommended by manufacturer for high velocity installations. For high limit sensors, position remote enough to allow full moisture absorption into the air stream before reaching the sensor.

I. Differential Pressure Transmitters: Provide valve bypass arrangement to protect against over pressure damaging the transmitter.

J. Flow Switches: Where possible, install in a straight run of pipe at least 15 diameters in length to minimize false indications.

K. Current Switches for Motor Status Monitoring: Adjust so that setpoint is below minimum operating current and above motor no load current.

L. Supply Duct Pressure Transmitters:
1. General: Install pressure tips with at least 4 'round equivalent' duct diameters of straight duct with no takeoffs upstream. Install pressure tips securely fastened with tip facing upstream in accordance with manufacturer's installation instructions. Locate the transmitter at an accessible location to facilitate calibration.
2. VAV System 'Down-Duct' Transmitters: Locate pressure tips approximately 2/3 of the hydraulic distance to the most remote terminal in the air system.

M. Cutting and Patching Insulation: Repair insulation to maintain integrity of insulation and vapor barrier jacket. Use hydraulic insulating cement to fill voids and finish with material matching or compatible with adjacent jacket material.

3.03 Refrigerant Monitor

A. Install in accordance with the manufacturer's instructions. Place sensing tips in locations to maximize effectiveness.

B. Hard wire interlocks to the emergency ventilation and shutdown of combustion devices.

END OF SECTION 23 09 51

SECTION 23 09 53

BAS FIELD PANELS

PART 1 - GENERAL

1.01 SECTION INCLUDES:

A. Building Controller (BC)

B. Advance Application Specific Controller (AAC)

C. Application Specific Controller (ASC)

1.02 RELATED DOCUMENTS:

A. Section 23 09 50 - Building Automation System (BAS) General - Refer to this section for definitions of terminology

B. Section 23 09 51 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 23 09 54 - BAS Communications Devices

D. Section 23 09 55 - BAS Software

E. Section 23 09 58 - Sequence of Operation

F. Section 23 09 59 - BAS Commissioning

1.03 DESCRIPTION OF WORK:

A. Furnish and install DDC Control units and/or Smart Devices required to support specified building automation system functions.

B. Refer to Section 23 09 50 for general requirements.

PART 2 - PRODUCTS

2.01 Stand-Alone Functionality

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

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

C. The following configurations are considered acceptable with reference to a controller's standalone functionality:
   1. Points packaged as integral to the controller such that the point configuration is listed as an essential piece of information for ordering the controller (having a unique ordering number).
   2. Controllers with processors and modular back planes that allow plug in point modules as an integral part of the controller.
   3. I/O point expander boards, plugged directly into the main controller board to expand the point capacity of the controller.

4. I/O point expansion devices connected to the main controller board via wiring and as such may be remote from the controller and that communicate via a sub LAN protocol. These arrangements to be considered standalone shall have a sub LAN that is dedicated to that controller and include no other controller devices (AACs or ASCs). All wiring to interconnect the I/O expander board shall be:
   a. Contained in the control panel enclosure;
   b. Or run in conduit. Wiring shall only be accessible at the terminations.

D. The following configurations are considered unacceptable with reference to a controller's standalone functionality:
   1. Multiple controllers enclosed in the same control panel to accomplish the point requirement.

2.02 Building Controller (BC)

A. General Requirements:
   1. The BC(s) shall provide fully distributed control independent of the operational status of the OWSs and CSS. All necessary calculations required to achieve control shall be executed within the BC independent of any other device. All control strategies performed by the BC(s) shall be both operator definable and modifiable through the Operator Interfaces.
   2. BCs shall perform overall system coordination, accept control programs, perform automated HVAC functions, control peripheral devices and perform all necessary mathematical and logical functions. BCs shall share information with the entire network of BCs and AACs/ASCs for full global control. Each controller shall be accessed through the CSS in normal operations. In the event that the CSS is not available, the controller shall permit multi-user operation from multiple OWS and mobile computers connected either locally or over the network. Each unit shall have its own internal RAM, non-volatile memory, microprocessor, battery backup, regulated power supply, power conditioning equipment, ports for connection of operating interface devices, and control enclosure. BCs shall be programmable from the CSS, OWS, mobile computer, or hand held device. BC shall contain sufficient memory for all specified global control strategies, user defined reports and trending, communication programs, and central alarming.
   3. BCs shall be connected to a controller network that qualifies as a controlling LAN.
   4. All BCs shall be provided with a UPS to protect against memory loss and allow for continuous communication with the CSS in the event of a loss of power.
      a. The UPS shall be a 500 VA UPS equal to APC Back-UPS CS, 300 Watts / 500 VA, Input 120V / Output 120V, Interface Port DB-9 RS-232, USB
   5. In addition BCs may provide intelligent, standalone control of BAS functions. Each BC may be capable of standalone direct digital operation utilizing its own processor, non-volatile memory, input/output, wiring terminal strips, A/D converters, real-time clock/calendar and voltage transient and lightning protection devices. Refer to standalone functionality specified above.
   6. The BC may provide for point mix flexibility and expandability. This requirement may be met via either a family of expander boards, modular input/output configuration, or a combination thereof. Refer to stand alone functionality specified above.
   7. All BC point data, algorithms and application software shall be modifiable from the CSS and OWS.
   8. Each BC shall execute application programs, calculations, and commands via a microprocessor resident in the BC. The database and all application programs for each BC shall be stored in non-volatile or battery backed volatile memory within the BC and will be able to upload/download to/from the CSS.
   9. BC shall provide buffer for holding alarms, messages, trends etc.
   10. Each BC shall include self-test diagnostics, which allow the BC to automatically alarm any malfunctions, or alarm conditions that exceed desired parameters as determined by programming input.

11. Each BC shall contain software to perform full DDC/PID control loops.
12. For systems requiring end-of-line resistors those resistors shall be located in the BC.
13. Input-Output Processing
    a. Digital Outputs (DO): Outputs shall be rated for a minimum 24 Vac or Vdc, 1 amp maximum current. Each shall be configurable as normally open or normally closed. Each output shall have an LED to indicate the operating mode of the output and a manual hand off or auto switch to allow for override. Each DO shall be discrete outputs from the BC's board (multiplexing to a separate manufacturer's board is unacceptable). Provide suppression to limit transients to acceptable levels.
    b. Analog Inputs (AI): AI shall be 0-5 Vdc, 0-10 Vdc, 0-20 Vdc, and 0-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the BC's board (multiplexing to a separate manufacturers board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 12 bits.
    c. Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board. Software multiplexing of an AI and resistors may only be done in non-critical applications and only with prior approval of Architect/Engineer.
    d. Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.
    e. Electronic Analog Outputs (AO): Voltage mode: 0-5 Vdc and 0-10 Vdc; Current mode: 4-20 mA. Provide zero and span calibration and circuit protection. Pulse Width Modulated (PWM) analog via a DO [and transducer] is acceptable only with State approval (Generally these will not be allowed on loops with a short time constant such as discharge temperature loops, economizer loops, pressure control loops and the like. They are generally acceptable for standard room temperature control loops.). Where these are allowed, transducer/actuator shall be programmable for normally open, normally closed, or hold last position and shall allow adjustable timing. Each DO shall be discrete outputs from the BC's board (multiplexing to a separate manufacturers board is unacceptable). D/A converters shall have a minimum resolution of 10 bits.
    f. Pulsed Inputs: Capable of counting up to 8 pulses per second with buffer to accumulate pulse count. Pulses shall be counted at all times.
14. A communication port for operator interface through a mobile computer shall be provided in each BC. It shall be possible to perform all program and database back-up, system monitoring, control functions, and BC diagnostics through this port. Standalone BC panels shall allow temporary use of portable devices without interrupting its normal operation.
15. Each BC shall be equipped with loop tuning algorithm for precise proportional, integral, derivative (PID) control. Loop tuning tools provided with the CSS software is acceptable. In any case, tools to support loop tuning must be provided such that P, I, and D gains are automatically calculated.
16. All analog output points shall have a selectable failure setpoint. The BC shall be capable of maintaining this failure setpoint in the event of a system malfunction, which causes loss of BC control, or loss of output signal, as long as power is available at the BC. The failure setpoint shall be selectable on a per point basis.
17. Slope intercepts and gain adjustments shall be available on a per-point basis.
18. BC Power Loss:
    a. Upon a loss of power to any BC, the other units on the controlling LAN shall not in any way be affected.
    b. Upon a loss of power to any BC, the battery backup shall ensure that the energy management control software, the Direct Digital Control software, the database parameters, and all other programs and data stored in the RAM are retained for a minimum of fifty (50) hours. An alarm diagnostic message shall indicate that the BC is under battery power.

c. Upon restoration of power within the specified battery backup period, the BC shall resume full operation without operator intervention. The BC shall automatically reset its clock such that proper operation of any time dependent function is possible without manual reset of the clock. All monitored functions shall be updated.
d. Should the duration of a loss of power exceed the specified battery back-up period or BC panel memory be lost for any reason, the panel shall automatically report the condition (upon resumption of power) and be capable of receiving a download via the network from the CSS or a mobile computer. In addition, the State shall be able to upload the most current versions of all energy management control programs, Direct Digital Control programs, database parameters, and all other data and programs in the memory of each BC to the CSS or a mobile computer via the network or the local USB or RS-232C port.

19. BC Failure:
    a. Building Controller LAN Data Transmission Failure: BC shall continue to operate in stand-alone mode. BC shall store loss of communication alarm along with the time of the event. All control functions shall continue with the global values programmable to either the last value or a specified value. Peer BCs shall recognize the loss and report alarm.
    b. BC Hardware Failure: BC shall cease operation and terminate communication with other devices. All outputs shall go to their specified fail position.
20. Each BC shall be equipped with firmware resident self-diagnostics for sensors and be capable of assessing an open or shorted sensor circuit and taking an appropriate control action (close valve, damper, etc.).
21. BCs may include network communications interface functions for controlling secondary controlling LANs Refer to Section 23 09 54 - BAS System Communications Devices for requirements if this function is packaged with the BC.
22. A minimum of four levels of privileges shall be provided at each BC.
23. All local user accounts shall be password protected. Strong password shall be used and complies with the State security standard.
24. BCs shall be mounted on equipment, in packaged equipment enclosures, or locking wall mounted in a NEMA 1 enclosure, as specified elsewhere.

B. BACnet Building Controller Requirements:
1. The BC(s) shall support all BIBBs defined in the BACnet-IP (B-BC) device profile as defined in the BACnet standard.
2. BCs shall communicate over the BACnet-IP LAN.
3. Each BC shall be connected to the BACnet-IP LAN communicating to/from other BCs.

2.03 AdvanceD Application Specific Controller (AAC) and Application Specific Controller (AsC)

A. General Requirements:
1. AACs and ASCs shall provide intelligent, standalone control of HVAC equipment. Each unit shall have its own internal RAM, non-volatile memory and will continue to operate all local control functions in the event of a loss of communications on the ASC LAN or sub-LAN. Refer to standalone requirements by application specified in Part 3 of this section. In addition, it shall be able to share information with every other BC and AAC /ASC on the entire network.
2. Each AAC and ASC shall include self-test diagnostics that allow the AAC /ASC to automatically relay to the BC, or LAN Interface Device, any malfunctions or abnormal conditions within the AAC /ASC or alarm conditions of inputs that exceed desired parameters as determined by programming input.
3. AACs and ASCs shall include sufficient memory to perform the specific control functions required for its application and to communicate with other devices.
4. Each AAC and ASC must be capable of stand-alone direct digital operation utilizing its own

processor, non-volatile memory, input/output, minimum 8 bit A to D conversion, voltage transient and lightning protection devices. All volatile memory shall have a battery backup of at least fifty- (50) hrs with a battery life of (5) five years.

5. All point data; algorithms and application software within an AAC /ASC shall be modifiable from the OWS.
6. AAC and ASC Input-Output Processing
   a. Digital Outputs (DO): Outputs shall be rated for a minimum 24 VAC or VDC, 1 amp maximum current. Each shall be configurable as normally open or normally closed. Each output shall have an LED to indicate the operating mode of the output and a manual hand off or auto switch to allow for override (Only AAC requires HOA). Each DO shall be discrete outputs from the AAC/ASC's board (multiplexing to a separate manufacturer's board is unacceptable). Provide suppression to limit transients to acceptable levels.
   b. Analog Inputs (AI): AI shall be O-5 Vdc, 0-10Vdc, 0-20Vdc, and 0-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the BC's board (multiplexing to a separate manufacturers board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 8-10 bits depending on application.
   c. Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board. Software multiplexing of an AI and resistors may only be done in non-critical applications and only with prior approval of Architect/Engineer
   d. Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.
   e. Electronic Analog Outputs (AO) as required by application: voltage mode, 0-5VDC and 0-10VDC; current mode (4-20 mA). Provide zero and span calibration and circuit protection. Pulse Width Modulated (PWM) analog via a DO [and transducer] is acceptable only with State approval (Generally, PWM will not be allowed on loops with a short time constant such as discharge temperature loops, economizer loops, pressure control loops and the like. They are generally acceptable for standard room temperature control loops.). Where PWM is allowed, transducer/actuator shall be programmable for normally open, normally closed, or hold last position and shall allow adjustable timing. Each DO shall be discrete outputs from the BC's board (multiplexing to a separate manufacturers board is unacceptable). D/A converters shall have a minimum resolution of 8 bits.

B. BACnet AAC(s) and ASC(s) Requirements:
   1. The AAC(s) and ASC(s) shall support all BIBBs defined in the BACnet Building Controller (B-AAC and B-ASC) device profile as defined in the BACnet standard.
   2. AAC(s) and ASC(s) shall communicate over the BACnet Building Controller LAN or the ASC LAN or sub-LAN.
   3. Each BC shall be connected to the BACnet Building Controller LAN communicating to/from other BCs.

C. Terminal Box Controllers:
   1. Terminal box controllers controlling damper positions to maintain a quantity of supply or exhaust air serving a space shall have an automatically initiated function that resets the volume regulator damper to the fully closed position on a scheduled basis. The controllers shall initially be set up to perform this function once every 24 hours. The purpose of this required function is to reset and synchronize the actual damper position with the calculated damper position and to assure the damper will completely close when commanded. The software shall select scheduled boxes randomly and shall not allow more than 5% of the total quantity of controllers in a building to perform this function at the same time. This reset shall be performed while the AHU is operating. The BAS shall send an alarm for any terminal box that has been reset and does not indicate 0 cfm flow with the damper

commanded closed.

PART 3 - EXECUTION

3.01 INSPECTION:

A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS:

A. General: Install systems and materials in accordance with manufacturer's instructions, specifications roughing-in drawings and details shown on drawings. Contractor shall install all controllers in accordance with manufacturer's installation procedures and practices.

3.03 HARDWARE APPLICATION REQUIREMENTS

A. General: The functional intent of this specification is to allow cost effective application of manufacturers standard products while maintain the integrity and reliability of the control functions. A BC as specified above is generally fully featured and customizable whereas the AAC/ASC refers to a more cost-effective unit designed for lower-end applications. Specific requirements indicated below are required for the respective application. Manufacturer may apply the most cost-effective unit that meets the requirement of that application.

B. Standalone Capability: Each Control Unit shall be capable of performing the required sequence of operation for the associated equipment. All physical point data and calculated values required to accomplish the sequence of operation shall originate within the associated CU with only the exceptions enumerated below. Refer to Item 2.01 above for physical limitations of standalone functionality. Listed below are functional point data and calculated values that shall be allowed to be obtained from or stored by other CUs or SDs via LAN.

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

D. Application Category 0 (Distributed monitoring)
   1. Applications in this category include the following:
      a. Monitoring of variables that are not used in a control loop, sequence logic, or safety.
   2. Points on BCs, AACs, and ASCs may be used in these applications as well as SDs and/or general-purpose I/O modules.
   3. Where these points are trended, contractor shall verify and document that the network bandwidth is acceptable for such trends and is still capable of acceptable and timely control function.

E. Application Category 1 (Application Specific Controller):
   1. Applications in this category include the following:
      a. Fan Coil Units
      b. Airflow Control Boxes (VAV and Constant Volume Terminal Units)
      c. Misc. Heaters
      d. Unitary equipment <15 tons (Package Terminal AC Units, Package Terminal Heat Pumps, Split-System AC Units, Split-System Heat Pumps, Water-Source Heat Pumps)
      e. Induction Units
      f. Variable Speed Drive (VSD) controllers not requiring safety shutdowns of the controlled device.
   2. ASCs may be used in these applications.
   3. Standalone Capability: Provide capability to execute control functions for the application for a given setpoint or mode, which shall generally be occupied mode control. Only the following data (as applicable) may be acquired from other controllers via LANs. In the event

of a loss of communications with any other controller, or any fault in any system hardware that interrupts the acquisition of any of these values, the ASC shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

Physical/Virtual Point	Default Value
Scheduling Period	Normal
Morning Warm-Up	Off (cold discharge air)
Load Shed	Off (no shedding)
Summer/Winter	Winter
[Trend Data	N/A]
[Smoke Pressurization Mode	Normal Mode]

4. Mounting:
   a. ASCs that control equipment located above accessible ceilings shall be mounted on the equipment in an accessible enclosure that does not hinder maintenance of mechanical equipment and shall be rated for plenum use.
   b. ASCs that control equipment mounted in a mechanical room may either be mounted in, on the equipment, or on the wall of the mechanical room at an adjacent, accessible location.
   c. ASCs that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the contractor) or in a nearby mechanical/utility room in which case it shall be enclosed in a NEMA 1, locking enclosure.
   d. Section 23 09 53 contractor may furnish ASCs to the terminal unit manufacturer for factory mounting.
5. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up parameters, interstage timing parameters, and mode settings. Application-specific block control algorithms may be used to meet the sequence of operations. The ability to customize the control algorithm is not required unless specifically indicated otherwise.
6. LAN Restrictions: Limit the number of nodes on the network to the maximum recommended by the manufacturer.

F. Application Category 2 (General Purpose Terminal Controller)
   1. Applications in this category include the following:
      a. Unitary Equipment >= 15 tons (Air Conditioners, Heat Pumps, Packaged Heating/Cooling Units, and the like)
      b. Small, Constant Volume Single Zone Air Handling Units
      c. Constant Volume Pump Start/Stop
      d. Misc. Equipment (Exhaust Fan) Start/Stop
      e. Misc. Monitoring (not directly associated with a control sequence and where trending is not critical)
      f. Steam Converter Control
   2. BCs may be used in these applications.
   3. ASC's may be used in these applications provided the ASC meets all requirements specified below. This category requires a general-purpose ASC to which application-specific control algorithms can be attached.
   4. Standalone Capability: Only the following data (as applicable) may be acquired from other ASCs via LANs. In the event of a loss of communications with any other ASCs, or any fault in any system hardware that interrupts the acquisition of any of these values, the AAC/ASC shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

Physical/Virtual Point	Default Delay Time	Default Value

Outside Air Temperature	3 minutes	80°F
Outside Air Humidity	3 minutes	60%RH
Outside Air Enthalpy	3 minutes	30 Btu/lb
Trend Data		N/A
Cooling/Heating Requests	3 minutes	None
Smoke Pressurization Mode	3 minutes	Normal Mode
Smoke Exhaust Command	3 minutes	Normal Mode

5. Mounting:
   a. ASCs that control equipment located above accessible ceilings shall be mounted on the equipment so as not to hinder mechanical maintenance and shall be rated for plenum use.
   b. ASCs that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the contractor) or in a nearby mechanical/utility room in which case it shall be enclosed in a NEMA 1, locking enclosure.
6. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up parameters, interstage timing parameters, and mode settings. Operator shall be able to address and configure spare inputs for monitoring. [Operator shall be able to address and configure spare outputs for simple single loop control actions or event initiated actions.] Application-specific block control algorithms shall used to meet the sequence of operations. The ability to customize the control algorithm is not required unless specifically indicated otherwise.
7. LAN Restrictions: Limit the number of nodes servicing any one of these applications on the AAC/ASC LAN to 32.

G. Application Category 3 (Advanced Application Controller)
1. Applications in this category include the following:
   a. Large Constant Volume Air Handlers
   b. VAV Air Handlers generally >5,000 and <10,000cfm
   c. Dual Duct Air Handlers generally >5000 and < 10,000 cfm
   d. Multizone Air Handlers
   e. Self-Contained VAV Units
2. BCs may be used in these applications.
3. AAC's may be used in these applications provided:
   a. The AAC's meets all requirements specified below.
   b. All control functions and physical I/O associated with a given unit resides in one AAC.
   c. Input A/D is 10-bit. Exception: 8-bit input A/D can be used when matched with high accuracy sensors, the range of which meets the resolution requirements specified for the applicable sensor in Section 23 09 51.
   d. Pulsed inputs required for the application can be monitored and accumulated effectively.
4. Standalone Capability: Only the following data (as applicable) may be acquired from other AACs via LANs. In the event of a loss of communications with any other AACs, or any fault in any system hardware that interrupts the acquisition of any of these values, the AAC shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

physical/virtual point	default delay time	default value
Outside Air Temperature	3 minutes	80°F
Outside Air Humidity	3 minutes	60%RH
Outside Air Enthalpy	3 minutes	30 Btu/lb
Enable Local Operation		Last Value
Cooling/Heating Requests	3 minutes	None
Smoke Pressurization Mode	3 minutes	Normal Mode

Smoke Exhaust Command	3 minutes	Normal Mode

5. Mounting:
   a. AACs that control equipment located above accessible ceilings shall be mounted on the equipment so as not to hinder mechanical maintenance and shall be rated for plenum use.
   b. AACs that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the contractor) or in a near by mechanical/utility room in which case it shall be enclosed in a NEMA 1, locking enclosure.
6. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up parameters, interstage timing parameters, and mode settings. Operator shall be able to address and configure spare inputs for monitoring. Operator shall be able to program custom DDC control algorithms and specify trending parameters, which will be retained in memory in the event of a loss of communications. Application-specific block control algorithms may be used provided they meet the sequence of operations. The control algorithms shall be completely customizable.
7. LAN Restrictions: Each LAN which participates in the transfer of data between the CU and the local operator workstation shall be subject to the following criteria:
   a. Limit the number of nodes servicing any one of these applications on the AAC/ASC LAN to 16.
   b. The Building Controller LAN shall be subject only to manufacturer's published LAN limitations.

H. Application Category 4
1. Applications in this category include the following:
   a. Central Cooling Plant
   b. Central Heating Plant
   c. Cooling Towers
   d. Sequenced or Variable Speed Pump Control
   e. Local Chiller Control (unit specific)
   f. Local Free Cooling Heat Exchanger Control
   g. Air Handlers over 10,000 cfm or serving critical areas
2. BCs shall be used in these applications.

3.04 CONTROL UNIT REQUIREMENTS

A. Refer to Section 23 09 50 for requirements pertaining to control unit quantity and location.

END OF SECTION 23 09 53

SECTION 23 09 54

BAS COMMUNICATION DEVICES

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Network Integration Devices

1.02 RELATED DOCUMENTS:

A. Section 23 09 50 - Building Automation System (BAS) General

B. Section 23 09 51 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 23 09 53 - BAS Field Panels

D. Section 23 09 55 - BAS Software

E. Section 23 09 58 - Sequences of Operation

F. Section 23 09 59 - BAS Commissioning

1.03 DESCRIPTION OF WORK

A. Contractor shall provide all interface devices and software to provide an integrated system connecting BCs, AACs, ASCs and Gateways to the State network.

PART 2 - PRODUCTS

2.01 Network Connection

A. State WAN: Refer Section 23 09 50 Part 1.11.C.1 - Building Automation System (BAS) General for description of System Architecture.

B. The following BIBBs must be supported on the Local Supervisory LAN using Ethernet either directly or through a gateway:
   1. BACnet Data Sharing Objects (DS-):
      a. Read Property (RP-A) Initiate
      b. Read Property (RP-B) Execute
      c. Read Property Multiple (RPM-A) Initiate
      d. Read Property Multiple (RPM-B) Execute
      e. Write Property (WP-A) Initiate
      f. Write Property (WP-B) Execute
      g. Write Property Multiple (WPM-A) Initiate
      h. Write Property Multiple (WPM-B) Execute
      i. COV Unsubscribed (COVU-A) Initiate
      j. COV Unsubscribed (COVU-B) Execute
   2. BACnet Alarm and Event Object (AE-)
      a. Confirmed Event Notification (N-B) Initiate
      b. Unconfirmed Event Notification (N-B) Initiate

C. Refer to Section 23 09 55 Part III for the BACnet Object naming convention.

2.02 BACnet Gateways

A. Gateways shall be provided to link non-BACnet control products to the BACnet inter-network. All of the functionality described in this section is to be provided by using the BACnet capabilities. Each Gateway shall have the ability to expand the number of BACnet objects of each type supported by 20% to accommodate future system changes.

B. Each Gateway shall provide values for all points on the non-BACnet side of the Gateway to BACnet devices as if the values were originating from BACnet objects. The Gateway shall also provide a way for BACnet devices to modify (write) all points specified by the AOC using standard BACnet services. All points are required to be writable for each site.

C. The Gateway shall implement BACnet schedule objects and permit both read and write access to the schedules from the BC.

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

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

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

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

H. All BACnet Interoperability Building Blocks (BIBBs) are required to be supported for each native BACnet device or Gateway. The Gateway shall support all BIBBs defined in the BACnet Gateway's device profile as defined in the BACnet standard.

2.03 Controller LOCAL AREA NETWORK Interface Devices (LANID)

A. The LANID shall be a microprocessor-based communications device which acts as a gateway/router between the Primary Controlling LAN and the Secondary Controlling LAN. It provides an operator interface. These may be provided within a BC or as a separate device.

B. The LANID shall perform information translation between the Primary Controlling LAN and the Secondary Controlling LAN, supervise communications on a polling Secondary Controlling LAN, and be applicable to systems in which the same functionality is not provided in the BC. In systems where the LANID is a separate device, it shall contain its own microprocessor, RAM, battery, real-time clock, communication ports, and power supply as specified for a BC in Section 23 09 53. Each LANID shall be mounted in a lockable enclosure.

C. Each LANID shall support interrogation, full control, and all utilities associated with all BCs on the Primary Controlling LAN, all AACs and ASCs connected to all Secondary Controlling LANs under the Primary Controlling LAN, and all points connected to those PCUs and SCUs.

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

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

F. All BACnet Interoperability Building Blocks (BIBBs) are required to be supported for each native BACnet device or Gateway. The Gateway shall support all BIBBs defined in the BACnet Gateway's device profile as defined in the BACnet standard.

2.04 Local Supervisory LAN Gateways/Routers

A. The gateway/router shall be a microprocessor-based communications device that acts as a gateway/router between the Supervisory LAN CSSs or OWS and the Controlling LAN.

B. The gateway/router shall perform information translation between the Controlling LAN and the Local Supervisory LAN, and shall use BACnet over IP. When BACnet is used, refer to the requirements of the BACnet Gateways specified herein.

C. The gateway/router shall contain its own microprocessor, RAM, battery, real-time clock, communication ports, and power supply as specified for a BC in Section 23 09 53. Each gateway/router shall be mounted in a lockable enclosure.

D. The gateway/router shall allow centralized overall system supervision, operator interface, management report generation, alarm annunciation, acquisition of trend data, and communication with control units. It shall allow system operators to perform the following functions from the CSS, and OWSs:
   1. Configure systems.
   2. Monitor and supervise control of all points.
   3. Change control setpoints.
   4. Override input values.
   5. Override output values
   6. Enter programmed start/stop time schedules.
   7. View and acknowledge alarms and messages.
   8. Receive, store and display trend logs and management reports.
   9. Upload/Download programs, databases, etc. as specified.

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

F. The gateway/router shall be transparent to control functions and shall not be required to control information routing on the Controlling LAN

2.05 Chiller Controls Interface Device (CID)

A. The CID shall be a microprocessor-based communications device that acts as a gateway between the control protocol and the applicable chiller controller.

B. The CID shall contain its own microprocessor, RAM, battery, communication ports and, power supply.

C. Each CID shall support full bi-directional communications translation as more fully specified in Section 23 09 55.

D. See drawings for required list of mapped points.

PART 3 - EXECUTION

3.01 INSPECTION:

A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS:

A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.

B. Contractor shall provide all interface devices and software to provide an integrated system.

C. Contractor shall closely coordinate with the State, or designated representative, to establish IP

addresses and communications to assure proper operation of the building control system on the State (DE) network.

END OF SECTION 23 09 54

SECTION 23 09 55

BAS SOFTWARE AND PROGRAMMING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. System Software

B. Programming Description

C. Control Algorithms

D. Energy Management Applications

E. Password Protection

F. Alarm Reporting

G. Trending

H. Data Acquisition and Storage

I. Point Structuring

J. Dynamic Color Graphics

1.02 RELATED DOCUMENTS:

A. Section 23 09 50 - Building Automation System (BAS) General

B. Section 23 09 51 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 23 09 53 - BAS Field Panels

D. Section 23 09 54 - BAS Communications Devices

E. Section 23 09 58 - Sequences of Operation

F. Section 23 09 59 - BAS Commissioning

1.03 DESCRIPTION OF WORK:

A. Fully configure systems and furnish and install all software, programming and dynamic color graphics for a complete and fully functioning system as specified.

B. Refer to Section 23 09 50 - Building Automation System (BAS) for general requirements

C. Refer to 23 09 58 - Sequence of Operation for specific sequences of operation for controlled equipment.

1.04 LICENSING

A. Include licensing for all software packages at all required workstations.

B. All operator interface, programming environment, networking, database management and any other software used by the Contractor to install the system or needed to operate the system to its full capabilities shall be licensed and provided to the State.

C. All BAS software should be available on CSS(s) provided, and on all Portable Operator Terminals. All software keys to provide all rights shall be installed on CSS. At least 2 sets of media (CD or DVD) shall be provided with backup software and configurations for all software provided, so that the State may reinstall any software as necessary

D. Provide licensing and original software media for each device. Include all BAS software licenses and all required third party software licenses.

E. Upgrade all software packages to the release (version) in effect at the end of the Warranty Period.

F. Refer to Section 23 09 50 - Building Automation System (BAS) General for further requirements.

PART 2 - PRODUCTS

2.01 SYSTEM SOFTWARE-GENERAL

A. Functionality and Completeness: The Contractor shall furnish and install all software and programming necessary to provide a complete and functioning system as specified. The Contractor shall include all software and programming not specifically itemized in these Specifications, which is necessary to implement, maintain, operate, and diagnose the system in compliance with these Specifications.

B. Configuration: The software shall support the system as a distributed processing network configuration.

2.02 CONTROLLER SOFTWARE

A. BC Software Residency: Each BC as defined below shall be capable of controlling and monitoring of all points physically connected to it. All software including the following shall reside and execute at the BC:
1. Real-Time Operating System software
2. Real-Time Clock/Calendar and network time synchronization
3. BC diagnostic software
4. LAN Communication software/firmware
5. Direct Digital Control software
6. Alarm Processing and Buffering software
7. Energy Management software
8. Data Trending, Reporting, and Buffering software
9. I/O (physical and virtual) database
10. Remote Communications software

B. AAC/ASC Software Residency: Each AAC/ASC as defined below shall be capable of controlling and monitoring of all points physically connected to it. As a minimum, software including the following shall reside and execute at the AAC/ASC. Other software to support other required functions of the AAC/ASC may reside at the BC or LAN interface device (specified in Section 23 09 54) with the restrictions/exceptions per application provided in Section 23 09 53:
1. Real-Time Operating System software
2. AAC/ASC diagnostic software
3. LAN Communications software
4. Control software applicable to the unit it serves that will support a single mode of operation
5. I/O (physical and virtual) database to support one mode of operation

C. Standalone Capability: BC shall continue to perform all functions independent of a failure in other BC/AAC/ASC, CSS, or other communication links to other BCs/AACs/ASCs or CSSs. Trends and runtime totalization shall be retained in memory. Runtime totalization shall be available on all digital input points that monitor electric motor status. Refer also to Section 23 09 53 for other aspects of standalone functionality.

D. Operating System: Controllers shall include a real-time operating system resident in ROM. This software shall execute independently from any other devices in the system. It shall support all specified functions. It shall provide a command prioritization scheme to allow functional override of control functions. Refer also to Section 23 09 53 for other aspects of the controller's operating system.

E. Network Communications: Each controller shall include software/firmware that supports the networking of CUs on a common communications trunk that forms the respective LAN. Network support shall include the following:
   1. Controller communication software shall include error detection, correction, and re-transmission to ensure data integrity.
   2. Operator/System communication software shall facilitate communications between other BCs, all subordinate AACs/ASCs, Gateways and LAN Interface Devices or CSS. Software shall allow point interrogation, adjustment, addition/deletion, and programming while the controller is online and functioning without disruption to unaffected points. The software architecture shall allow networked controllers to share selected physical and virtual point information throughout the entire system.

F. Diagnostic Software: Controller software shall include diagnostic software that checks memory and communications and reports any malfunctions.

G. Alarm/Messaging Software: Controller software shall support alarm/message processing and buffering software as more fully specified below.

H. Application Programs: CUs shall support and execute application programs as more fully specified below:
   1. All Direct Digital Control software, Energy Management Control software, and functional block application programming software templates shall be provided in a 'ready-to-use' state, and shall not require (but shall allow) user programming.

I. Security: Controller software shall support multiple level privileges access restriction as more fully specified below.

J. Direct Digital Control: Controller shall support application of Direct Digital Control Logic. All logic modules shall be provided pre-programmed with written documentation to support their application. Provide the following logic modules as a minimum:
   1. Proportional-Integral-Derivative (PID) control with analog, PWM and floating output
   2. Two Position control (Hi or Low crossing with deadband)
   3. Single-Pole Double-Throw relay
   4. Delay Timer (delay-on-make, delay-on-break, and interval)
   5. Hi/Low Selection
   6. Reset or Scaling Module
   7. Logical Operators (AND, OR, NOT, XOR)

K. Psychrometric Parameters: Controller software shall provide preprogrammed functions to calculated and present psychrometric parameters (given temperature and relative humidity) including the following as a minimum: Enthalpy, Wet Bulb Temperature.

L. Updating/Storing Application Data: Site-specific programming residing in volatile memory shall be uploadable/downloadable from an OWS or CSS using BACnet services connected locally or through the network. Initiation of an upload or download shall include all of the following methods: Manual, Scheduled, and Automatic upon detection of a loss or change.

M. Restart: System software shall provide for orderly shutdown upon loss of power and automatic restart upon power restoration. Volatile memory shall be retained; outputs shall go to programmed fail-safe (open, closed, or last) position. Equipment restart shall include a user definable time delay on each piece of equipment to stagger the restart. Loss of power shall be

alarmed at operator interface indicating date and time.

N. Time Synchronization: Automatic time synchronization shall be provided using BACnet services. Operators shall be able to set the time and date in any device on the network that supports time-of-day functionality. The operator shall be able to select to set the time and date for an individual device, devices on a single network, or all devices simultaneously.

O. Misc. Calculations: System software shall automate calculation of psychometric functions, calendar functions, kWh/kW, and flow determination and totalization from pulsed or analog inputs, curve-fitting, look-up table, input/output scaling, time averaging of inputs and A/D conversion coefficients.

2.03 APPLICATION PROGRAMMING DESCRIPTION

A. The application software shall be user programmable.

B. This specification generally requires a programming convention that is logical, easy to learn, use, and diagnose. General approaches to application programming shall be provided by one, or a combination, of the following conventions:
   1. Point Definition: Provide templates customized for point type, to support input of individual point information. Use standard BACnet Objects as applicable.
   2. Graphical Block Programming: Manipulation of graphic icon 'blocks', each of which represents a subroutine, in a functional/logical manner forming a control logic diagram. Blocks shall allow entry of adjustable settings and parameters via pop-up windows. Provide a utility that shall allow the graphic logic diagrams to be directly compiled into application programs. Logic diagrams shall be viewable either off-line, or on-line with real-time block output values.
   3. Functional Application Programming: Pre-programmed application specific programs that allow/require limited customization via 'fill-in-the-blanks' edit fields. Typical values would be setpoints gains, associated point names, alarm limits, etc.

C. Provide a means for testing and/or debugging the control programs both off-line and on-line.

2.04 ENERGY MANAGEMENT APPLICATIONS

A. System shall have the ability to perform all of the following energy management routines via preprogrammed function blocks or template programs. As a minimum provide the following whether or not required in the software:
   1. Time-of-Day Scheduling
   2. Calendar-Based Scheduling
   3. Holiday Scheduling
   4. Temporary Schedule Overrides
   5. Optimal Start / Optimal Stop based on space temperature offset, outdoor air temperature, and building heating and cooling capacitance factors as a minimum
   6. Night Setback and Morning Recovery Control, with ventilation only during occupancy
   7. Economizer Control (enthalpy or dry-bulb)
   8. Peak Demand Limiting / Load Shedding
   9. Dead Band Control

B. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in Section 23 09 58 - Sequence of Operation.

2.05 ACCESS PRIVILEGES

A. Multiple-level access privileges shall be provided. A minimum of four (4) levels of access shall be supported.

B. The highest level of access, Administrator Level access, shall allow the BAS administrator to

perform application, database, and user management functions.

C. Each login credentials shall be assigned to a pre-defined level of access. Alternately, a comprehensive list of accessibility/functionality items shall be provided, to be enabled or disabled for each user according to the level of access granted.

D. Operators shall be able to perform only those commands available for the access level assigned to their login credentials.

E. Login credentials are stored in the BC's local database. A minimum of 20 user names shall be supported and programmed per the State's direction.

F. Login credentials can be looked up using the Lightweight Directory Access (LDAP) through the BAS server.

G. Strong password shall be used on all login credentials.

H. User-definable, automatic log-off timers from 1 to 60 minutes shall be provided to prevent users from inadvertently leaving interface device unattended.

I. At system handover, all default and Contractor created login credentials for the system shall be provided to the State and all temporary login credentials shall be removed.

2.06 ALARM AND EVENT MANAGEMENT REPORTING

A. Alarm management shall be provided to monitor, buffer, and direct alarms and messages to operator devices and memory files. Each BC shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall a BCs ability to report alarms be affected by either operator activity at an OWS or local handheld device, or by communications with other panels on the network.

1. Alarm Descriptor: Each alarm or point change shall include that point's English language description, and the time and date of occurrence. In addition to the alarm's descriptor and the time and date, the user shall be able to print, display and store an alarm message to more fully describe the alarm condition or direct operator response.
2. Alarm Prioritization: The software shall allow users to define the handling and routing of each alarm by their assignment to discrete priority levels. A minimum of five (5) priority levels shall be provided - Level 1 Life Safety (i.e. smoke detector), Level 2 Critical (i.e. controller failure), Level 3 Abnormal (i.e. out-of-range temperature), Level 4 Energy Waste (i.e. fighting valves), Level 5 Maintenance Message (i.e. runtime monitor, filter status). For each priority level, users shall have the ability to enable or disable an audible tone whenever an alarm is reported and whenever an alarm returns to normal condition. Users shall have the ability to manually inhibit alarm reporting for each individual alarm and for each priority level. Contractor shall coordinate with the State on establishing alarm priority definitions.
3. Alarm Report Routing: Each alarm priority level shall be associated with a unique user-defined list of operator devices including any combination of local or remote workstations, printers and workstation disk files. All alarms associated with a given priority level shall be routed to all operator devices on the user-defined list and/or email to designated State email address (mailbox resource) associated with that priority level. For each priority level, alarms shall be automatically routed to a default operator device in the event that alarms are unable to be routed to any operator device assigned to the priority level.
4. Auto-Dial Alarm Routing: For alarm priority levels that include a mobile device as one of the listed reporting destinations, the BC shall initiate a call to report the alarm, and shall terminate the call after alarm reporting is complete. System shall be capable of multiple retries and buffer alarms until a connection is made. If no connection is made, system

shall attempt connection to an alternate mobile device. System shall also be able to dial multiple mobile devices upon alarm activation.

5. Alarm Acknowledgment: For alarm priority levels that are directed to a OWS, an indication of alarm receipt shall be displayed immediately regardless of the application is in use at the OWS, and shall remain on the screen until acknowledged by a user having a privilege that allows alarm acknowledgment. Upon acknowledgment, the complete alarm message string (including date, time, and user name of acknowledging operator) shall be stored in a selected file on the BC or CSS.

B. It shall be possible for any operator to receive a summary of all alarms regardless of acknowledgement status; for which a particular recipient is enrolled for notification; based on current event state; based on the particular BACnet event algorithm (e.g., change of value, change of state, out of range, and so on); alarm priority; and notification class.

C. BACnet Alarming Services: All alarms and events shall be implemented using standard BACnet event detection and notification mechanisms. The workstation shall receive BACnet alarm and event notifications from any gateway or BACnet controller in the system and display them to an operator. Either intrinsic reporting or algorithmic change reporting may be used but the intrinsic reporting method is preferred. The workstation shall also log alarms and events, provide a way for an operator with sufficient privilege to acknowledge alarms, and log acknowledgements of alarms. It shall be possible for an operator to receive, at any time, a summary of all alarms that are currently in effect at any site whether or not they have been acknowledged. Operators shall also be able to view and change alarm limits for any alarm at the appropriate access level.

D. Alarm Historical Database: The database shall store all alarms and events object occurrences in an ODBC or an OLE database-compliant relational database. Provide a commercially available ODBC driver or OLE database data provider, which would allow applications to access the data using standard Microsoft Windows data access services.

2.07 TRENDING

A. The software shall display historical data in both a tabular and graphical format. The requirements of this trending shall include the following:
   1. Provide trends for all physical points, virtual points and calculated variables.
   2. BACnet Trend Objects are preferred but where not possible trend data shall be stored in relational database format as specified in herein under Data Acquisition and Storage.
   3. In the graphical format, the trend shall plot at least 4 different values for a given time period superimposed on the same graph. The 4 values shall be distinguishable by using unique colors. In printed form the 4 lines shall be distinguishable by different line symbology. Displayed trend graphs shall indicate the engineering units for each trended value.
   4. The sample rate and data selection shall be selectable by the operator.
   5. The trended value range shall be selectable by the operator.
   6. Where trended values on one table/graph are COV, software shall automatically fill the trend samples between COV entries.

B. Control Loop Performance Trends: Controllers incorporating PID control loops shall also provide high resolution sampling in less than six second increments for verification of control loop performance.

C. Data Buffering and Archiving: Trend data shall be buffered at the BC, and uploaded to hard disk storage when archival is desired. All archived trends shall be transmitted to the CSS. Uploads shall occur based upon a user-defined interval, manual command, or automatically when the trend buffers become full.

D. Time Synchronization: Provide a time master that is installed and configured to synchronize the clocks of all BACnet devices supporting time synchronization. Synchronization shall be done using Coordinated Universal Time (UTC). All trend sample times shall be able to be

synchronized. The frequency of time synchronization message transmission shall be selectable by the operator.

2.08 Dynamic Plotting

A. Provide a utility to dynamically plot in real-time at least four (4) values on a given 2-dimensional dynamic plot/graph with at least two Y-axes. At least five (5) dynamic plots shall be allowed simultaneously.

2.09 Data acquisition and Storage

A. All points included in the typical equipment point list must be represented in a common, open or accessible format. All points should be provided as BACnet standard analog, binary, schedule, or trend objects when possible. Naming conventions for these points and network addressing are discussed in the 'Point Naming Conventions' paragraph below.

B. Non-BACnet data from the BAS shall be stored in relational database format. The format and the naming convention used for storing the database files shall remain consistent across the database and across time. The relational structure shall allow for storage of any additional data points, which are added to the BAS in future. The metadata/schema or formal descriptions of the tables, columns, domains, and constraints shall be provided for each database.

C. The database shall allow applications to access the data while the database is running. The database shall not require shutting down in order to provide read-write access to the data. Data shall be able to be read from the database without interrupting the continuous storage of trend data being carried by the BAS.

D. The database shall be ODBC or OLE database compliant. Provide a commercially-available ODBC driver or OLE database data provider, which would allow applications to access the data using standard Microsoft Windows data access services.

2.10 TOTALIZATION

A. The software shall support totalizing analog, digital, and pulsed inputs and be capable of accumulating, storing, and converting these totals to engineering units used in the documents. These values shall generally be accessible to the Operator Interfaces to support management-reporting functions.

B. Totalization of electricity use/demand shall allow application of totals to different rate periods, which shall be user definable.

C. When specified to provide electrical or utility Use/Demand, the Contractor shall obtain from the local utility all information required to obtain meter data, including k factors, conversion constants, and the like.

2.11 EQUIPMENT SCHEDULING

A. Provide a graphic utility for user-friendly operator interface to adjust equipment-operating schedules.

B. All schedules shall be implemented using BACnet objects and messages. All building systems with date and time scheduling requirements shall have schedules represented by the BACnet Schedule object. All operators shall be able to view the entries for a schedule. Operators with sufficient privilege shall be able to modify schedule entries from any BACnet workstation.

C. Scheduling feature shall include multiple seven-day master schedules, plus holiday schedule, each with start time and stop time. Master schedules shall be individually editable for each day and holiday.

D. Scheduling feature shall allow for each individual equipment unit to be assigned to one of the master schedules.

E. Timed override feature shall allow an operator to temporarily change the state of scheduled

equipment. An override command shall be selectable to apply to an individual unit, all units assigned to a given master schedule, or to all units in a building. Timed override shall terminate at the end of an operator selectable time, or at the end of the scheduled occupied/unoccupied period, whichever comes first. A privilege level that does not allow assignment of master schedules shall allow a timed override feature.

F. A yearly calendar feature shall allow assignment of holidays, and automatic reset of system real time clocks for transitions between daylight savings time and standard time.

2.12 Point structuring and naming

A. General: The intent of this section is to require a consistent means of naming points across all State facilities. Contractor shall configure the systems from the perspective of the Enterprise, not solely the local project. The following requirement establishes a standard for naming points and addressing Buildings, Networks, Devices, Instances, and the like. The convention is tailored towards the BACnet-based format and as such, the interface shall always use this naming convention. Native BACnet systems shall also use this naming convention. For non-BACnet systems, the naming convention shall be implemented as much as practical, and any deviations from this naming convention shall be approved by the State. The Contractor shall contact the State to determine the Building number and abbreviation.

B. Point Summary Table
   1. The term 'Point' is a generic description for the class of object represented by analog and binary inputs, outputs, and values in accordance with ASHARE 135 standard.
   2. With each schematic, Contractor shall provide a Point Summary Table listing:
      a. Building number and abbreviation
      b. System type
      c. Equipment type
      d. Point suffix
      e. Full point name (see Point Naming Convention paragraph)
      f. Point description
      g. Ethernet backbone network number
      h. Network number
      i. Device ID
      j. Device MAC address
      k. Object ID (object type, instance number)
      l. Engineering units.
   3. Additional fields for non-BACnet systems shall be appended to each row. Point Summary Table shall be provided in both hard copy and in electronic format (ODBC-compliant).
   4. Point Summary Table shall also illustrate Network Variables/BACnet Data Links Bindings.
   5. The Contractor shall coordinate with the State's representative and compile and submit a proposed Point Summary Table for review prior to any object programming or project startup.
   6. The Point Summary Table shall be kept current throughout the duration of the project by the Contractor as the Master List of all points for the project. Project closeout documents shall include an up-to-date accurate Point Summary Table. The Contractor shall deliver to the State the final Point Summary Table prior to Substantial Completion of the system. The Point Summary Table shall be used as a reference and guide during the commissioning process.
   7. The Point Summary Table shall contain all data fields on a single row per point. The Point Summary Table is to have a single master source for all point information in the building that is easily sorted and kept up-to-date. Although a relational database of Device ID-to-point information would be more efficient, the single line format is required as a single master table that will reflect all point information for the building. The point description shall be an easily understandable English-language description of the point.

Point Summary Table Example
Row Headers and Examples
(Transpose for a single point per row format)

Campus	RK
Building Number	006
Building Association	ZZ = no association (default to ZZ)
System Type	Cooling
Equipment Type	Chiller
Point Suffix	CHLR1KW
*Point Name (Object Name)	CA0006ZZ.COOLING.CHILLER.CHLR1KW
*Point Description (Object Description)	Chiller 1 kW
Ethernet Network Number	600
Network Number	610
Device ID	1024006
Device MAC address	24
Object Type	AI
Instance Number	4
Engineering Units	KW
Network Variable?	True
Server Device	1024006
Client Devices	1028006
Included with Functional	

*Represents information that shall reside in the relevant BACnet property for the object

C. Point Naming Convention
   1. All point names shall adhere to the format as established below. Said objects shall include all physical I/O points, calculated points used for standard reports, and all application program parameters. For each BAS object, a specific and unique BACnet object name shall be required.
   2. For each point, four (4) distinct descriptors shall be linked to form each unique object name: Building, System, Equipment, and Point. Use alphanumeric characters. Space and special characters are not allowed. Each of the four descriptors must be bound by a period to form the entire object name. Reference the paragraphs below for an example of these descriptors.
   3. The State shall designate the Building descriptor. The System descriptor shall further define the object in terms of air handling, cooling, heating, or other system. The Equipment descriptor shall define the equipment category; e.g., Chiller, Air Handler, or other equipment. The Point descriptor shall define the hardware or software type or function associated with the equipment; e.g., supply temperature, water pressure, alarm, mixed air temperature setpoint, etc. and shall contain any numbering conventions for multiples of equipment; e.g., CHLR1KW, CHLR2KW, BLR2AL (Boiler 2 Alarm), HWP1ST (Hot Water Pump 1 Status).
   4. A consistent object (point) naming convention shall be utilized to facilitate familiarity and operational ease across the BAS network. Inter-facility consistency shall be maintained to ensure transparent operability to the greatest degree possible. The table below details the object naming convention and general format of the descriptor string.
      BACnet Object Name Requirements

Descriptors		Comment
Campus, Building Number & Building Association	RK0006ZZ AZ0134ZZ	The Master Building List also has the correct abbreviations for each building.
System	AIRHANDLING - EXHAUST - HEATING - COOLING - UTILITY - ENDUSE - MISC	Boilers and ancillary equipment Chillers and ancillary equipment Main electrical and gas meters Specific building loads by type
Equipment	BOILERS - CHILLERS - FACILITY - TOWERS - WEATHER	Non-specific boiler system points - Non-specific chiller system points
Point Suffix	See Input/Output point summary table for conventions	

5. Examples: Within each object name, the descriptors shall be bound by a period. Within each descriptor, words shall not be separated by dashes, spaces, or other separators as follows:
   a. RK0006ZZ.COOLING.CHILLERS.CHWP1ST
   b. RK0006ZZ.HEATING.BOILERS.BLR1CFH

D. Device Addressing Convention:
   1. BACnet network numbers and Device Object IDs shall be unique throughout the network.
   2. All assignment of network numbers and Device Object IDs shall be coordinated with the State.
   3. Each Network number shall be unique throughout all facilities and shall be assigned in the following manner unless specified otherwise:
      a. BBBFF, where: BBB = 1-655 assigned to each building, FF = 00 for building backbone network, 1-35 indicating floors or separate systems in the building.
   4. Each Device Object Identifier property shall be unique throughout the system and shall be assigned in the following manner unless specified otherwise:
      a. XXFFBBB, where: XX = number 0 to 40, FF = 00 for building backbone network, 1-35 indicating floors or separate systems in the building. BBB = 1-655 assigned to each building.
   5. The BAS Contractor shall coordinate with designated State representative to ensure that no duplicate Device Object IDs occur.
   6. Alternative Device ID schemes or cross project Device ID duplication if allowed shall be approved before project commencement by the State.

2.13 OPERATOR INTERFACE GRAPHIC SOFTWARE

A. Graphic software shall facilitate user-friendly interface to all aspects of the System Software specified above. The intent of this specification is to require a graphic package that provides for intuitive operation of the systems without extensive training and experience. It shall facilitate logical and simple system interrogation, modification, configuration, and diagnosis.

B. Graphic software shall support multiple simultaneous screens to be displayed and resizable in a web-based environment. All functions excepting text entry functions shall be executable with a mouse.

C. Graphic software shall display current operating mode (i.e. warm-up, dehumidification, et al) for equipment with multiple modes of operation.

D. Graphic software shall provide for multitasking such that other application can be used while the operator is accessing the BAS. Software shall provide the ability to alarm graphically even

when operator is in another software package.

E. The software shall be compatible to the current and current minus one versions of Microsoft Windows operating system. The software shall allow for the State's creation of user-defined, color graphic displays of geographic maps, building plans, floor plans, and mechanical and electrical system schematics. These graphics shall be capable of displaying all point information from the database including any attributes associated with each point (i.e., engineering units, etc.). In addition, operators shall be able to command equipment or change setpoints from a graphic through the use of a pointing device; e.g. mouse and touch screen.

F. Screen Penetration: The operator interface shall allow users to access the various system graphic screens via a graphical penetration scheme by using the pointing device to select from menus or 'button' icons. Each graphic screen shall be capable of having a unique list of other graphic screens that are directly linked through the selection of a menu item or button icon.

G. Dynamic Data Displays: Dynamic physical point values shall automatically updated at a minimum frequency of 6 updates per minute without operator intervention. Point value fields shall be displayed with a color code depicting normal, abnormal, override and alarm conditions.

H. Point Override Feature: Each displayed point shall be individually enabled/disabled to allow pointing device driven override of digital points or changing of analog points. Such overrides or changes shall occur in the control unit, not just in the BAS software. The graphic point override feature shall be subject to privilege level protection. Points that are overridden shall be reported as an alarm, and shall be displayed in a coded color. The alarm message shall include the operator's login name. A list of points that are currently in an override state shall be available through menu selection and include the time/date of the override along with the operator's login name that initiated that override.

I. Dynamic Symbols: Provide a selection of standard symbols that change in appearance based on the value of an associated point.
   1. Analog symbol: Provide a symbol that represents the value of an analog point as the length of a line or linear bar.
   2. Digital symbol: Provide symbols such as switches, pilot lights, rotating fan wheels, etc. to represent the value of digital input and output points.
   3. Point Status Color: Graphic presentations shall indicate different colors for different point statuses. (For instance, green = normal, red = alarm, gray (or '???') for non-response.

J. Graphics Development Package: Graphic development and generation software shall be provided to allow the user to add, modify, or delete system graphic displays.
   1. The Contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g. fans, cooling coils, filters, dampers, etc.), mechanical system components (e.g., pumps, chillers, cooling towers, boilers, etc.), complete mechanical systems (e.g. constant volume-terminal reheat, VAV, etc.) and electrical symbols.
   2. The Graphic Development Package shall use a pointing device to allow the user to perform the following:
      a. Define symbols
      b. Position items on graphic screens
      c. Attach physical or virtual points to a graphic
      d. Define background screens
      e. Define connecting lines and curves
      f. Locate, orient and size descriptive text
      g. Define and display colors for all elements
      h. Establish correlation between symbols or text and associated system points or other displays
      i. Create hot spots or link triggers to other graphic displays or other functions in the

software

K. Graphic images shall reside on the CSS.

L. The software shall be capable of initiating communication between the BC and the CSS:
   1. Upon user command, to perform all specified functions.
   2. In accordance with user-programmed time schedules to report alarms and upload trend and report data to the CSS.

M. The software shall automatically terminate the communication when all specified functions are completed.

PART 3 - EXECUTION

3.01 SYSTEM CONFIGURATION

A. Contractor shall thoroughly and completely configure BAS system software, supplemental software, network communications, BC and CSS, if necessary .

3.02 SITE-SPECIFIC APPLICATION PROGRAMMING

A. Provide all database creation and site-specific application control programming as required by these Specifications, national and local standards and for a fully functioning system. Contractor shall provide all initial site-specific application programming and thoroughly document programming. Generally meet the intent of the written sequences of operation. It is the Contractor's responsibility to request clarification on sequence issues that require such clarification.

B. All site-specific programming shall be fully documented and submitted for review and approval, both prior to downloading into the panel, at the completion of functional performance testing, and at the end of the warranty period.

C. All programming, graphics and data files must be maintained in a logical system of directories with self-explanatory file names. All files developed for the project will be the property of the State and shall remain on the BC and CSS at the completion of the project.

3.03 PRIVILEGE LEVELs SETUP

A. Set up the following privilege levels to include the specified capabilities:
   1. Level 1: (State's BAS Administrator)
      a. Level 2 capabilities
      b. Configure system software
      c. Modify graphic software
      d. View, add, change and delete user login credentials and privilege levels
      e. All unrestricted system capabilities including all network management functions.
   2. Level 1a (Contractor Technician)
      a. Level 2 capabilities
      b. Configure system software
      c. Modify graphic software
   3. Level 2: (Maintenance Manager)
      a. Level 3 capabilities
      b. Modify control unit programs
   4. Level 3: (Senior BAS Technician)
      a. Level 4 capabilities
      b. Override output points
      c. Change setpoints
      d. Change equipment schedules
   5. Level 4: (Junior BAS Technician and Trainee)
      a. Level 5 capabilities

b. Acknowledge alarms
c. Temporarily override equipment schedules

6. Level 5: (Read Only)
   a. Display all graphic data
   b. Trend point data

B. Contractor shall assist:
1. State's BAS Administrator with assigning user login credentials and privilege levels, configure system software and modify graphic software.
2. Maintenance Manger with modifying control unit programs.

3.04 POINT PARAMETERS

A. Provide the following minimum programming for each analog input:
1. Name
2. Address
3. Scanning frequency or COV threshold
4. Engineering units
5. Offset calibration and scaling factor for engineering units
6. High and low alarm values and alarm differentials for return to normal condition
7. High and low value reporting limits (reasonableness values), which shall prevent control logic from using shorted or open circuit values.
8. Default value to be used when the actual measured value is not reporting. This is required only for points that are transferred across the primary and/or secondary controlling networks and used in control programs residing in control units other than the one in which the point resides. Events causing the default value to be used shall include failure of the control unit in which the point resides, or failure of any network over which the point value is transferred.
9. Selectable averaging function that shall average the measured value over a user selected number of scans for reporting.

B. Provide the following minimum programming for each analog output:
1. Name
2. Address
3. Output updating frequency
4. Engineering units
5. Offset calibration and scaling factor for engineering units
6. Output Range
7. Default value to be used when the normal controlling value is not reporting.

C. Provide the following minimum programming for each digital input:
1. Name
2. Address
3. Engineering units (on/off, open/closed, freeze/normal, etc.)
4. Debounce time delay
5. Message and alarm reporting as specified
6. Reporting of each change of state, and memory storage of the time of the last change of state
7. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

D. Provide the following minimum programming for each digital output:
1. Name
2. Address
3. Output updating frequency
4. Engineering units (on/off, open/closed, freeze/normal, etc.)

5. Direct or Reverse action selection
6. Minimum on-time
7. Minimum off-time
8. Status association with a DI and failure alarming (as applicable)
9. Reporting of each change of state, and memory storage of the time of the last change of state.
10. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.
11. Default value to be used when the normal controlling value is not reporting.

3.05 Trends

A. Contractor shall establish and store trend logs. Trend logs shall be prepared for each physical input and output point, and all dynamic virtual points such as setpoints subject to a reset schedule, intermediate setpoint values for cascaded control loops, and the like as directed by the State.

B. The State will analyze trend logs of the system operating parameters to evaluate normal system functionality. Contractor shall establish these trends and ensure they are being stored properly.
   1. Data shall include a single row of field headings and the data thereafter shall be contiguous. Each record shall include a date and time field or single date stamp. Recorded parameters for a given piece of equipment or component shall be trended at the same intervals and be presented in a maximum of two separate 2-dimensional formats with time being the row heading and field name being the column heading.

C. Sample times indicated as COV (±) or change-of-value mean that the changed parameter only needs to be recorded after the value changes by the amount listed. When output to the trending file, the latest recorded value shall be listed with any given time increment record. The samples shall be filled with the latest values also if the points include different time intervals. If the BAS does not have the capability to record based on COV, the parameter shall be recorded based on the interval common to the unit.

D. Trending intervals or COV thresholds shall be dictated by the State upon system start-up.

E. The Contractor shall demonstrate functional trends as specified for a period of 30 days after successful system demonstration before Substantial Completion of the system.

3.06 TREND GRAPHS

A. Prepare controller and graphic software to display graphical format trends. Trended values and intervals shall be the same as those specified.

B. Lines shall be labeled and shall be distinguishable from each other by using either different line types, or different line colors.

C. Indicate engineering units of the y-axis values; e.g. degrees F., inches w.g., Btu/lb, percent open, etc.

D. The y-axis scale shall be chosen so that all trended values are in a readable range. Do not mix trended values on one graph if their unit ranges are incompatible.

E. Trend outside air temperature, humidity, and enthalpy during each period in which any other points are trended.

F. All points trended for one subsystem (e.g. air handling unit, chilled water system, etc.) shall be trended during the same trend period.

G. Each graph shall be clearly labeled with the subsystem title, date, and times.

3.07 ALARMS

A. Override Alarms: Any point that is overridden through the override feature of the graphic software shall be reported as a Level 3 alarm.

B. Analog Input Alarms: For each analog input, program an alarm message for reporting whenever the analog value is outside of the programmed alarm limits. Report a 'Return-to-Normal' message after the analog value returns to the normal range, using a programmed alarm differential. The alarm limits shall be individually selected by the Contractor based on the following criteria:
   1. Space temperature, except as otherwise stated in sequence of operation: Level 3
      a. Low alarm: 64°F
      b. Low return-to-normal: 68°F
      c. High alarm: 85°F
      d. High return-to-normal: 80°F
   2. Controlled media temperature other than space temperature (e.g. AHU discharge air temperature, steam converter leaving water temperature, condenser water supply, chilled water supply, etc.): Level 3 (If controlled media temperature setpoint is reset, alarm setpoints shall be programmed to follow setpoint)
      a. Low alarm: 3°F below setpoint
      b. Low return-to-normal: 2°F below setpoint
      c. High alarm: 3°F above setpoint
      d. High return-to-normal: 2°F above setpoint.
   3. AHU mixed air temperature: Level 4
      a. Low alarm: 45°F
      b. Low return-to-normal: 46°F
      c. High alarm: 90°F
      d. High return-to-normal: 89°F
   4. Duct Pressure:
      a. Low alarm: 0.5”w.g. below setpoint
      b. Low return-to-normal: 0.25”w.g. below setpoint
      c. High alarm: 0.5”w.g. above setpoint
      d. High return-to-normal: 0.25”w.g. above setpoint
   5. Space humidity:
      a. Low alarm: 35%
      b. Low return-to-normal: 40%
      c. High alarm: 75%
      d. High return-to-normal: 70%

C. HOA Switch Tampering Alarms: The Sequences of Operation are based on the presumption that motor starter Hand-Off-Auto (HOA) switches are in the 'Auto' position. [If a motorized equipment unit starts without a prior start command from the FMS, (as sensed by status sensing device), then FMS shall perform the remaining sequence as specified.] BAS shall also enunciate the following Level 5 alarm message if status indicates a unit is operational when the run command is not present:
   1. DEVICE XXXX FAILURE: Status is indicated on the device even though it has been commanded to stop. Check the HOA switch, control relay, status sensing device, contactors, and other components involved in starting the unit. Acknowledge this alarm when the problem has been corrected.

D. Maintenance Alarms: Enunciate Level 5 alarms when runtime accumulation exceeds a value specified by the operator
   1. DEVICE XXXX REQUIRES MAINTENANCE. Runtime has exceeded specified value since last reset.

E. See requirements for additional equipment-specific alarms specified in Section 23 09 59 - Sequences of Operation.

3.08 GRAPHIC SCREENS

A. Floor Plan Screens: The contract document drawings will be made available to the Contractor in AutoCAD (current version) format upon request. These drawings may be used only for developing backgrounds for specified graphic screens; however the State does not guarantee the suitability of these drawings for the Contractor's purpose.
   1. Provide graphic floor plan screens for each [floor] [wing] [tower] [other] of the building. Indicate the location of all equipment that is not located on the equipment room screens. Indicate the location of temperature sensors associated with each temperature-controlled zone (i.e., VAV terminals, fan-coils, single-zone AHUs, etc.) on the floor plan screens. [Zone background color shall change based on the temperature offset from setpoint]. Display the space temperature point adjacent to each temperature sensor symbol. Use a distinct line symbol to demarcate each terminal unit zone boundary. Use distinct colors to demarcate each air handling unit zone. [Mechanical floor plan drawings will be made available to the contractor upon request for the purpose of determining zone boundaries.] Indicate room numbers as provided by the State. Provide a drawing link from each space temperature sensor symbol and equipment symbol shown on the graphic floor plan screens to each corresponding equipment schematic graphic screen.
   2. Provide graphic floor plan screens for each mechanical equipment room and a plan screen of the roof. Indicate the location of each item of mechanical equipment. Provide a drawing link from each equipment symbol shown on the graphic plan view screen to each corresponding mechanical system schematic graphic screen.
   3. If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views and/or plan views as necessary to graphically indicate the location of all of the larger scale floor plans. Link graphic building key plan to larger scale partial floor plans. Provide links from each larger scale graphic floor plan screen to the building key plan and to each of the other graphic floor plan screens.
   4. Provide a graphic site plan with links to and from each building plan.

B. System Schematic Screens: Provide graphic system schematic screen for each subsystem controlled with each I/O point in the project appearing on at least one graphic screen. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc. as applicable. General layout of the system shall be schematically correct. Input/output devices shall be shown in their schematically correct locations. Include appropriate engineering units for each displayed point value. Verbose names (English language descriptors) shall be included for each point on all graphics; this may be accomplished by the use of a hover box when the operator moves the cursor over the displayed point. Indicate all adjustable setpoints on the applicable system schematic graphic screen or, if space does not allow, on a supplemental linked-setpoint screen.
   1. Provide graphic screens for each air handling system. Indicate outside air temperature and enthalpy, and mode of operation as applicable (i.e., occupied, unoccupied, warm-up, cool-down). Link screens for air handlers to the heating system and cooling system graphics. Link screens for supply and exhaust systems if they are not combined onto one screen.
   2. Provide a graphic screen for each zone. Provide links to graphic system schematic screens of air handling units that serve the corresponding zone.
   3. Provide a cooling system graphic screen showing all points associated with the chillers, cooling towers and pumps. Indicate outside air dry-bulb temperature and calculated wet-bulb temperature. Link screens for chilled water and condenser water systems if they cannot fit onto one cooling plant graphic screen.
   4. Link screens for heating and cooling system graphics to utility history reports showing

current and monthly electric uses, demands, peak values, and other pertinent values.

C. Bar Chart Screens: On each graphic Bar Chart Screen, provide drawing links to the graphic air handling unit schematic screens.
   1. Provide a graphic chilled water valve screen showing the analog output signal of all chilled water valves in a bar chart format, with signals expressed as percentage of fully open valve (percentage of full cooling). Indicate the discharge air temperature and setpoint of each air handling unit, cooling system chilled water supply and return temperatures and the outside air temperature and humidity on this graphic. Provide drawing links between the graphic cooling plant screen and this graphic screen.
   2. Provide a graphic heating water valve screen showing the analog output signal of all air handling unit heating water valves in a bar chart format, with signals expressed as percentage of fully open valve (percentage of full heating). Indicate the temperature of the controlled medium (such as AHU discharge air temperature or zone hot water supply temperature) and the associated setpoint and the outside air temperature and humidity.

D. Alarms: Each programmed alarm shall appear on at least one graphic screen. In general, alarms shall be displayed on the graphic system schematic screen for the system that the alarm is associated with (for example, chiller alarm shall be shown on graphic cooling system schematic screen). For all graphic screens, display analog values that are in a 'high alarm' condition in a red color, 'low alarm' condition in a blue color. Indicate digital values that are in alarm condition in a red color.

END OF SECTION 23 09 55

SECTION 23 09 58

SEQUENCE OF OPERATION

PART 1 - GENERAL

1.01 Section Includes

A. Air Handling Units

B. Chilled Water System

C. Terminal Units

D. Exhaust Fans

1.02 Related Documents:

A. Section 23 09 50 - Building Automation System (BAS) General

B. Section 23 09 51 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 23 09 53 - BAS Field Panels

D. Section 23 09 54 - BAS Communications Devices

E. Section 23 09 55 - BAS Software

F. Section 23 09 59 - BAS Commissioning

1.03 System Description

A. The systems to be controlled under work of this section basically comprise (describe the scope of the project). The systems being controlled are (describe the configuration of and the type of systems included in the project).

B. This Section defines the manner and method by which controls function.

1.04 Submittals

A. Refer to Section 23 09 50 and Division 1 for requirements for control shop drawings, product data, User Manual, etc.

B. Programming Manual: Provide BAS system programming manual as well as documentation of site-specific programming prior to the start of Acceptance Phase.

1.05 Project Record Documents

A. Within two weeks of the completion of commissioning, provide record documents to represent the final control configuration with actual setpoints and tuning parameters as existed at acceptance.

B. Record documents shall be modified control drawings with the actual installed information. Drawings shall be delivered in both reproducible hard copy and electronic format in AutoCAD (current version) drawing files. Provide all supporting files, blocks, fonts, etc. required by the drawings.

C. Provide final points list as described above.

D. Provide final detailed wiring diagrams with all wire numbers and termination points indicated.

E. Accurately record final sequences and control logic made after submission of shop drawings.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Sequences specified herein indicate the functional intent of the systems operation and may not fully detail every aspect of the programming that may be required to obtain the indicated operation. Contractor shall provide all programming necessary to obtain the sequences/system operation indicated.

B. When an air handling unit is not in operation, control devices shall remain in their “off” positions. “Off” positions may differ from the “normal” (meaning failed) position. Except as specified otherwise, “off” and “normal” positions of control devices shall be as follows:

Device	"Off Position"	"Normal Position"
Heating coil valves	closed	open
Cooling coil valves	closed	closed
Outside air damper	closed	closed
Return air damper	open	open
Exhaust/relief air damper	closed	closed
Var. Freq. Drive	off	Min. speed

C. Except as specified otherwise, throttling ranges, proportional bands, and cycle differentials shall be centered on the associated setpoint. All modulating feedback control loops shall include the capability of having proportional, integral, and derivative action. Unless the loop is specified “proportional only” or “P+I”, Contractor shall apply appropriate elements of integral and derivative gain to each control loop which shall result in stable operation, minimum settling time, and shall maintain the primary variable within the specified maximum allowable variance.

D. Scheduling Terminology: When air handlers are scheduled throughout the day, the following defines the terminology used (Designer coordinate with The State regarding actual occupancy schedules and initial setpoints):
   1. Occupied Period: Period of time when the building is in use and occupied. Unless indicated otherwise, this period is defined as X:XX AM - X:XX PM weekdays and X:XX AM to 12:00PM (noon) Saturdays. Exclude all national holidays. Generally systems will be fully operational throughout this period and ventilation air shall be continuously introduced. Space temperature setpoints will generally be in the “normal” range of 69-77°F.
   2. Unoccupied period: Period of time when the building or zone is not in use and unoccupied. Ventilation air shall not be introduced.
   3. Preoccupancy Period: Time prior to the Occupied period when the systems are returning the space temperatures from setback to “normal” or occupied setpoints (warm-up and cool-down). Ventilation air shall not be introduced unless outside air conditions permit free-cooling. Time period shall be determined by an optimum start strategy unless otherwise specified.
   4. Setback Period: Setback will typically coincide start with the end of the occupied period and end with the start of the preoccupancy period, however it shall be provided with its own schedule. Generally systems will be off except to maintain a “setback” temperature.

E. Where any sequence or occupancy schedule calls for more than one motorized unit to start simultaneously, the BAS start commands shall be staggered by 5 second (adj.) intervals to minimize inrush current.

F. Alarm messages specified throughout the sequences are assigned to discrete priority levels. Priority levels dictate the handling and destination of alarm reports, and are defined in Section 23 09 55 - ATC System Software and Programming.

G. Wherever a value is indicated as adjustable (adj.), it shall be modifiable, with the proper privilege level, from the operator interface or via a function block menu. For these points, it is unacceptable to have to modify programming statements to change the setpoint.

H. When a power failure is detected in any phase, the BAS start commands shall be retracted immediately from all electrically powered units served by the failed power source. If the associated primary control unit (PCU) is powered by normal or emergency power, it may monitor its own power source as an indication of power status. If the PCU is powered by uninterruptable power supply (UPS), or if PCU is not capable of monitoring its own power for use in sequences, Contractor shall provide at least one voltage monitor (three phase when applicable) per building. When the BAS detects that power has been restored, all equipment for which the BAS start command had been retracted shall be automatically restarted on staggered 5 second intervals to minimize inrush current. When loss of equipment status coincides with a power failure, system shall not alarm individual equipment failures. Instead, only a single Level 2 alarm shall be enunciated as follows:
   1. BUILDING XXXX POWER FAILURE: Notify electric shop. Acknowledge alarm when power is restored.

I. Where reset action is specified in a sequence of operation, but a reset schedule is not indicated on the drawings, one of the following methods shall be employed:
   1. Contractor shall determine a fixed reset schedule which shall result in stable operation and shall maintain the primary variable within the specified maximum allowable variance.
   2. A floating reset algorithm shall be used which increments the secondary variable setpoint (setpoint of control loop being reset) on a periodic basis to maintain primary variable setpoint. The recalculation time and reset increment shall be chosen to maintain the primary variable within the specified maximum allowable variance.
   3. Primary variable shall control the devices directly using a PID feedback control loop without resetting the secondary variable. However, the control devices shall still modulate as necessary to maintain upper and lower limits on the secondary variable. Proportional band, integral gain, and derivative term shall be selected to maintain the primary variable within the specified maximum allowable tolerance while minimizing overshoot and settling time. Contractor shall gain prior approval for implementing this method of reset.

J. Where a supply air temperature or duct pressure setpoint is specified to be reset by the space temperature of the zones calling for the most cooling/heating, the following method shall be employed:
   1. A floating reset algorithm shall be used which increments the secondary variable (e.g., supply air temperature or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g. space temperature) setpoint. The reset increment shall be determined by the quantity of “need heat” or “need cool” requests from individual SCU's. A SCU's “need heat” virtual point shall activate whenever the zone's space temperature falls below the currently applicable (occupied or unoccupied) heating setpoint throttling range. A SCU's “need cool” virtual point shall activate whenever the zone's space temperature rises above the currently applicable (occupied, unoccupied, or economy) cooling setpoint throttling range. The recalculation time and reset increment shall be chosen to maintain the primary variable within the specified maximum allowable variance while minimizing overshoot and settling time. Reset range maximum and minimum values shall limit the setpoint range.

K. Where “prove operation” of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the BAS shall, after an adjustable time delay after the device is commanded to operate (feedback delay) , confirm that the device is operational via the status

input. If the status point does not confirm operation after the time delay or anytime thereafter for an adjustable time delay (debounce delay) while the device is commanded to run, an alarm shall be enunciated audibly and via an alarm message at the operator interface and print at the alarm printers. A descriptive message shall be attached to the alarm message indicating the nature of the alarm and actions to be taken. Contractor shall provide messages to meet this intent. [Upon failure of equipment with redundant backup, run command shall be removed from equipment and the device shall be locked out until the alarm is manually acknowledged. Upon failure of equipment without redundant backup, run command shall remain energized and the alarm shall be latched until reset by an operator.BAS shall provide for adjustable maximum rates of change for increasing and decreasing output from the following analog output points:

1. Speed control of variable speed drives
2. Chiller supply water temperature setpoint reset
3. Chiller demand limit
4. Travel rate of tower isolation and chiller isolation valves

L. Wherever a value is indicated to be dependent on another value (i.e.: setpoint plus 5°F) BAS shall use that equation to determine the value. Simply providing a virtual point that the operator must set is unacceptable. In this case three virtual points shall be provided. One to store the parameter (5°F), one to store the setpoint, and one to store the value which is the result of the equation.

M. The following chilled water sequence applies to the classic primary/secondary chilled water system where the bypass is positioned for equal percent unloading of all chillers, constant speed primary pumps one per chiller, multiple secondary chilled water pumps controlled from a variable speed drive. Various staging scenarios are included and the designer should select the most optimal method for the applicable job.

3.02 Demand Limiting Control:

A. BAS shall monitor kW demand over a 15-minute sliding window period.

B. Demand limiting shall be disabled during the winter billing period. When demand limiting is enabled, it shall be possible for the operator to disable it on a daily basis, but it shall be automatically re-enabled each day at 12 midnight.

C. On a rise in kW to within [200] kW (adj.) of setpoint, a Level 4 alarm shall be enunciated and BAS shall begin to make one “load shed” command every [3] minutes (adj.). On a fall in kW to [200] kW less than the demand setpoint, BAS shall begin to broadcast one ”load restore” command every [3] (adj.) minutes on a first shed, first restored basis. If demand exceeds the demand setpoint and there are no more loads left to shed, the demand setpoint shall be increased to the maximum demand experienced. Demand setpoint shall be automatically reset to an adjustable value at the beginning of each billing period.

D. “Loads” available for shedding are defined elsewhere in this specification section.

E. On a rise in kW to within [50] kW (adj.) of setpoint, a Level 3 and Level 4 alarm shall be enunciated.

3.03 Air Handling Units - General

A. Logic Strategies: The BAS shall fully control the air handlers. Generally the BAS shall energize the AH (start the fans and activate control loops) as dictated for each air handle. The following indicates when and how the BAS shall energize the AHs and control various common aspects of them. The following “logic strategies” shall be included by reference with each air handler with any specific clarifications required:

1. Scheduled Occupancy: BAS shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the common control aspects related to the scheduled occupancy.

a. Occupied Period: BAS shall energize the AH during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain the required building component of ventilation per ASHREA 62. Specific times shall be as directed by the A/E. Minimum OA flow setpoint shall be as scheduled on the drawings. "Normal" setpoints shall apply.
b. Unoccupied Period: Minimum OA flow shall be 0 CFM or the minimum OA damper position shall be 0%. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period. The unoccupied period and the preoccupancy period will typically overlap.
c. Setback Period: BAS shall deenergize the unit except as required to maintain a setback temperature as indicated in the individual sequences with a 5°F cycle differential. Generally, where setback temperatures apply in multiple zones, the worst zone shall control the system. Setback setpoints generally apply except during preoccupancy [and night purge]. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period.
d. Preoccupancy: BAS shall energize the AH continuously during the preoccupancy period. Minimum OA flow shall be 0 CFM or the minimum OA damper position shall be 0%. "Normal" setpoints shall apply. Preoccupancy duration shall be one of the following as specified by reference:
    1) Fixed: The duration of the preoccupancy period shall be fixed as scheduled by the operator.
    2) Optimum: The duration of the morning warm-up period shall vary according to outside air temperature and space temperature such that the space temperature rises to occupied period heating setpoint at the beginning of, but not before, the scheduled occupied period. The duration of the cool-down period shall vary according to outside air temperature and space temperature such that the space temperature falls to the occupied period cooling setpoint at the beginning of, but not before, the scheduled occupied period.

2. Minimum OA Control: BAS shall maintain minimum ventilation during the occupied period. The following strategies may apply:
    a. Balanced Position: During the occupied period, applicable mixing and OA dampers shall never be positioned less than the position set for the required minimum OA ventilation rate. If the air handler has a single OA damper that is capable of economizer, the minimum position output shall be determined by the balancer. If the AH has a two position minimum OA damper, that position shall be fully open to its balanced position. This logic strategy is only applicable to constant volume Ahs.
    b. Reset Balanced Position: During the occupied period, applicable mixing and OA dampers shall never be positioned less than the minimum position. Minimum position shall be reset between limits of a position delivering system exhaust make-up air CFM and the design minimum position delivering design minimum CFM to maintain a CO2 setpoint of 900 ppm (adj.). Loop shall be a "sample and bump" or dynamic proportional only loop tuned for the slow response. The balancer shall determine the minimum position outputs at both extreme points. This logic strategy is only applicable to constant volume AHs.
    c. Damper Controlled Fixed: During the occupied period, applicable mixing dampers shall be modulated to maintain an OA flow rate of no less than the MVR as dictated in the design and required by ASHRAE 62. Setpoint flow rates shall be provided by the A/E. Flow rate shall be determined in any of the following ways as specified for the particular AH:
        1) Measured directly by an OA flow station
        2) As determined by CO2 mixing equations using the SA, OA, and RA CO2 sensors
    d. Damper Controlled Reset: During the occupied period, applicable mixing dampers

shall be modulated to maintain an OA flow rate setpoint. Setpoint shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain an RA CO2 setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for the slow response. Setpoint flow rates shall be provided by the A/E. Flow rate shall be determined in any of the following ways as specified for the particular AH:

1) Measured directly by an OA flow station
2) As determined by CO2 mixing equations using the SA, OA, RA, and/or Space CO2 sensors

e. Mixed Air Plenum Pressure Control: Minimum position of the OA damper shall be set to obtain the design required minimum OA. This balanced position shall remain fixed whenever to minimum loop is active BAS shall control the return air damper to maintain a mixed air plenum pressure (relative to outside) setpoint which will be specified by the balancer (-.5”). Ensure the OA reference pressure is adequately dampened against wind fluctuations using a wind resistance static tip, restrictors, and air volume capacitance.

3. VAV Return Fan Capacity Control: BAS shall control the output of the return fan as follows:
   a. Flow Tracking: The return air fan shall run to maintain a return flow setpoint of the supply flow minus an offset value. The offset value shall be determined as follows:
      1) Fixed Differential: It shall be fixed at the design minimum OA value.
      2) Differential Reset from RA CO2:::It shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain an RA CO2 setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for the slow response. Setpoint flow rates shall be provided by the A/E.
      3) Differential Reset from Measured OA to Maintain Fixed OA: It shall be reset to maintain the measured minimum OA flow at the design value any time the economizer mode is inactive. Whenever it is inactive, it shall be set to the value that existed when the unit became active.
      4) Differential Reset from Measured OA to Maintain Reset OA When the economizer mode is inactive, it shall be reset to maintain the measured OA flow setpoint. The OA setpoint shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain a CO2 setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for the slow response. Setpoint flow rates shall be provided by the A/E. Whenever the economizer is active, it shall be set to the value that existed when the unit became active.
   b. Rescaled Output Capacity Control: The output for the return fan capacity control shall be rescaled from the output of the to the supply device such that the design minimum OA temperature is maintained at both maximum and 50% flow conditions. The balancing contractor shall determine the coordinated output.
4. Airside Economizer: BAS shall modulate the mixing dampers to provide “free cooling” when conditions merit. The free cooling shall generally be staged before any mechanical cooling. While conditions merit, dampers shall be modulated in a DA PID loop to maintain mixed air temperature at a setpoint as specified for the individual unit. Economizer logic shall remain enabled during setback cooling where applicable. One of the following strategies shall be used to enable the economizer mode:
   a. Dry Bulb Comparison: Economizer mode shall be active while the unit is energized AND when OA enthalpy fall below 28 btu/# AND outside air temperature falls below return air temperature (with 2°F cycle differential). Economizer mode shall be inactive when OA enthalpy rises above 29 btu/# ORoutside air temperature rises above return air temperature (with 2°F cycle differential), dampers shall return to their scheduled minimum positions as specified above. Economizer shall remain enabled during setback cooling.

b. Dry Bulb Switch: Economizer mode shall be active while the unit is energized AND when OA enthalpy fall below 28 btu/# AND outside air temperature falls below the switching setpoint of 70°F (adj.) (with 5°F cycle differential). Economizer mode shall be inactive when OA enthalpy rises above 29 btu/# OR outside air temperature rises above switching setpoint, dampers shall return to their scheduled minimum positions as specified above.
c. Enthalpy Comparison: Economizer mode shall be active while the unit is energized AND when outside air enthalpy falls below return air enthalpy (with 2btu/# cycle differential). Economizer mode shall be inactive when outside air enthalpy rises above return air enthalpy, dampers shall return to their scheduled minimum positions as specified above.

5. Sequenced Heating and Cooling: BAS shall control the heating and cooling coils and air side economizer as detailed for the particular AH. Program logic shall directly prohibit the heating and cooling valves as well as the heating valve and economizer damper to be open (or above minimum) simultaneously. This does not apply to cooling and reheat valves that are used simultaneously for dehumidification.
6. Mixed Air Low Limit Override: BAS shall override the signal to the OA damper via a proportional only loop to maintain a minimum mixed air temperature of 45°F (adj.) (loop shall output 0% at 45°F which shall be passed to the output via a low selector).
7. Freeze Safety: Upon operation of a freezestat, unit shall be deenergized with the exception of the heating loops. Typically supply and return fans where applicable shall be deenergized via a hardwired interlock, [, and an indication of the operation shall be sensed by the BAS. BAS shall enunciate appropriate alarm and remove and lock out the start command], [which shall initiate "fan failure" alarms]. OA dampers shall close and heating loops shall remain active.
8. Smoke Safety: Upon indication of smoke by a smoke detector, FAC shall deenergize the AH. Smoke detector shall notify the fire alarm system and BAS, shut down the fans, and close the smoke dampers via hard-wired interlock.
9. High or Low Pressure Safety: Upon activation of a high or low pressure safety switch, AH shall be deenergized, fans shall be deenergized via a hard wired interlock [, and an indication of the operation shall be sensed by the BAS. BAS shall enunciate appropriate alarm and remove and lock out the start command], [which shall initiate "fan failure" alarms].
10. Vibration Safety (Applicable To Units >50,000 cfm): Upon activation of a vibration safety switch, respective fan shall be deenergized, fan shall be deenergized via a hard wired interlock and an indication of the operation shall be sensed by the BAS]. BAS shall enunciate appropriate alarm and remove and lock out the start command.

B. The detailed “logic strategies” above shall be required by reference to them in each of the individual sequences specified below.

3.04 AIr Handling Unit Diagnostics - General

A. Diagnostic Strategies: In addition to the standard alarm limits specified for all sensed variables the BAS monitor and diagnose anomalies in the operation of the air handlers. The following “diagnostic strategies” shall be included by reference with each air handler with any specific clarifications required:
1. Run Time Limit: BAS shall accumulate the runtime of the status of associated rotating equipment and enunciate a level 5 alarm to indicate that the unit is in need of service.
2. Filter Monitoring: BAS shall monitor the differential pressure transmitter across the filter bank(s). A level 5 alarm shall be reported when pressure drop exceeds the transmitter's setting.
3. Start Monitoring: BAS shall accumulate the starts of cycling equipment. BAS shall further enunciate a level 5 alarm when the number of starts exceeds the specified value within the

specified time period. (ie: more than 3 starts in a 30 min period)

4. Heating Valve Leak: While heating valve is closed, if the temperature increase across the heating coil exceeds 2°F continuously for 30 minutes; or if the discharge temperature is more than 5°F above setpoint for more than 30 minutes continuously, enunciate the following alarm at level 3 and 4 priority:
   a. ENERGY WASTE: An unexpected temperature rise is occurring across the heating coil. Please check for leaking valve or faulty controls.
5. Cooling Valve Leak: While cooling valve is closed, if the temperature drop across the cooling coil exceeds 2°F continuously for 30 minutes; or if the discharge temperature is more than 5°F below setpoint for more than 30 minutes continuously, enunciate the following alarm at level 3 and 4 priority:
   a. ENERGY WASTE: An unexpected temperature drop is occurring across the cooling coil. Please check for leaking valve or faulty controls.
6. Cooling Capacity Shortage: BAS shall monitor the output to the valve. If the output exceeds 99% open for 1 hour continuously, enunciate the following alarm
   a. Lack of Capacity: The cooling valve of XXX has been commanded to the full open position for an extended time period. Ensure that the setpoint for the control loop is at a reasonable value and that flow to the coil has not been obstructed as in a plugged strainer, throttled balancing valve, debris in the control valve, etc.
7. Economizer Anomaly: If mixed air temperature is less than low limit mixed air temperature °F or greater than [85]; or if the outside air temperature is between 55°F and 65°F and the mixed air temperature is more than 2°F different from the outside air temperature for more than 30 minutes continuously, enunciate the following alarm at level 3 and 4 priority:
   a. ENERGY WASTE: An unexpected mixed air temperature indicates a possible problem with the economizer damper controls. Please check for faulty dampers or controls.
8. Fighting Valves: BAS shall monitor the valve positions of the preheat and cooling coils and shall enunciate the following level 3 alarm if the valve positions are both over 10% open.
   a. Fighting Valves: The preheat and the cooling valves are opening simultaneously on XXX. Coordinate the control loops.
9. Fighting Thermal Zones: BAS shall monitor the mode of multiple terminal zones within a thermal zone and enunciate the following level 3 alarm if some are in heating mode, and others are in cooling mode:
   a. FIGHTING TERMINAL UNITS: Simultaneous heating and cooling exists in XXX. Coordinate the setpoints.
10. Fighting Humidity Zones: BAS shall monitor the mode of multiple terminal zones within a humidity zone and enunciate the following level 3 alarm if some are in heating mode, and others are in cooling mode:
    a. FIGHTING TERMINAL UNITS: simultaneous humidification and dehumidification exists in XXX. Coordinate the setpoints.
11. Unstable Control: BAS shall monitor the output to the actuator. BAS shall calculate the average change in output per second over a 30-min. period. The average change in output signal shall be calculated as follows: å [(Abs(Current Output(%)-Last Output(%)) / (Scan Interval(s))] / (# of Scans in 30 min). The program shall execute the check once every 14 hours (start the 30-min. interval change accumulation, after 30 min. perform the check and clear the sum). BAS shall enunciate the following alarm if the average rate of change exceeds 1%/sec or one half of the maximum rate of change programmed for the point.
    a. Unstable Control: The control loop on XXX appears to be unstable. Establish a plot of the valve output to validate this. If the damper is hunting unacceptably, tune the loop.

3.05 Central plant equipment - MONITORING AND MANAGEMENT

A. General: The BAS shall monitor various aspects of the heating and cooling systems and calculate parameters as specified below to facilitate plant operations and management.

B. Trending: The BAS shall continuously monitor, calculate and display the following parameters at the intervals indicated. These values shall be stored and reported per the trending requirements defined in Section 23 09 55.

C. Parameters to be trended:
   1. Load on the secondary systems in MBH per the following equation: (Return Temp-Supply Temp) * (GPM) / .5. This shows cooling as a positive heat load and heating as a negative heat load. Note that multipliers on this value to accommodate the BAS processors are acceptable as long as they are clearly indicated. This value shall be trended and stored every two hours.
   2. All temperature sensors at 1 hour intervals
   3. All relative humidity sensors at 1 hour intervals
   4. All pressure sensors at 1 hour intervals
   5. All run requests and statuses on a change in value
   6. All analog loop outputs on 1 hour intervals
   7. Calculated enthalpies in 2 hour intervals
   8. Summed cooling and heating requests on 2 hour intervals

END OF SECTION 23 09 58

SECTION 23 09 59

BAS SYSTEM COMMISSIONING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. BAS and equipment testing and start-up

B. Validation of proper and thorough installation of BAS and equipment

C. Functional testing of control systems

D. Documentation of tests, procedures, and installations

E. Coordination of BAS training

F. Documentation of BAS Operation and Maintenance materials

1.02 RELATED SECTIONS:

A. Section 23 09 50 - BAS General Requirements

B. Section 23 09 51 - BAS Basic Materials and Devices

C. Section 23 09 53 - BAS Field Panels

D. Section 23 09 54 - BAS Communication Devices

E. Section 23 09 55 - BAS Software and Programming

F. Section 23 09 58 - Sequence of Operation

1.03 GENERAL DESCRIPTION

A. This section defines responsibilities of the Controls Contractor to commission the BAS.

B. The Government, at Government's expense, shall retain a Commissioning Authority (CA) who shall work with the Contractor to ensure that the systems, equipment, and interfaces are installed, tested, and operate per the design intent; that the systems are adequately documented; and that the Government is adequately trained on system intent, operation, and maintenance.

The following is written based on the use of a separate Commissioning Authority (CA). If that is not the case on the project, the Contractor must still start up and commission the BAS. Therefore edit the responsibilities as appropriate for the project commissioning requirements.

1.04 CONTRACTOR RESPONSIBILITIES

A. Completely install and thoroughly inspect, startup, test, adjust, balance, and document all systems and equipment.

B. Assist Commissioning Authority in performing verification and performance testing. This will generally include the following:

1. Attend Commissioning (Cx) progress and coordination meetings.
2. Prepare and submit required draft forms and systems information.
3. Establish trend logs of system operation as specified herein.
4. Demonstrate system operation.
5. Manipulate systems and equipment to facilitate testing.
6. Provide instrumentation necessary for verification and performance testing.
7. Manipulate control systems to facilitate verification and performance testing.
8. Train State's Representatives as specified in Part III of this section.

C. Provide a BAS Technician to work at the direction of Commissioning Authority for software optimization assistance for a minimum of [80] hours. Refer to Part 3 for a description of the software optimization.

1.05 SEQUENCING

A. The following list outlines the general sequence of events for submittals and commissioning:
   1. Submit product data and shop drawings, and receive approval.
   2. Submit BAS logic documentation, and receive approval.
   3. Submit Start-Up Checklists and manufacturer's start-up procedures for all equipment provided by the BAS Contractor.
   4. Install BAS.
   5. Submit BAS Start-Up Test Agenda and Schedule for review.
   6. Receive BAS start up Test Agenda/schedule approval.
   7. Submit Training Plan.
   8. Simulate sequencing and debug program off-line to the extent practical.
   9. Place systems under BAS control where applicable during a scheduled outage.
   10. Perform BAS start up where applicable during a scheduled outage.
   11. Prepare and initiate trend log data storage and format trend graphs.
   12. Submit completed BAS Start-Up Reports and initial draft of the O&M Manuals.
   13. Receive BAS Start Up Report approval and approval to schedule Demonstrations and Commissioning.
   14. Demonstrate systems to Commissioning Authority and The State.
   15. Submit Trend Logs in format specified.
   16. Receive demonstration approval and approval to schedule Acceptance Period.
   17. Train The State on BAS operation and maintenance.
   18. Substantial Completion.
   19. Begin Acceptance Phase.
   20. Two week Operational Test.
   21. Perform Functional Performance Testing.
   22. Receive Acceptance Period approval, which is Functional Completion for the BAS.
   23. Train The State on final sequences and modes of operation.
   24. Install framed control drawings. (See Section 23 09 50/1.09/G)
   25. Provide Level 1 password access to the State.
   26. Revise and re-submit record drawings and O&M Manuals.
   27. Substantial Completion.
   28. Begin Warranty Phase.
   29. Schedule and begin Opposite Season acceptance period.
   30. Receive Opposite Season acceptance period approval.
   31. Submit as-built drawings and O&M Manuals.
   32. Update framed control drawings. (See Section 23 09 50/1.09/G)
   33. Complete State personnel Training.
   34. End-of-Warranty date/period.

PART 2 - PRODUCTS

2.01 INSTRUMENTATION

A. Instrumentation required to verify readings and test the system and equipment performance shall be provided by Contractor and made available to Commissioning Authority. Generally, no testing equipment will be required beyond that required to perform Contractors work under these Contract Documents. All equipment used for testing and calibration shall be NIST/NBS traceable and calibrated within the preceding 6-month period. Certificates of calibration shall be submitted.

2.02 TAB & COMMISSIONING Portable operators terminal

A. For new projects, Contractor shall provide a portable operators terminal or hand held device to facilitate Testing, Adjusting, and Balancing (TAB) and calibration. This device shall support all functions and allow querying and editing of all parameters required for proper calibration and start up.

B. Connections shall be provided local to the device being calibrated. For instance, for VAV boxes, connection of the operator's terminal shall be either at the sensor or at the terminal box. Otherwise a wireless system shall be provided to facilitate this local functionality.

PART 3 - EXECUTION

3.01 BAS Start-Up TESTING, ADJUSTING, CALIBRATION

A. Work and/or systems installed under this Division shall be fully functioning prior to Demonstration and Acceptance Phase. Contractor shall start, test, adjust, and calibrate all work and/or systems under this Contract, as described below:
   1. Inspect the installation of all devices. Review the manufacturer's installation instructions and validate that the device is installed in accordance with them.
   2. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.
   3. Verify integrity/safety of all electrical connections.
   4. For the following control settings, initially use the control setting that was used by existing control system, unless otherwise indicated. For AHUs that use a throttled outside air damper position when minimum outside air is required, contractor shall mark existing minimum outside air damper position to allow replication by new controls.
   5. Coordinate with TAB subcontractor to obtain control settings that are determined from balancing procedures. Record the following control settings as obtained from TAB contractor, and note any TAB deficiencies in the BAS Start-Up Report:
      a. Optimum duct static pressure setpoints for VAV air handling units.
      b. Minimum outside air damper settings for air handling units.
      c. Optimum differential pressure setpoints for variable speed pumping systems.
      d. Calibration parameters for flow control devices such as VAV boxes and flow measuring stations.
         1) BAS contractor shall provide hand-held device as a minimum to the TAB and CA to facilitate calibration. Connection for any given device shall be local to it (i.e. at the VAV box or at the thermostat). Hand-held device or portable operator's terminal shall allow querying and editing of parameters required for proper calibration and start-up.
   6. Test, calibrate, and set all digital and analog sensing and actuating devices. Calibrate each instrumentation device by making a comparison between the BAS display and the reading at the device, using an instrument traceable to the National Bureau of Standards, which shall be at least twice as accurate as the device to be calibrated (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range). Record the measured value and displayed value for each device in the BAS Start Up Report.
   7. Check and set zero and span adjustments for all transducers and transmitters.
   8. For dampers and valves:
      a. Check for adequate installation including free travel throughout range and adequate seal.
      b. Where loops are sequenced, check for proper control without overlap.
   9. For actuators:
      a. Check to insure that device seals tightly when the appropriate signal is applied to the operator.
      b. Check for appropriate fail position, and that the stroke and range is as required.
      c. For pneumatic operators, adjust the operator spring compression as required to

achieve close-off. If positioner or volume booster is installed on the operator, calibrate per manufacturer's procedure to achieve spring range indicated. Check split-range positioners to verify proper operation. Record settings for each device in the BAS Pre-Commissioning Report.

d. For sequenced electronic actuators, calibrate per manufacturer's instructions to required ranges.

10. Check each digital control point by making a comparison between the control command at the CU and the status of the controlled device. Check each digital input point by making a comparison of the state of the sensing device and the Operator Interface display. Record the results for each device in the BAS Start-Up Report.
11. For outputs to reset other manufacturer's devices (for example, VSDs) and for feedback from them, calibrate ranges to establish proper parameters. Coordinate with representative of the respective manufacturer and obtain their approval of the installation.
12. Verify proper sequences by using the approved checklists to record results and submit with BAS Start-Up Report. Verify proper sequence and operation of all specified functions.
13. Verify that all safety devices trip at appropriate conditions. Adjust setpoints accordingly.
14. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in the BAS Start Up Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted):
    a. Duct air temperature: ±1°F.
    b. Space Temperature: ±2°F
    c. Chilled Water: ±1°F
    d. Hot water temperature: ±3°F.
    e. Condenser water temperature: ±3°F.
    f. Duct pressure: ± 0.25” w.g.
    g. Water pressure: ±1 psid
    h. Duct or space Humidity: ±5%
    i. Air flow control: ±5% of setpoint velocity. [For fume hoods ±10% on full sash travel (from min to max in 3 seconds) within 3 seconds. Refer to Section 15995 for fume hood acceptance requirements.] [For minimum OA flow loops being reset from CO2, response to upset max time is one hour.]
    j. Space Pressurization (on active control systems): ±0.05” wg with no door or window movements.
15. For interface and DDC control panels:
    a. Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the record drawings.
    b. Ensure that terminations are safe, secure and labeled in accordance with the record drawings.
    c. Check power supplies for proper voltage ranges and loading.
    d. Ensure that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in trough.
    e. Check for adequate signal strength on communication networks.
    f. Check for standalone performance of controllers by disconnecting the controller from the LAN. Verify the event is annunciated at Operator Interfaces. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.
    g. Ensure that all outputs and devices fail to their proper positions/states.
    h. Ensure that buffered and/or volatile information is held through power outage.
    i. With all system and communications operating normally, sample and record update/annunciation times for critical alarms fed from the panel to the Operator Interface.
    j. Check for adequate grounding of all DDC panels and devices.

16. For Operator Interfaces:
    a. Verify that all elements on the graphics are functional and are properly bound to physical devices and/or virtual points, and that hot links or page jumps are functional and logical.
    b. Output all specified BAS reports for review and approval.
    c. Verify that the alarm printing and logging is functional and per requirements.
    d. Verify that trends are archiving to disk and provide a sample to the [Commissioning Authority and] State for review.
    e. Verify that paging/dial-out alarm annunciation is functional.
    f. Verify the functionality of remote Operator Interfaces and that a robust connection can be established consistently.
    g. Verify that required third party software applications required with the bid are installed and are functional.
17. Start-up and check out control air compressors, air drying, and filtering systems in accordance with the appropriate section and with manufacturer's instructions.
18. Verify proper interface with fire alarm system.

B. Submit Start-Up Test Report: Report shall be completed, submitted, and approved prior to Substantial Completion.

3.02 Sensor Checkout and Calibration

A. General Checkout: Verify that all sensor locations are appropriate and are away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading of each other for pressure. Tolerances for critical applications may be tighter.

B. Calibration: Calibrate all sensors using one of the following procedures:
    1. Sensors Without Transmitters - Standard Application: Make a reading with a calibrated test instrument within 6 inches of the site sensor at various points across the range. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified for the sensor. If not, adjust offset and range, or replace sensor. Where sensors are subject to wide variations in the sensed variable, calibrate sensor within the highest and lowest 20% of the expected range.
    2. Sensors With Transmitters - Standard Application: Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until the ammeter reads 4 mA. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the OI. Record all values and recalibrate controller as necessary to conform to tolerances. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

C. Sensor Tolerance: Sensors shall be within the tolerances specified for the device. Refer to Section 23 09 51.

3.03 Coil Valve Leak Check

A. Verify proper close-off of the valves. Ensure the valve seats properly by simulating the maximum anticipated pressure difference across the circuit. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Via the Operator Interface, command the valve to close. Energize fans. After 5 minutes observe air temperature difference across coil. If a temperature difference is indicated, and the piping surface temperature entering the coil is

within 3°F of the water supply temp, leakage is probably occurring. If it appears that it is occurring, close the isolation valves to the coil to ensure the conditions change. If they do, this validates the valve is not closing. Remedy the condition by adjusting the stroke and range, increasing the actuator size/torque, replacing the seat, or replacing the valve as applicable.

3.04 Valve Stroke Setup and Check

A. For all valve and actuator positions checked, verify the actual position against the Operator Interface readout.

B. Set pumps to normal operating mode. Command valve closed, verify that valve is closed, and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command the valve to various few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

3.05 BAS DEMONSTRATION

A. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the Commissioning Authority and State. Schedule the demonstration with the State's representative 1 week in advance. Demonstration shall not be scheduled until all hardware and software submittals, and the Start-Up Test Report are approved. If the Work fails to be demonstrated to conform with Contract specifications, so as to require scheduling of additional site visits by the Commissioning Authority for re-demonstration, Contractor shall reimburse The State for costs of subsequent Commissioning Authority site visits.

B. The Contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, instruments, ladders, etc. Contractor-supplied personnel must be competent with and knowledgeable of all project-specific hardware, software, and the HVAC systems. All training documentation and submittals shall be at the job site.

C. Demonstration shall typically involve small representative samples of systems/equipment randomly selected by the State and CA.

D. The system shall be demonstrated following the same procedures used in the Start-Up Test by using the approved Commissioning Checklists. Demonstration shall include, but not necessarily be limited to, the following:
   1. Demonstrate that required software is installed on BAS workstations. Demonstrate that graphic screens, alarms, trends, and reports are installed as submitted and approved.
   2. Demonstrate that points specified and shown can be interrogated and/or commanded (as applicable) from all workstations, as specified.
   3. Demonstrate that remote dial-up communication abilities are in accordance with these Specifications.
   4. Demonstrate correct calibration of input/output devices using the same methods specified for the Start-Up Tests. A maximum of 10 percent of I/O points shall be selected at random by the Commissioning Authority and/or State for demonstration. Upon failure of any device to meet the specified end-to-end accuracy, an additional 10 percent of I/O points shall be selected at random by Commissioning Authority for demonstration. This process shall be repeated until 100 percent of randomly selected I/O points have been demonstrated to meet specified end-to-end accuracy.
   5. Demonstrate that all DDC and other software programs exist at respective field panels. The Direct Digital Control (DDC) programming and point database shall be as submitted and approved.
   6. Demonstrate that all DDC programs accomplish the specified sequences of operation.
   7. Demonstrate that the panels automatically recover from power failures, as specified.

8. Demonstrate that the stand-alone operation of panels meets the requirements of these Specifications. Demonstrate that the panels' response to LAN communication failures meets the requirements of these Specifications.
9. Identify access to equipment selected by Commissioning Authority. Demonstrate that access is sufficient to perform required maintenance.
10. Demonstrate that required trend graphs and trend logs are set up per the requirements. Provide a sample of the data archive. Indicate the file names and locations.

E. BAS Demonstration shall be completed and approved prior to Substantial Completion.

F. Any tests successfully completed during the demonstration will be recorded as passed for the functional performance testing and will not have to be retested.

3.06 BAS ACCEPTANCE PERIOD

A. After approval of the BAS Demonstration and prior to Contract Close Out Acceptance Phase shall commence. Acceptance Period shall not be scheduled until all HVAC systems are in operation and have been accepted, all required cleaning and lubrication has been completed (i.e., filters changed, piping flushed, strainers cleaned, and the like), and TAB report has been submitted and approved. Acceptance Period and its approval will be performed on a system-by-system basis if mutually agreed upon by the Contractor and the Government.

B. Operational Test: At the beginning of the Acceptance Phase, the system shall operate properly for two weeks without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with these specifications. At the end of the two weeks, contractor shall forward the trend logs to the Commissioning Authority for review. Commissioning Authority shall determine if the system is ready for functional performance testing and document any problems requiring contractor attention.
   1. If the systems are not ready for functional performance testing, Contractor shall correct problems and provide notification to the State's representative that all problems have been corrected. The Acceptance Period shall be restarted at a mutually scheduled time for an additional one-week period. This process shall be repeated until Commissioning Authority issues notice that the BAS is ready for functional performance testing.

C. During the Acceptance Period, the contractor shall maintain a hard copy log of all alarms generated by the BAS. For each alarm received, Contractor shall diagnose the cause of the alarm, and shall list on the log for each alarm, the diagnosed cause of the alarm, and the corrective action taken. If in the Contractor's opinion, the cause of the alarm is not the responsibility of the Contractor, Contractor shall immediately notify the State's representative.

3.07 Trend Logs

A. Contractor shall configure and analyze all trends required under Section 23 09 55.

3.08 TREND Graphs

A. Trend graphs as specified in Section 23 09 55 shall generally be used during the Acceptance Phase to facilitate and document testing. Prepare controller and workstation software to display graphical format trends during the Acceptance Period. Trend graphs shall demonstrate compliance with contract documents.

B. Each graph shall be clearly labeled with HVAC subsystem title, date, and times.

3.09 Warranty Phase BAS OPPOSITE SEASON Trending and Testing:

A. Trending: throughout the Warranty Phase, trend logs shall be maintained as required for the Acceptance Period. Contractor shall forward archive trend logs to the Commissioning Authority/ State for review upon Commissioning Authority/ State's request. Commissioning Authority/ The State will review these and notify contractor of any warranty work required.

B. Opposite Season Testing: Within 6 months of completion of the Acceptance Phase, Commissioning Authority/ The State shall schedule and conduct Opposite Season functional performance testing. Contractor shall participate in this testing and remedy any deficiencies identified.

3.10 SOFTWARE OPTIMIZATION ASSISTANCE

A. The Contractor shall provide the services of a BAS Technician as specified above at the project site to be at the disposal of the Commissioning Authority. The purpose of this requirement is to make changes, enhancements and additions to control unit and/or workstation software that have been identified by the Commissioning Authority during the construction and commissioning of the project and that are beyond the specified Contract requirements. The cost for this service shall be included with the bid. Requests for assistance shall be for contiguous or non-contiguous 8-hour days, unless otherwise mutually agreed upon by Contractor, Commissioning Authority, and State. The State's representative shall notify contractor 2 days in advance of each day of requested assistance.

B. The BAS Technician provided shall be thoroughly trained in the programming and operation of the controller and workstation software. If the BAS Technician provided cannot perform every software task requested by the Commissioning Authority in a timely fashion, contractor shall provide additional qualified personnel at the project site as requested by the Commissioning Authority, to meet the total specified requirement on-site.

3.11 BAS OPERATOR TRAINING and o&M manuals

A. Provide up to 4 complete sets of the approved Operations and Maintenance (O&M) Manuals (hard copy and one electronic copy) to be used for training.

B. Contractor shall submit a Training Plan for the scope of training for which they are responsible. Training Plan shall be forwarded to the Division 23 Contractor who will compile, organize, format, and forward to the Engineer for review.

C. On-Site Training: Provide services of controls contractor's qualified technical personnel for [five] 8-hour days to instruct State's personnel in operation and maintenance of BAS. Instruction shall be in classroom setting at the project site for appropriate portions of the training. Training may be in non-contiguous days at the request of the State. The State's representative shall notify contractor 1 week in advance of each day of requested training. The Contractor's designated training personnel shall meet with the Engineer and State's representative for the purpose of discussing and fine-tuning the training agenda prior to the first training session. Training agenda shall generally be as follows:
   1. Basic Operator Workstation (OWS) Training - For all potential users of the OWS:
      a. Brief walk-through of building, including identification of all controlled equipment and condensed demonstration of controller portable and built-in operator interface device display capabilities.
      b. Brief overview of the various parts of the O&M Manuals, including hardware and software programming and operating publications, catalog data, controls installation drawings, and DDC programming documentation.
      c. Demonstration of workstation login/logout procedures, password setup, and exception reporting.

d. Demonstration of workstation menu penetration and broad overview of the various workstation features.
e. Overview of systems installed.
f. Present all site-specific point naming conventions and points lists, open protocol information, configuration databases, back-up sequences, upload/download procedures, and other information as necessary to maintain the integrity of the BAS.
g. Overview of alarm features.
h. Overview of trend features.
i. Overview of workstation reports.

2. BAS Hardware Training - For Maintenance and Control Technicians
   a. Review of installed components and how to install/replace, maintain, commission, and diagnose them
3. BAS Technician Training
   a. Introduction to controller programming and overview of the programming application interface.
   b. General review of sequence of operation and control logic for the project site, including standalone and fail-safe modes of operation.
   c. Uploading/Downloading and backing up programs.
   d. Network administration.
   e. Review of setpoint optimization and fine-tuning concepts.
4. Advanced Training: Advanced Training shall be provided for one (1) individual and be provided at an off-site training facility containing installations of the proposed system. Contractor shall pay training registration and materials fee and the State shall pay all employee expenses (travel, per diem, salary).
   a. Contractor shall provide the standard, advanced training offering on all Control Programming Applications.
   b. Contractor shall provide the standard, advanced training offering on Advanced Installation, Configuration, Maintenance, and Network Administration.
   c. For Echelon-based systems, advanced training shall include a Lon systems integration course.

END OF SECTION 23 09 59

SECTION 23 09 69

VARIABLE FREQUENCY CONTROLLERS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.02 SUMMARY

A. This Section includes solid-state, PWM, VFCs for speed control of three-phase motors.

1.03 Definitions

A. BMS: Building management system.

B. IGBT: Integrated gate bipolar transistor.

C. LAN: Local area network.

D. PID: Control action, proportional plus integral plus derivative.

E. PWM: Pulse-width modulated.

F. VFC: Variable frequency controller.

1.04 SUBMITTALS

A. Product Data: For each type of VFC, provide dimensions; mounting arrangements; location for conduit entries; shipping and operating weights; and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.

B. Shop Drawings (for each VFC):
   1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:
      a. Each installed unit's type and details.
      b. Nameplate legends.
      c. Short-circuit current ratings of integrated unit.
      d. UL listing for series rating of overcurrent protective devices in combination controllers.
   2. Wiring Diagrams: Power, signal, and control wiring for VFC. Provide schematic wiring diagram for each type of VFC.

C. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around VFCs where pipe and ducts are prohibited. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

D. Qualification Data: For testing agency and manufacturer.

E. Field Test Reports: Written reports specified in Part 3.

F. Manufacturer's field service report.

G. Operation and Maintenance Data: For VFCs, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1 Section " Operation and Maintenance Data," include the following:
   1. Routine maintenance requirements for VFCs and all installed components.

2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

H. Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.

I. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that dip switch settings for motor running overload protection suit actual motor to be protected.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications: Maintain, within 100 miles of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.

B. Testing Agency Qualifications: An independent testing agency, acceptable to authorities having jurisdiction, with the experience and capability to conduct the testing indicated, as documented according to ASTM E 548.

C. Source Limitations: Obtain VFCs of a single type through one source from a single manufacturer.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

E. Comply with NFPA 70.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Store VFCs indoors in clean, dry space with uniform temperature to prevent condensation. Protect VFCs from exposure to dirt, fumes, water, corrosive substances, and physical damage.

1.07 COORDINATION

A. Coordinate layout and installation of VFCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate features of VFCs, installed units, and accessory devices with pilot devices and control circuits to which they connect.

C. Coordinate features, accessories, and functions of each VFC and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

1.08 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents:
   1. Spare Fuses: Furnish one spare for every five installed, but not less than one set of three of each type and rating
   2. Indicating Lights: Two of each type installed.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. ABB Power Distribution, Inc.; ABB Control, Inc. Subsidiary.

2. Yaskawa, Inc.
3. Danfoss

2.02 VARIABLE FREQUENCY CONTROLLERS

A. Microprocessor based Bypass Controller - Manual or automatic (selectable) transfer to line power via contactors. A keypad to control the bypass controller is to be mounted on the enclosure door. The bypass keypad shall include a one line diagram and status LEDs to indicate the mode of operation and "External Fault" conditions. When in the "Normal" mode, the bypass contactor is open and the drive output contactor is closed. In the "Test" position, both contactors are open, in the "Bypass" position, the drive output contactor is open, and the bypass contactor is closed. Start/stop via customer supplied maintained contact shall be 24V or 115V compatible and shall function in both the "Normal" and "Bypass" modes. The voltage tolerance of the bypass power supply shall be ± 35% to eliminate the problem of contactor coil burnout. The design shall include single-phase protection in both the AFD and bypass modes.

B. Customer Interlock Terminal Strip – provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. Include fireman's override and damper control circuit as standard. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass modes.

C. Automatic bypass operation shall be selectable in the standard microprocessor based bypass design.

D. Door / cover interlocked circuit breaker disconnect switch which will disconnect all input power from the drive and all internally mounted options. The disconnect handle shall be through the door, and be padlockable in the "Off" position.

E. Fast acting semi-conductor fuses exclusive to the AFD – fast acting semi-conductor fuses allow the AFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs which have no such fuses, or that incorporate fuses common to both the AFD and the bypass will not be accepted. In such designs, a fuse clearing failure would render the bypass unusable.

F. Class 10 or 20 (selectable) electronic motor overload protection shall be included in the microprocessor bypass to protect the motor in bypass mode.

G. 3% DC line reactor

H. Input AC Line Reactor

I. The following operating information displays shall be standard on the AFD digital display. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of two operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):
   1. Output Frequency
   2. Motor Speed (RPM, %, or Engineering units)
   3. Motor Current
   4. Calculated Motor Torque
   5. Calculated Motor Power (kW)
   6. DC Bus Voltag
   7. Output Voltage
   8. Heatsink Temperature (0F)
   9. Analog Input Values
   10. Analog Output Value
   11. Keypad Reference Values
   12. Elapsed Time Meter (resettable)
   13. kWh meter (resettable)

14. mWh meter
15. Digital input status
16. Digital output status

J. Communications: Provide an ethernet interface allowing VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via a BACNet IP BMS. Provide capability for VFC to retain these settings within the nonvolatile memory.

2.03 ENCLOSURES

A. Enclosure: NEMA 250 Type I, with hinged full front access.

2.04 FACTORY FINISHES

A. Finish: Manufacturer's standard paint applied to factory-assembled and -tested VFCs before shipping.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFCs for compliance with requirements, installation tolerances, and other conditions affecting performance.

B. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION

A. Anchor each VFC assembly to steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with VFC mounting surface.

B. Controller Fuses: Install fuses in each fusible switch. Comply with requirements in Division 26 Section "Fuses."

3.03 IDENTIFICATION

A. Identify VFCs, components, and control wiring according to Division 15 Section "Mechanical identification."

B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.04 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including pretesting and adjusting VFCs.

B. Test Reports: Prepare a written report to record the following:
1. Test procedures used.
2. Test results that comply with requirements.
3. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.

3.05 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Complete installation and startup checks according to manufacturer's written instructions.

3.06 CLEANING

A. Clean VFCs internally, on completion of installation, according to manufacturer's written instructions. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

3.07 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain VFCs.

END OF SECTION