Fairfax County PUBLIC SCHOOLS
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Department of Facilities and Capital Programs
Office of Facilities Management
5025 Sideburn Road
Fairfax. VA 22032

March 21, 2025

ADDENDUM #1

TO ALL PROSPECTIVE BIDDERS:

SUBJECT: Automatic Temperature Control System Replacement at Rolling Valley Elementary School (MMB-064-25)

BID OPENING DATE: (ORIGINAL DATE) March 26, 2025, at 10:00 A.M.

THE SUBJECT INVITATION FOR BID IS AMENDED AS FOLLOWS:

THIS ADDENDUM IS SUPPLEMENTARY TO THE PLANS AND SPECIFICATIONS FOR THE ABOVE SUBJECT REQUIREMENT. ALL CHANGES, ADDITIONS, AND DELETIONS SHALL BECOME PART OF THE CONTRACT.

CLARIFICATIONS: The following is being submitted to bidders as clarification:

FCPS requires either a signed original of its bid bond, or an eBond containing a digital signature and digital seal with evidence of authenticity (much like what is seen when using a platform like DocuSign). It is not acceptable for a bidder to upload a scanned image of its bid bond, FCPS requires a hard copy original or the eBond version.

INFORMATION: Attached is the Virginia Department of Labor and Industry Wage Determination Decision for the above subject project.

CHANGE: Attached is the revised version of Technical Specification BAS Master Specification 230900, the Procurement area has been revised.

All other terms and conditions remain unchanged.

Amanda L. Hutchison

Amanda L. Hutchison, Buyer II
Office of Administrative Services

THIS ADDENDUM IS ACKNOWLEDGED AND IS CONSIDERED A PART OF THE SUBJECT INVITATION FOR BID.

SIGNATURE:_____ DATE:_____

NAME OF FIRM:_____

A SIGNED COPY MAY BE RETURNED PRIOR TO BID OPENING OR MAY ACCOMPANY YOUR BID.

COMMONWEALTH of VIRGINIA
DEPARTMENT OF LABOR AND INDUSTRY

Gary G. Pan
COMMISSIONER

Main Street Centre
600 East Main Street, Suite 207
Richmond, Virginia 23219
PHONE (804) 371-2327
FAX (804) 371-6524

Virginia Department of Labor and Industry Wage Determination Decision

Project Name	Automatic Temperature Replacement Project at Rolling Valley Elementary School
State Project Code	N/A
DOLI Project Number	FCPS-25-0005
County or Independent City	Fairfax County
Publication Date	03/06/2025
Construction Type	Building

Wage Determinations	Wage	Fringe
Asbestos Worker/Heat & Frost Insulator (Duct, Pipe & Mechanical System Insulation)*	$40.77	$20.17
Boilermaker	$42.62	$24.81
Brick Pointer/Caulker/Cleaner	$19.68	
Bricklayer	$23.67	
Carpenter (Includes Acoustical Ceiling Installation, Drywall Hanging, and Form Work)	$23.34	$5.04
Cement Mason/Concrete Finisher	$24.69	$5.55
Drywall Finisher/Taper	$25.53	$7.86
Electrician (Includes Low Voltage Wiring and Installation of Alarms and Sound and Communication Systems)	$53.00	$21.35

Wage Determinations	Wage	Fringe
Elevator Mechanic**	$49.84	$37.89
Firestopper***	$30.21	$10.43
Floor Layer: Soft Floors	$18.75	
Glazier	$30.52	$13.85
Ironworker	$37.86	$25.86
Ironworker, Reinforcing	$27.46	$8.71
Laborer: Common or General, including brick mason tending and cement mason tending	$15.74	$3.43
Laborer: Pipelayer	$16.81	$4.26
Mason - Stone	$43.16	$20.28
Operator: Backhoe/Excavator/Trackhoe	$21.81	
Operator: Bobcat/Skid Steer/Skid Loader	$18.95	$4.03
Operator: Bulldozer	$21.99	$4.98
Operator: Crane	$32.52	$2.64
Operator: Drill	$21.75	$1.57
Operator: Forklift	$21.56	$7.57
Operator: Loader	$22.26	$3.57
Operator: Roller	$16.25	$4.88
Painter (Brush, Roller, and Spray)	$27.46	$11.56
Pipefitter (Includes HVAC Pipe, Unit and Temperature Controls Installations)****	$52.27	$23.79
Plumber*****	$51.25	$22.46
Roofer	$21.55	$7.01
Sheet Metal Worker (Includes HVAC Duct Installer)******	$47.92	$22.72
Sprinkler Fitter (Fire Sprinklers)	$42.32	$26.39
Tile Finisher	$28.09	$12.29
Tile Setter	$33.41	$12.67
Truck Driver: Dump Truck	$19.22	$2.58
Waterproofer	$21.75	$1.57

Additional Notes

* Asbestos Worker/Heat & Frost Insulator (Duct, Pipe & Mechanical System Insulation) * PAID HOLIDAYS: New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the day after Thanksgiving and Christmas Day provided the employee works the regular workday before and after the paid holiday. *

** Elevator Mechanic ** PAID HOLIDAYS: New Year's Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the Friday after Thanksgiving and Christmas Day. VACATIONS: 6% men under 5 years based on regular hourly rate and 8% men over 5 years based on regular hourly rate for all hours worked. **

*** Firestopper *** Includes the application of materials or devices within or around penetrations and openings in all rated wall or floor assemblies, in order to prevent the passage of fire, smoke of other gases. The application includes all components involved in creating the rated barrier at perimeter slab edges and exterior cavities, the head of gypsum board or concrete walls, joints between rated wall or floor components, sealing of penetrating items and blank openings. PAID HOLIDAYS: New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the day after Thanksgiving and Christmas Day provided the employee works the regular workday before and after the paid holiday. ***

**** Pipefitter (Includes HVAC Pipe, Unit and Temperature Controls Installations) **** PAID HOLIDAYS: New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the day after Thanksgiving and Christmas Day provided the employee works the regular workday before and after the paid holiday. ****

***** Plumber ***** PAID HOLIDAYS: New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the day after Thanksgiving and Christmas Day provided the employee works the regular workday before and after the paid holiday. *****

****** Sheet Metal Worker (Includes HVAC Duct Installer) ****** PAID HOLIDAYS: New Year's Day, Martin Luther King Day, Memorial Day, Independence Day, Labor Day, Veterans' Day, Thanksgiving Day, the day after Thanksgiving and Christmas Day. ******

All wage rates to be used on a contract will be set at the time the contract is awarded. While DOLI maintains a list of wage determinations online for reference purposes, only the wage determinations made in an official Wage Determination Decision, sent by DOLI to the contracting agency, can be used to ascertain the exact rates to be paid for a specific contract.

All rates are determined by DOLI and any appeals of specific classifications may be made through the Wage Determination Appeal form available at https://doli.virginia.gov/wp-content/uploads/2022/05/Appeal-for-Clarification-of-Wage-Determination.pdf

Any additional classifications may be requested through the Additional Wage Classification form available at https://doli.virginia.gov/wp-content/uploads/2022/05/Appeal-for-Clarification-of-Wage-Determination.pdf

Understand your duties as a contractor under Virginia law by referencing our Contractor Responsibilities information sheet available at http://www.doli.virginia.gov/wp-content/uploads/2021/04/PREVAILING-WAGE-CONTRACTOR-RESPONSIBILITIES.pdf

Your employees have specific rights, which can be found on our List of Employee Rights information sheet available at http://www.doli.virginia.gov/wp-content/uploads/2021/04/PREVAILING-WAGE-EMPLOYEE-RIGHTS.pdf

Any further questions should be directed to PrevailingWage@doli.virginia.gov

SECTION 230900 - BUILDING AUTOMATION SYSTEM (BAS) GENERAL

PART I. GENERAL

1.01 RELATED DOCUMENTS

A. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

B. Section 230902 - BAS Operator Interfaces

C. Section 230903 - BAS Field Panels

D. Section 230904 - BAS Communication Devices

E. Section 230905 - BAS Software and Programming

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

1.02 DESCRIPTION OF WORK

A. Furnish and install a direct digital control and building automation system (BAS). The BAS shall utilize BTL-listed equipment and the BACnet protocol for communication and integration. Electronic sensing, microprocessor-based digital control, and electronic actuation of dampers and valves shall be utilized to perform control sequences and functions specified. Refer also to control drawings, sequences of operation, and point lists.

B. The BAS shall interface with an Ethernet network at the building level. Contractor shall provide all specified objects and services and have them configured/mapped as applicable. FCPS shall coordinate the inclusion of the BAS into the FCPS WAN by assigning all pertinent network address parameters and active links upon completion of the project.

C. All control work shall be installed by the BAS contractor, unless specified otherwise. Certain building systems, including but not limited to: power metering, lighting control, mechanical equipment, plumbing equipment and special systems, are equipped with manufacturer furnished controls that must be integrated into the BAS for monitoring and control. All labor, materials, equipment, software, and services necessary for the installation of a complete integrated system shall be provided, with exceptions as noted in this specification.

D. All interlock wiring for mechanical system equipment shall be by this contractor, unless specifically stated otherwise; electrical connections to power BAS equipment shall be by the BAS contractor. This shall include (but not be limited to) items such as thermostats for unit heaters, interlock wiring to central boiler control panels, chiller flow switches, etc.

E. The systems to be controlled under work of this section is equipment shown on the project drawings. The systems to be controlled or monitored by the BAS include: central heating and cooling plants, air handling systems, terminal equipment,

water, electricity and gas meters, lighting and other miscellaneous equipment. This Section defines the manner and method by which these controls function.

1.03 BACNET CONFORMANCE (ASHRAE STANDARD 135)

The Contractor shall submit a Vendor Compliance Statement indicating compliance on the following minimum BACnet Interoperability Building Blocks (BIBB) and Device Profiles. Refer to Protocol Implementation Conformance Statement (PICS) as per Annex A of the BACnet Standard as a submission guideline. It is important that the minimum acceptable conformance be confirmed as:

- BIBB and Device Profiles
- Minimum Conformance – BIBB and Device Profiles
- Definitions (relevant to the BIBB and Device Profiles)

A. Data Sharing

1. Data Sharing is defined as the exchange of information between BACnet devices. It may be uni-directional or bi-directional.

B. Alarm and Event Management

1. Alarm and Event Management is the exchange of data between BACnet devices specifically related to the occurrence of a pre-defined condition.
2. In the case of an Alarm, interoperability shall mean the ability to annunciate, acknowledge and display data related to the event.

C. Scheduling

1. Scheduling is the exchange of data between BACnet devices that permit the establishment and maintenance of dates and times at which specified output actions are to be taken.
2. Interoperability in this area permits the use of date and time schedules for the purpose of starting and stopping equipment and changing of control setpoints as well as other analogue or binary parameters.

D. Device and Network Management

1. Device and Network Management is the exchange of data between BACnet devices concerning the operation and status of specified devices.
2. Interoperability shall permit the determination of which devices are present on a given network.
3. Interoperability shall permit the start-up and shut down of the communication activities of a particular device.
4. Interoperability shall permit the synchronization of time in devices.
5. Interoperability shall permit the re-initialization of a particular device.

E. Trending and Archiving

1. Trending and Archiving is the accumulation of (Time and Value) pairs at specified rates and for a specified duration.

2. Trending is not defined as real time plotting and or display of data derived from network device.
3. Interoperability shall permit the establishment of trending parameters and the subsequent retrieval and storage of the data.
4. Trending intervals shall be a minimum of one (1) second.
5. Trending intervals shall be a maximum of one (1) year.
6. Trending data value for a particular interval shall be selectable as “Average over the Interval” or “Minimum during the Interval” of “Maximum during the Interval”.
7. The number of Trending Intervals possible within a particular network device shall be stated by the vendor in terms of how many Trend arrays, containing two (2) discrete analogue point values of five (5) digits plus decimal point each along with the time stamp for the values, for 1000 intervals of one (1) hour are possible. The time stamp shall contain at minimum, DD/MM/YYYY – hh/mm/ss. The Vendor shall state the number of Trend arrays possible within the context of the fully configured system as specified, with operating programs, schedules, setpoints, etc.

1.04 PROCUREMENT

A. The BAS, DDC, and communications components installed as work of this contract, shall be an integrated distributed processing system by one of the following manufacturers (subject to specification requirements):

1. Delta: enteliWEB
2. Trane: Tracer SC
3. Siemens: Apogee

B. The EMS shall be installed by competent technicians regularly employed by a specialty firm that is in the full-time business of designing and installing environmental control systems and is an authorized representative of one of the pre-qualified control equipment manufacturers listed.

C. Acceptable Installers

1. Engineered Services, Inc.
2. Boland Trane Services, Inc
3. Siemens Building Technologies
4. Substitutions: NONE

1.05 QUALITY ASSURANCE

A. **Reserved**

B. **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 1 year since date of final completion in at least 10 installations of

comparative size and complexity. Submittals shall document this requirement with references.

C. **Installer's Qualifications**: Firms specializing and experienced in control system installations for not less than 5 years. Firms with experience in DDC 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. Sub-Contractors for installation of wiring, tubing, and conduit must also meet these requirements. Experience starts with awarded Final Completion of previous projects. Submittals must document this experience with references.

D. **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.

E. **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. 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.

F. **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 1-year history of servicing the proposed product line.

G. **Installer's Response Time and Proximity**

1. Installer must maintain a fully capable service facility within a 50-mile radius of the project site. Service facility shall manage emergency service dispatches and maintain inventory of spare parts.

2. Emergency response times are listed below in this section. Installer must demonstrate ability to meet response times.

H. **Installer's Quality Assurance Plan**

1. Installer must provide a description of their quality assurance operations from contract award through final delivery. The description shall include organizational responsibilities for each department represented within the execution of this document from installers to engineers, service technicians and management.

1.06 CODES AND STANDARDS

A. The following codes and standards are intended to apply to the project or installation as applicable. All references to codes and standards herein refer to the latest edition at the time of contract execution.

B. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

1. Standard 90.1: Energy Standard for Buildings except Low-Rise Residential Buildings

2. Standard 62.1: Ventilation for Acceptable Indoor Air Quality

3. Standard 135: BACnet - A Data Communication Protocol for Building Automation and Control Networks. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. current version including all annexes and addenda.

4. Standard 55: Thermal Environmental Conditions for Human Occupancy.

C. Electronics Industries Alliance

1. EIA-709.1: Control Network Protocol Specification

2. EIA-709.3: 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

10. EIA-852: Tunneling of Component Network Data over IP Channels

D. Underwriters Laboratories

1. UL 916: Energy Management Systems

2. UUKL 864: UL Supervised Smoke Control

E. NEMA Compliance

1. NEMA 250: Enclosure for Electrical Equipment

2. NEMA ICS 1: General Standards for Industrial Controls.

F. 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)

G. 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

4. IEEE 519: Recommended Practices and Requirements for Harmonic Control in Electric Power Systems

1.07 DEFINITIONS

A. **Accuracy**: As stated in Section “Building Automation System (BAS) Basic Materials, Interface Devices, and Sensors”, accuracy shall include combined effects of nonlinearity, non-repeatability and hysteresis.

B. **Adjustable (Adj):** A characteristic of a control logic parameter such that it can be varied by the operator without downloading the program. See also initial value.

C. **Analog Calibration Offsets**: For all analog input measured variables with the exception of velocity pressure, there is a requirement to adjust the value measured by the hardware based analog input point to match the value reported by a certified test instrument. An analog calibration offset is a parameter that can be added or subtracted from the raw value measured by the sensor to produce a calibrated value that will be use by the control logic and reported to the operator workstations. The initial value of this parameter is set at zero and it

is adjusted when the calibration process is executed. This adjustment is referred to as a single point calibration. These parameters are mandatory for all analog inputs except velocity pressure sensors (requirements for velocity pressure sensors are presented elsewhere).These offset values are configuration parameters and as such shall be written to EEPROM. It shall be possible to change the value of these parameters from a graphic page.

D. **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.

E. **FCPS WAN**: Reference to the corporate Information Technology network, used for normal business-related e-mail and Internet communication. IEEE 802.3 based network connecting multiple facilities with a central data warehouse and server, accessible via standard web-browser or client installed software.

F. **Application Programming Tool**: A vendor unique software tool used to create applications for programmable controllers.

G. **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).

H. **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.

I. **BACnet/BACnet Standard**: Communication requirements as defined by ASHRAE/ANSI 135 current version including all annexes and addenda.

J. **Bandwidth Utilization**: The average utilization of the network capacity. Network loading is controlled by the use of event driven broadcast based data propagation and the use of appropriate binding services.

K. **Binding**: The association of an output network variable from one device to the input network variable of a second device.

L. **Building Automation System (BAS)**: The entire integrated energy management and control system

M. **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 LAN backbone and sub-LANs, and data storage for trend information, time schedules, and alarm data.

N. **Change of Value (COV)**: An event that occurs when a measured or calculated analog value changes by a predefined amount (ASHRAE 135).

O. **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.

P. **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)

Q. **Control System Server (CSS)**: A device that is a provider of services to a client. A client device makes requests of and receives responses from a server device. As the BAS network devices are stand-alone, the CSS is not required for communications to occur.

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

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

T. **Functional Profile:** A collection of variables required to define 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.

U. **Gateway (GTWY)**: A device, which contains two or more dissimilar networks/protocols, permitting information exchange between them (ASHRAE 135).

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

W. **LAN Interface Device (LANID)**: Device used to facilitate communication and sharing of data throughout the BAS.

X. **Master-Slave/Token Passing (MS/TP)**: Data link protocol as defined by the BACnet standard. (ASHRAE 135).

Y. **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.

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

AA. **Operator Workstation (OWS)**: The user's interface with the BAS system via the internet or the Local Supervisory LAN. As the BAS network devices are stand-alone, the OWS is not required for communications to occur.

BB. **Peer to Peer Communication**: Data is broadcast from its origin and is received by the final device requiring the data without being received and retransmitted by a third device.

CC. **Polling Communication**: The process by which a control device requests a network variable from a second control device at a specified interval. Polling communication is typically used to populate dynamic data on an active graphic

page and for temporary or short term trending of data where the trend data is not stored at the controller level.

DD. **Portable Operators Terminal (POT):** Laptop PC used both for direct connection to a controller and for remote network connection.

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

FF. **Repeater**: A physical device used to connect two segments. A repeater does not filter any message traffic. A repeater does isolate physical problems such as short circuits to a single segment and is typically required to allow the use of additional devices or additional cable length.

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

HH. **Secondary Controlling LAN:** Subordinate LAN connecting AACs and ASCs to the Primary Controlling LAN. Refer to System Architecture below.

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

JJ. **SQL**: Standardized Query Language, a standardized means for requesting information from a database.

KK. **Stand-Alone Controller**: A stand-alone controller has provisions for all of the physical inputs and physical outputs associated with a single mechanical component such as a terminal unit, air handling unit, chiller or boiler. The controller shall also have embedded in it all of the control logic that associated the physical inputs to the physical outputs. A stand-alone controller may rely on other networked devices for time schedule inputs and trend data storage.

1.08 FUNCTIONAL INTENT

A. Detailed requirements are specified throughout this section and related documents, 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 in coordination with the BAS contractor. However, these will only be allowed with prior approval by FCPS.

1.09 SUBMITTALS

A. **Submittals**: Control submittals and O&M information shall be provided electronically in Adobe PDF format, along with three (3) bound hard copies. Control drawings shall be electronically provided in Adobe PDF in a size no less than 11”x17”. Documents will be developed in a preferred format or converted from their native electronic format directly to a preferred format. Any documents scanned as images must be converted to a searchable text format using OCR (Optical Character Recognition) and reduced in size prior to submission. O&M manual shall include electronic versions of the project Mechanical and Electrical design drawings.

B. **Qualifications**: Manufacturer, Installer, and Key personnel qualifications as indicated for the appropriate item above. Include QA/QC plan for all phases (design, install, Cx, warranty) along with documentation of industry standard QA/QC practices followed.

C. **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.

D. **Shop Drawings**: Submit shop drawings electronically in PDF format (and in hard copy, as noted above) 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. Shop drawings 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, drawing reference number, and controller type for each control unit. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the diagram. Indicate relevant communication protocol on each network segment.

b) Indicate device instance and MAC address for each CU. Indicate media, protocol, baud rate, and type of each LAN.

c) Provide floor plans locating all control units, LAN interface devices, gateways, and remote sensor locations. Include all WAN and LAN communication wiring routing, power wiring, power originating sources, and low voltage power wiring. 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.

a) Include written description of sequence of operation; identify each major component (hardware and software) involved in the control scheme by its tag identifier. Show locations for all global measurement instruments for interior or exterior ambient conditions such as outside air temperature sensors, outside air humidity sensors, static pressure references, etc.

b) 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.

c) 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 230905 for additional requirements.

d) Label each control device with setting or adjustable range of control.

e) Label each input and output with the appropriate range.

f) 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.

g) Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that is existing, factory-installed and portions to be field-installed.

h) Provide details of control panels, including controls, instruments, and labeling. Indicate the installed locations and allocated service clearances. Provide panel layout drawing including power supply, control unit(s) and wiring terminals.

3. Provide a Control Valve Schedule, listing valve and actuator information including: size, C_v, design flow, design pressure drop, manufacturer, model number, close off rating, control signal, line size, line pressure, ANSI class rating, tag number, system service, valve type, material construction of body, stem, and disc. Indicate normal positions of automatic return valves.
4. Provide a Control Damper Schedule listing damper and actuator information including: size, material, blade arrangement, manufacturer, model number, control signal, and close off rating. Indicate normal positions of automatic return dampers.
5. Provide an Air Flow Monitoring Station Schedule listing the following information: size, material, manufacturer, model number, control signal, design CFM, and velocity.
6. Provide a Metering Device Schedule listing the following information: flow range, fluid type, mechanical input type (magnetic, wheel, ultrasonic), manufacturer, model, purpose, and location.
7. Graphics: Provide color printouts of all specified graphic files including equipment schematics, tabular equipment data and floor plates.
8. All sheets in the submittal shall be consecutively numbered.
9. Each sheet shall have a title indicating the type of information included and the HVAC system controlled.
10. A Table of Contents shall list sheet titles and sheet numbers followed by a symbol legend and list of abbreviations.

E. **Open Protocol (BACnet) Information:**

1. BACnet object description, object ID, and device ID, for each I/O point.
2. Submit PICS indicating the BACnet functionality and configuration of each controller.

F. **As-Built Control Drawings**: Provide and mount as-built shop drawings for all controlled systems and equipment. Drawings should be of sufficient size to be easily read. Locate as-built drawings as follows:

1. During construction, drawings may be placed in plastic sleeves and mount in the control panel. The final drawings shall be laminated and permanently mounted in the control panel.

2. For central plant equipment, provide framed control drawings and wall mount.

3. For terminal units, print as-built drawings on adhesive-backed label and apply to controller enclosure or unit casing.

G. **Control Logic Documentation**

1. Submit control logic program listings (for graphical programming, if the requirements below are met) and logic flow charts illustrating (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. Graphic programs that provide simple blocks connected by multiple lines that are not specific in detail and easily understandable are not acceptable. 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 with all requirements of the sequence provided in detail. Provide in detail all virtual and real points, variables, PID loops, reset blocks, switches, timers, high/low selectors, alarms, proofing modules, staging blocks, etc. to fully describe the 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.

9. This portion of the submittal may be submitted after approval of all hardware, but shall be provided prior to installation of the network controller.

H. **Operation and Maintenance Materials:**

1. Documents shall be provided electronically as described for electronic submittals.

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 and for all workstation hardware and software and workstation peripherals.

4. Submit BAS Advanced Programming Manuals for each controller type and for all workstation software.

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.

M. Refer to Section 230995 for additional commissioning submittal requirements.

1.10 RECORD DOCUMENTS

A. Record documents shall be provided electronically; links to this documentation shall be provided on each equipment graphic for access to the as-built shop drawings, point lists, and sequences of operation. Three (3) bound hard copies shall also be provided.

B. Product data and control shop drawings updated to reflect the final installed condition.

C. Approved control logic programming and database uploaded and stored on the project BAS server. 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. Approved project specific graphic software on electronic media (disk, USB drive).

E. Network architecture drawings showing all nodes including a description field with specific controller identification, description and location information.

F. Individual floor plans with controller locations with all interconnecting wiring routing including space sensors, LAN wiring, power wiring, and low voltage power wiring. Indicate device instance, MAC address and drawing reference number.

G. Riser diagram showing the location of all controllers.

H. 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 the contract documents. Contractor shall include all items not specifically itemized in the specifications that are necessary to implement, maintain, and operate the system in compliance with the functional intent of contract documents.

B. The system architecture shall consist of an Ethernet-based, wide area network (WAN), a single Local Area Network (LAN) or multi-leveled LANs that support BCs, AACs, ASCs, Operator Workstations (OWS), and Control Systems Servers (CSS) as applicable. The BAS shall seamlessly communicate using the BACnet protocol at all network levels. The following indicates a functional description of the BAS structure.

1. **FCPS WAN**: Internet-based network connecting multiple facilities. This is an existing infrastructure and the Contractor is not required to configure any components of this WAN.

2. **Supervisory LAN**: The Supervisory LAN is an extension of the FCPS WAN. Contractor will be provided specific ports dedicated for control module/interface device connectivity. The LAN is IEEE 802.3 compliant with switches and routers that support 100 Mbps minimum throughput. Contractor may not extend this network without prior approval from FCPS. Power-line carrier communication shall not be acceptable for communications.

a) If necessary, the Contractor will be responsible for the installation of a temporary Ethernet network that will serve the purpose of the Supervisory LAN until such time as the permanent Supervisory LAN is available. Should the temporary network be required, the BAS Contractor shall be responsible for the coordination and implementation of the Supervisory LAN to conform to the eventual permanent LAN settings and addresses for the BAS.

b) The Supervisory LAN shall be an Ethernet-based, 100 Mbps LAN connecting Primary Control LANs and local or proprietary OWSs. Each BC and OWS shall be connected directly to a dedicated port of connection to FCPS WAN. LAN shall be IEEE 802.3 Category 6 cable. No switches and routers shall be connected between BC or OWS and FCPS WAN entry port. Power-line carrier communication shall not be acceptable for communications.

c) The higher level layers of this network shall conform to the requirements of a BACnet Local Supervisory LAN (BACnet/IP) and share a common network number for the Ethernet backbone as defined in the BACnet standard.

3. **Primary Controller LAN ('Primary LAN')**: High-speed, peer-to-peer communicating LAN used to connect Building Controllers (BCs) and

communicate exclusively control information. Acceptable technologies include:

a) Ethernet (IEEE802.3)

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

4. **Secondary Controller LAN ('Secondary LAN')**: Network used to connect AACs, and ASCs. These can be BACnet MS/TP, 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 times and trending requirements required.

C. **Control Systems Server (CSS):** This shall be a computer (or computers) that maintain the systems configuration, programming database, and historical trend data. 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 230902 - BAS Operator Interfaces for additional requirements.

D. **Individual Controllers**: The BCs, AACs, and ASCs 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 230903 - BAS Field Panels.

E. **Administration Touch-Screen Override Panel:** Provide a local touch-screen override panel (as indicated on the drawings) in the Administration area to override equipment zones. Refer to 230902 - BAS Operator Interfaces for its requirements.

F. **BACnet Standards**: The following apply to all DDC controls provided:

1. All DDC controls are to be compliant with ASHRAE / ANSI Standard 135 -BACnet – Data Communication Protocol for Building Automation and Control Systems.
2. All DDC controls to be BTL listed. BACnet device numbering and subnet LAN addressing shall to be configured within a range consistent with the individual School Number (FCPS provided).
3. 'Out of Service' flags are not to be used on any points.
4. The use of proprietary objects for network data communication is not permitted.
5. LON devices and/or LONtalk communication is not permitted.

G. **Remote Data Access**: Coordinate remote access connectivity with FCPS. The system shall support the following method of remote access to the building data.

1. Browser-based access: A remote user using a standard browser shall be able access all control system facilities and graphics with proper password. FCPS shall provide the continuous Internet connection. The following paradigms are acceptable for browser-based access:

a) Native Internet-based user interfaces (HTML, Java, XML, etc.) that do not require a plug-in.

b) User interfaces that via a standard browser use a freely distributed and automatically downloaded and installed plug-in or 'thick' client that presents the user interface across the web.

1.12 WARRANTY MAINTENANCE

A. Contractor shall warrant all products and labor for a period of **2 years** after Final Acceptance.

B. FCPS (or designated representative) reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. Contractor shall warrant parts and installation work regardless of any such changes made by FCPS, unless the Contractor provides clear and convincing evidence that a specific problem is the result of such changes to the BAS. Any disagreement between FCPS and Contractor on such matters shall be subject to resolution through the contract 'Disputes' clause.

C. **Maintenance Services:** During the warranty period, the Contractor shall provide maintenance services for software and hardware components as specified below, at no cost to FCPS:

1. Maintenance services shall be provided for BAS hardware, software, installation, and programming provided under this and related sections.

a) Service and perform preventive maintenance for all equipment per the manufacturer's recommendations.

b) 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 FCPS to the Contractor.

a) Response by telephone to any request for service shall be provided within two (2) hours of FCPS'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 site within four (4) hours of the 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 FCPS 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 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 site within three (3) working days of the initial telephone request for such services, as specified.

4. Site Visit Protocol: At any time during the warranty period that the Contractor is on site for maintenance, emergency, or normal service, they shall notify the local building operating personnel. Contractor shall notify said personnel of all work anticipated being involved for the service work. In addition, no work affecting system operation shall commence until permission is granted. After the work is completed, a work order ticket describing in detail all work performed (i.e. hardware replaced or serviced, software or firmware modifications made, etc.), hours worked, follow-up work required, etc., must be signed by an authorized FCPS representative.

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

6. Product Updates: In the last month of the warranty period, all system software and controller firmware, software, drivers, etc. shall be upgraded to the latest release (version) in effect at the end of the Warranty Period. Updates and upgrades shall not be performed without authorization by FCPS.

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.

B. Portions of the BAS utilized for fire/smoke management, stairwell pressurization controls and monitoring shall be listed by Underwriters Laboratories (UUKL 864).

PART II. PRODUCTS

2.01 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 be used in any way for the permanent installation except where drawings or specifications specifically allow existing materials to remain in place or be reinstalled.

B. This installation may not be used as a product test site unless explicitly approved in writing by FCPS. Spare parts shall be available for at least five years after completion of this contract.

C. Within 45 days of approved shop drawings provide a complete package of spare parts as follows:

1. Provide the following quantities of each type of controller used on this contract including all expanded boards:

Quantity Used	Spares Required
1-9	1
10-49	10% rounded up
50+	5

2. Provide ten (10) room sensors used for terminal units. Provide one (1) spare space sensor used for each RTU.
3. Provide five (5) space humidity sensors
4. Provide one (1) space CO2 sensor for each applicable unit.
5. Provide one (1) outdoor air temperature sensor and one (1) outdoor humidity sensor
6. Provide the quantity of valve and damper actuators consistent with the requirement for the quantity of controllers specified in item 1.
7. Provide an itemized list of proposed spare parts, for review prior, to submitting spare parts.

2.02 UNIFORMITY

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

2.03 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Sensors and Transmitters (230901)

1. Airflow stations
2. Flow Meters

3. Flow Switches
4. Pressure sensor wells and sockets
5. Temperature sensor wells and sockets

B. Control Valves (230901)

1. Control Valves

C. Control Dampers (230901)

1. BAS Automated Dampers

2.04 INSTALLER-PROVIDED CONTROL SUB-SYSTEM INTEGRATION

A. **General**: Where Installer-Provided Control Sub-Systems are to integrate to the BAS, timely coordination shall occur and integration shall be provided for the specified systems, as defined below. Refer to Section 230904 – BAS Communication Devices for additional requirements.

B. **Coordination Meetings**: The Contractor shall coordinate meetings between all necessary parties to coordinate the details of the interface between the following products and the DDC network. The BAS contractor may choose to subcontract a BACnet integration specialist in the cases of specific existing equipment. FCPS or designated representative shall be present at every coordination meeting. Submittals for these products shall not be approved prior to the completion of this meeting. Any issues identified during these meetings must also be resolved satisfactorily and with agreement between the BAS Contractor and the Installer(s) prior to the submittal being approved. Each Installer shall provide FCPS and BAS Contractor and all other Installers with the details of the proposed interface including the following;

1. BACnet PICS
2. Point List
3. Wiring Requirements
4. Communication Specifications for speed, type etc.
5. Required Network Accessories
6. Network Identifiers
7. Any known and undocumented configuration parameters required to properly establish a permanent solution to meet the specifications.

C. **Utility Monitoring Interfaces (Power, Gas, Water)**

1. Power Monitor: The switchgear vendor shall furnish an interface to the control and monitoring points indicated on the control drawings. The connection to these points shall be of the following methods determined during the coordination meetings:

a) Hardwired connection such as relay, 0-10VDC, or 4-20mA

b) BACnet/IP network connection

c) BACnet MS/TP network connection

2. Gas Meter: The gas meter shall be provided with an interface to the control and monitoring points indicated on the control drawings. The connection to these points shall be of the following methods determined during the coordination meetings:

a) Hardwired connection such as relay, 0-10VDC, or 4-20mA

b) BACnet/IP network connection

c) BACnet MS/TP network connection

3. Water Meter: The water meter shall be provided with an interface to the control and monitoring points indicated on the control drawings. The connection to these points shall be of the following methods determined during the coordination meetings:

a) Hardwired connection such as relay, 0-10VDC, or 4-20mA

b) BACnet/IP network connection

c) BACnet MS/TP network connection

D. **Variable Frequency Drives**

1. Variable Frequency Drives: The variable frequency drive (VFD) vendor shall furnish all VFDs with an interface to the control and monitoring points indicated on the control drawings. The connection to these points shall be of the following methods determined during the coordination meetings:

a) Hardwired connection such as relay, 0-10VDC, or 4-20mA

b) BACnet/IP network connection (if indicated on the project drawings)

c) BACnet MS/TP network connection

E. **Communications with Other Third Party Equipment**:

1. Any additional integral control systems included with the products integrated with the work of this section shall be furnished with a BACnet/IP interface for integration into the Direct Digital Control System described in this section

PART III. 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.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions for resolution before starting rough-in work.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies and obtain written instructions for changes necessary to accommodate Section 230900 work with work of others. Contractor shall perform, at their expense, necessary changes in specified work caused by failure or neglect to report discrepancies.

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

3.03 CONTROL PANELS, CONTROLLER QUANTITY AND LOCATION

A. Control panels shall consist of one or multiple controllers to meet requirements of this specification. No controllers are to be mounted inside units, with the exception of VAV box control enclosures. Control panels shall be wall mounted within mechanical equipment rooms. Electrical equipment rooms may be used with prior FCPS approval. No panels, other than terminal unit controllers, shall be located above ceilings unless approved by FCPS.

B. Where a control panel is referenced, Contractor shall provide at least one (1) controller, and additional controllers as required, in sufficient quantity to meet the requirements of these specifications. Restrictions in applying controllers are specified in Section 230903 - BAS Field Panels. The Contractor shall extend power to the control panel from an acceptable power panel. If the control contractor wishes to further distribute panels to other locations, control contractor is responsible for extending power to that location also. Furthermore, contractor is responsible for ensuring adequate locations for the panels that do not interfere with other requirements of the project and maintain adequate clearance for maintenance access.

C. Contractor shall locate control panels as referenced. It is the Contractor's responsibility to provide enough controllers to ensure a completely functioning system, according to the point list and sequence of operations.

D. Contractor shall provide a minimum of the following:

1. One control panel (including at least one controller) in each chilled water/hot water plant mechanical room

2. One control panel (including at least one controller) for each air handler located in applicable mechanical room or on roof

3. One control panel (including at least one controller) for each critical fan system

4. One control panel (including at least one controller) for each pumping system

5. One control panel (including at least one controller) for each steam pressure reducing station

6. One controller for each piece of terminal equipment (VAV, UV, FCU) located at the equipment.

3.04 SURGE PROTECTION

A. Contractor shall furnish and install any power supply surge protection, filters, etc. as necessary for proper operation and protection of all BCs, AACs, 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 affect on hardware, software, communications, and data storage.

3.05 SEQUENCE OF WORK

A. General: All work involving changeover of control functions from existing systems to the new 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 construction server, 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 coordinated with FCPS.

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 all conduit and wiring that does not require interruption of the existing system.
2. Install CUs 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 system.
3. Load CU software. Connect CU(s) to LAN.
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 points. Install and calibrate remainder of new BAS materials and equipment for this subsystem.
6. Perform all field testing and calibration.
7. Notify the contracting officer prior to this step. Place the system under the control of the new BAS equipment. Conclude field testing and submit field testing report prior to placing the next subsystem under control. FCPS 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 materials and equipment (except materials to be reused in accordance with provisions specified elsewhere). All existing equipment for those subsystems that have not yet been converted shall remain intact, on-line, and fully functional.

3.06 CONTROL POWER SOURCE AND SUPPLY

A. Section 230900 Contractor shall extend all power source wiring required for operation of all equipment and devices provided under this and related sections.

B. General requirements for obtaining power include the following:

1. In the case where additional power is required, 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 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.

3. Provide an uninterruptible power supply (UPS) system providing battery backup for each BC. UPS shall protect against blackouts, brownouts, surges and noise. UPS shall include LAN port and modem line surge protection.

3.07 POWER MONITORING

A. Building Power Monitor: The BAS shall communicate directly with the building power monitor or switchgear] to read building power information. For BACnet interface, refer to Section 230904 for additional requirements.

B. Power Sub-Metering: The BAS shall provide sub-metering for selected HVAC systems and equipment.

C. Refer to control drawings for specific requirements.

D. The BAS shall also monitor a dry contact status point from each transient voltage surge suppression (TVSS) device in the building.

3.08 NATURAL GAS MONITORING

A. Building Gas Meter: The BAS shall communicate directly with the meter to read building gas consumption information. For BACnet interface, refer to Section 230904 for interface requirements.

3.09 DOMESTIC WATER MONITORING

A. Building Water Meter: The BAS shall communicate directly with the meter to read building water consumption information. For BACnet interface, refer to Section 230904 for interface requirements.

3.10 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 on CD in PDF format) to be used for training.

B. Contractor shall submit a Training Plan for the scope of training for which they are responsible. Once approved by the Engineer and/or CxA, training times shall be coordinated with the FCPS Project Manager for acceptance of the times and class outline.

C. **Local Training**: The local control contractor shall provide:

1. One four (4) hour training course for the designated FCPS personnel, to be performed at system demonstration.
2. The class shall be taught by qualified personnel educated in the systems/products and adult learning techniques.
3. Agenda: The course agenda shall include instruction on specific systems and instructions for operating the installed system. Topics covered shall include as a minimum:

a) HVAC System Overview

b) Operation of Control System

c) Function of each Component

d) System Operating Procedures

e) Programming Procedures

f) Maintenance Procedures

END OF SECTION 230900

SECTION 230901 - BAS BASIC MATERIALS, INTERFACE DEVICES, AND SENSORS

PART IV. GENERAL

4.01 RELATED DOCUMENTS

A. Section 230900 - Building Automation System (BAS) General

B. Section 230902 - BAS Operator Interfaces

C. Section 230903 - BAS Field Panels

D. Section 230904 - BAS Communication Devices

E. Section 230905 - BAS Software and Programming

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

4.02 DESCRIPTION OF WORK

A. Refer to Section 230900 for general requirements.

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

C. Provide the following electrical work as 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 enunciator 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.

4.03 WORK BY OTHERS

A. Control Valves furnished under this section shall be installed under the applicable piping section under the direction of Section 230901 Contractor who will be fully responsible for the proper operation of the valve.

B. Water Pressure Taps, Thermal Wells, Flow Switches, Flow Meters, etc. that will have wet surfaces, shall be installed under the applicable Division 23 Section under the direction of Section 230901 Contractor who will be fully responsible for the proper installation and application.

C. Smoke Detectors: Duct type smoke detectors for HVAC systems shall be intelligent and shall be furnished under Division 26. Provide relays and interlock wiring as required to accomplish specified shutdown and smoke management control sequences under this section.

D. Power wiring for controlled equipment shall be furnished and installed under Division 26. Where 120 volt (V) control devices are used to control the equipment, Division 26 Contractor shall extend 120V power wiring to the equipment. Section 230901 Contractor shall extend 120V power wiring from the equipment to the control devices.

PART V. PRODUCTS

5.01 MATERIALS AND EQUIPMENT

A. General: Provide electronic control products in sizes and capacities indicated, consisting of valves, dampers, controllers, sensors, and other components as required for complete installation. 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. Substitutions: With FCPS approval only.

5.02 INSTRUMENT PIPING AND TUBING

A. **Hydronic and Instruments**

1. **Connection to Main Piping**: Provide ½ inch minimum size thread-o-let, ½" x 2-inch brass nipple, and ½" ball valve for connection to welded steel piping. Provide tee fitting for other types of piping.
2. **Remote Instruments**: Adapt from ball valve to specified tubing and extend to remote instruments. Provide a union or otherwise removable fitting at ball valve so that connection to main can be cleaned with straight rod. Where manifolds with test ports are not provided for instrument, provide tees with ¼" FPT branch with plug for use as test port. Adapt from tubing size to instrument connection.
3. **Line Mounted Instruments**: Extend rigid piping from ball valve to instrument. Do not use close or running thread nipples. Adapt from ball valve outlet to instrument connection size. Provide a plugged tee if pipe makes 90-degree bend at outlet of valve to allow cleaning of connection to main with straight rod without removing instrument.
4. **Instrument Tubing**: Seamless copper tubing, Type K or L, ASTM B 88; with cast-bronze solder joint fittings, ANSI B1.18; or wrought-copper solder-joint fittings, ANSI B16.22; or brass compression-type fittings. Solder shall be 95/5 tin antimony, or other suitable lead free composition solder. Tubing OD size shall be not less than the larger of ¼" or the instrument connection size.
5. **Rigid Piping for Line Mounted Instruments**: Schedule 40 threaded brass, with threaded brass fittings.

B. **Low Pressure Air Instrument Sensing Lines**

1. **Connections:** Use suitable bulkhead type fitting and static sensing tip for static pressure connections. Adapt tubing to instrument connection.
2. **Indoor Tubing**: Virgin polyethylene non-metallic tubing type FR, ASTM D 2737, with flame-retardant harness for multiple tubing. Use compression or push-on brass fittings.
3. **Outdoor Tubing**: Seamless copper tubing, Type K or L, ASTM B 88; with cast-bronze solder joint fittings, ANSI B1.18; or wrought-copper solder-joint fittings, ANSI B16.22; or brass compression-type fittings. Solder shall be 95/5 tin antimony, or other suitable lead free composition solder. Tubing OD size shall be not less than the larger of ¼" or the instrument connection size. Outdoor tubing shall be painted silver.

5.03 CONTROL WIRING

A. **Communication Wiring**: All wiring shall be in accordance with the latest edition of the National Electrical Code and Division 26.

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, etc.).

2. **Local Supervisory and Primay LANs**: For any portions of this network required under this section of the specification, Contractor shall use Category 6 cable per TIA/EIA 68 (100BaseT). Network shall be run with no splices and separate from any wiring over thirty (30) volts.

3. **Secondary Controller LAN**: Communication wiring shall be individually 100% shielded pairs per manufacturer's recommendations for distances installed, with overall PVC cover, Class 2 run with no splices and separate from any wiring over thirty (30) volts. Refer to Division 26 for separation requirements. Shield shall be terminated and wiring shall be grounded as recommended by building controller manufacturer.

B. **Signal Wiring**: Contractor shall run all signal wiring in accordance with the latest edition of the National Electrical Code and Division 26.

1. Signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, etc. shall be per manufacturer's requirements.

2. Signal wiring shall be run with no splices and separate from any wiring above thirty (30) volts.

C. **Low Voltage Analog Output Wiring**: Contractor shall run all low voltage control wiring in accordance with the latest edition of the National Electrical Code and Division 26.

1. Low voltage control wiring shall be per manufacturer's requirements.

2. Low voltage control wiring shall be run with no splices separate from any wiring above thirty (30) volts.

5.04 CONTROL PANELS

A. **General**: Provide control panels with suitable brackets for wall mounting, unless noted otherwise, for each control system. Locate panel adjacent to systems served or as indicated on the floor plans. Mount center of control panels 60*"* above finished floor in mechanical rooms or adjacent to unitary equipment installed outside mechanical rooms.

B. All Controllers, Relays, Transducers, etc., required for stand-alone control shall be housed in a UL-rated, NEMA enclosure suitable for the installed conditions.

C. **Panels inside the Building Envelope**: Panels shall be constructed of 16-gage steel, totally enclosed on four sides, with removable perforated backplane, hinged door and keyed lock, with manufacturer's standard shop- painted finish and color.

D. Control panels shall be completely factory wired and piped, and all electrical connections made to a terminal strip.

E. All gauges and control components shall be identified by means of nameplates.

F. All control tubing and wiring shall be run neatly and orderly fashion, providing 50% additional capacity, in open slot wiring duct with cover.

G. Complete wiring and tubing termination drawings shall be mounted in, and a second set mounted adjacent to, each panel in a frame with Lexan cover of sufficient size to be easily readable.

5.05 CONTROL VALVES

A. **General**: Provide factory fabricated control valves of type, body material and pressure class indicated. All valves shall include local position indication. 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 for any valve/actuator combination shall be 110% of the total system (pump) head for water applications or 50 psig, whichever is greater.

B. **Globe Valves (not for Steam Service):**

1. **Valve Sizing**: Modulating valves shall be sized for maximum full flow pressure drop of 5 PSIG unless scheduled otherwise. Where not specifically indicated in the contract documents, 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) Belimo

b) Bray

c) Siemens

C. **Globe Valves for Steam Service**:

1. **Valve Sizing**: Modulating valves for applications of 15 psig or less shall be sized 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**: Linear characteristics. Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.

3. **Temperature Rating**: 250°F maximum for applications of 15 psig or less; 366°F maximum for applications of greater than 15 psig up to 150 psig.

4. **Body**: Bronze, screwed, 250 psig steam maximum working pressure for 1/2" to 2"; Cast Iron, flanged, 100 psig steam maximum working pressure for 2-1/2" and larger for applications of 50 psig or less.

5. **Valve Trim**: Plug, Seat and Stem: Polished stainless steel.

6. **Packing**: Spring Loaded Teflon.

7. **Disc**: Replaceable Composition or Stainless Steel Filled PTFE.

8. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:

a) Belimo

b) Bray

c) Siemens

D. **Butterfly Valves:**

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. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:

a) Belimo

b) Bray

c) Siemens

E. **Ball Valves:**

1. **Body**:

a) 2" or less: Valves shall utilize bronze bodies with female NPT threads. Valve bodies may also be stainless steel, titanium or nickel.

b) 2-1/2" or greater: Valves shall have flanged carbon steel or stainless steel bodies rated at 300 psi working pressure.

2. **Seat**: Reinforced Teflon.

3. **Ball**: Stainless steel.

4. **Port**: Segmented design with equal-percentage characteristic.

5. **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.

6. **Stem**: Stainless steel, blow-out proof design, extended to match thickness of insulation.

7. **Cold Service Pressure**: 200 psi WOG.

8. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:

a) Belimo

b) Bray

c) Siemens

5.06 BALANCING VALVES

A. **General**: Balancing valves shall be sized according to the manufacturer's recommendations. Contractor shall provide balancing valve submittals, which will include cut sheets and a detailed balancing valve schedule. The schedule, at the minimum, shall include pipe runout size, valve size, flow rate, valve Cv (where applicable), and actual head loss or pressure drop across the valve.

5.07 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 indicated on drawings or as recommended by manufacturers sizing techniques. For dampers located near fan outlets, provide dampers rated for fan outlet velocity and close-off pressure, and as recommended by damper manufacturer for fan discharge damper service. Control dampers used for outside air or exhaust air service shall have insulated blades. Control dampers used for smoke dampers shall comply with UL 555S. Control Dampers used for fire dampers shall comply with UL 55. Furnish all automatic control dampers and smoke dampers required except for specific dampers that will be provided by the equipment manufacturers where so noted on

Drawings. Coordinate sizes of all dampers with duct sub-contractor prior to ordering and delivery to job site.

B. 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**: Graphite impregnated nylon.
9. **Leakage**: Less than one percent based on approach velocity of 1500 ft./min. (7.62 m/s) and 1" w.c. (249 Pa).
10. **Maximum Pressure Differential**: 2.5" w.c. (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.

C. General Isolation and Modulating Control Service in rectangular ducts in excess of item B but 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" w.c. (249 Pa).

10. **Maximum Pressure Differential**: 6" w.c. (1493 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. General Isolation and Modulating Control Service in rectangular ducts at velocities in excess of item B but not greater than 4000 fpm, differential pressure in excess of item C but not greater than 12" w.c. (2984 Pa). Provide parallel or opposed blade dampers as indicated on drawings or as recommended by manufacturers sizing techniques, typically for mixing applications. Provide opposed blade dampers as indicated on drawings or as recommended by manufacturers sizing techniques, typically for throttling applications:

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" x 3/4" (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" w.c. (249 Pa) differential pressure.

8. **Maximum Pressure Differential**: 12” w.c. (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. 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” w.c. (249 Pa) differential pressure.

8. **Maximum Pressure Differential**: 4” w.c. (994 Pa).

9. **Temperature Limits**: -40 to 300 °F (-40 to 149 °C).

F. General Isolation and Modulating Control Service in round ducts in excess of item E 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, 1/4 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, with 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" w.c. (249 Pa) differential pressure.

9. **Maximum Pressure Differential**: 6" w.c. (1492 Pa).

10. **Temperature Limits**: -40 to 250 °F (-40 to 121 °C).

5.08 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. Actuators relying on batteries for any operation are not acceptable.

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. Provide end switches as required.

3. **Electronic Actuators**: Provide actuators with spring return for two-position (24v) or 0-10VDCas required. All modulating applications for primary HVAC equipment shall utilize true analog actuators. Simulated analog such as 3-point shall only be acceptable for VAV box terminal unit control.

a) Actuators shall travel full stroke in less than 90 seconds (VAV terminal box actuators may be up to 300 second full stroke time).

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

c) Actuators shall have positive positioning circuit, stroke indicator, current limiting motor protection, and manual position override.

d) Modulating actuators for valves shall have minimum range-ability of 40 to 1.

e) All actuator torque ratings shall be 150% of the requirements of the application. The minimum rating shall be 70 in-lbs. for all actuators other than VAV box actuators. Provide a minimum of one actuator for each 25 square feet of damper area. For Multizone unit zones, provide 140 in-lbs for applications with four (4) or greater blades where one blade includes both hot and cold deck dampers

f) **Close-Off Pressure**: Provide the minimum torque required, and spring return for fail positioning sized for required close-off pressure. Required close-off rating of air damper applications shall be shutoff pressure of associated fan, plus 10 percent.

g) **Acceptable Manufacturers**: Subject to compliance with requirements approved manufacturers are as follows:

1) Belimo

2) Delta

3) Johnson Controls

4) Siemens

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 a NEMA 4 epoxy coated metal enclosure, and shall have a minimum of two threaded conduit entries.

f) **Limit Switches**: Travel limit switches shall be UL 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 hand wheel type. For larger valves, the override shall be a fixed geared hand wheel type. An automatic power cut-off switch shall be provided to disconnect power from the motor when the hand wheel 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, and 2-10 vdc.

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

5.09 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, is not designed to work with ‘two-wire’ type transmitters, 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 and repeatability equal to, or better than, the accuracy and repeatability listed for respective field devices.

E. **Accuracy**: As stated in this Section, accuracy shall include combined effects of nonlinearity, non-repeatability and hysteresis.

5.10 TEMPERATURE SENSORS (TS)

A. **Sensor range**: When matched with A/D converter of BC, AAC, or ASC, sensor range shall provide a resolution of no worse than 0.5°F (unless noted otherwise).

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.

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.

C. **Room Temperature Sensor (Smart Sensor):** Shall be an element contained within a ventilated cover, suitable for wall mounting, unless noted otherwise.

1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.5°F accuracy at calibration point.
2. Provide all sensors with an insulated base.
3. Provide setpoint adjustment where indicated. The setpoint adjustment shall be a warmer/cooler indication that shall be scalable via the BAS (initially +/- 2°F).
4. Provide an occupancy override button on the room sensor enclosure where indicated. This shall be a momentary contact closure.
5. Provide current temperature indication via local display.
6. Local Access Port: Sensor shall be equipped with local access port to allow laptop or service tool connection to the BAS.
7. Multiple Sensors: Smart sensors may combine temperature, humidity, and CO2 sensors, provided accuracy requirements are met. See below for humidity and CO2 sensor requirements.

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.

1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.5°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.

1. 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.
2. Sensing element shall be platinum RTD, or thermistor, +/- 0.5°F accuracy at calibration point.

F. **Liquid Immersion Temperature Sensor:** Shall consist of sensing element and connection head for wiring connections.

1. Sensing element shall be platinum RTD, thermistor, or integrated circuit, +/- 0.5°F accuracy at calibration point.
2. Provide each sensor with brass or stainless steel thermowell of the appropriate length. Provide heat conductive compound between the well and sensor element.

G. **Outside air sensors** shall consist of a sensor, sun shield, utility box, and watertight gasket to prevent water seepage. Temperature range shall be as required for resolution indicated in paragraph A.

1. Sensing element - Platinum RTD, Thermistor, or integrated circuit, ± 0.4° F accuracy at calibration point.
2. Outside air temperature and humidity sensors shall be separate probes.

5.11 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% 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. For duct mounted installations, flange mount sensor to side of duct using manufacturer's standard recommendations and select probe lengths suitable for sensor location at center of duct.

C. Accessories: Duct-mounting plate, quick mount duct flange adapter, sensor dust filter, and single point calibrator for on-line/on-site calibration.

D. Provide other accessories as required to protect sensors for up to 2500 fpm velocities.

5.12 DIFFERENTIAL PRESSURE TRANSMITTERS (DP)

A. **General Purpose - Water**:

1. **General:** Loop powered two-wire transmitter.
2. **Output:** Two wire 4-20 mA output with zero and span adjustments.
3. **Overall Accuracy:** Plus or minus 1%.
4. **Range**: Select for specified setpoint to be between 25% and 75% full-scale
5. **Minimum Range:** 0 psig.
6. **Maximum Range:** 250 psig.
7. **Housing:** Polymer housing suitable for surface mounting.
8. **Acceptable Manufacturers**: Veris

B. **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. **Range**: Select for specified setpoint to be between 25% and 75% full-scale.
5. **Minimum Range**: 0.1 in. w.c.
6. **Maximum Range**: 10 inches w.c.
7. **Housing**: Polymer housing suitable for surface mounting.
8. **Static Sensing Element**: Pitot-type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.
9. **Acceptable Manufacturers**: Veris, Siemens, Setra

C. **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. **Range**: Select for specified setpoint to be between 25% and 75% full-scale.
5. **Minimum Range**: 0 in. w.c.
6. **Maximum Range**: 0.1, 0.25, or 0.5 inches w.c.
7. **Housing**: Polymer housing suitable for surface mounting.
8. **Static Sensing Element**: Pitot-type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.
9. **Acceptable Manufacturers**: Veris, Siemens, Setra

D. **VAV/CAV Velocity Pressure**: Generally for use to measure volume of 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. **Range**: Select for minimum range that will accept the maximum velocity pressure expected

8. **Acceptable Manufacturers**: Siemens and Setra

5.13 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. Mount 6' AFF. Kit shall include high and low pressure isolation valves, high and low pressure vent valves, calibration taps, and a bypass valve contained in a NEMA 1 enclosure.

5.14 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.

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

5.15 ROOM STATIC PRESSURE MONITOR AND PROBE

A. Provide flush or wall mounted room pressure monitor with room and reference pressure fittings to a remote pressure transducer with a 1 percent accuracy, 4-20ma analog output with a resolution of 0.001 inch w.c., red and green LEDs to alert operating personnel to the room pressure status and audible alarm horn with local silence button. Locate as shown on contract drawings. Alternates may include more descriptive display screens.

B. Provide power circuit and control transformer to power each monitor.

C. Provide factory calibration to NIST procedures with documentation

D. **Acceptable manufacturers**: Veris, Siemens, Setra. Substitutions shall be allowed per Division 1.

5.16 AIRFLOW MEASURING STATIONS (AFMS)

A. **Pitot Tube Stations**: 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.

1. Sensor Accuracy: ±2%

2. Electronics Accuracy: see Differential Pressure Transmitter requirements
3. Range: Select minimum range to accommodate the expected flow range of the project
4. Probe Quantities: per manufacturer's guidelines
5. Acceptable Manufacturer: Tek-Air TFP5000 Series or FCPS-approved equal.

B. **Thermal Dispersion Grid**: Provide a high density thermistor array for thermal dispersion airflow reading. Provide the electronics to output a linear analog signal (0-5/0-10 VDC or 4-20mA) of airflow with a resolution of 0.025% of full scale.

1. Sensor Accuracy: ±2%
2. Electronics Accuracy: ±3%, repeatability ±0.25%
3. Range: Select minimum range to accommodate the expected flow range of the project
4. Temperature Limits: -20-160°F
5. Acceptable Manufacturer: Ebtron Gold Series or FCPS-approved equal.

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 4-20 mA.

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. Manufacturer: Tek-Air Vortek Series or FCPS-approved equal.

5.17 DIFFERENTIAL PRESSURE SWITCHES (DPS)

A. **General Service Auto Reset - 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 Manual Reset - 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.

C. **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 and 0°F to 160°F operating temperature range.

5.18 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.

5.19 CURRENT SWITCHES (CS)

A. **Clamp-On 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 Manufacturer**s: Veris, Senva

B. **Clamp-on 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 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 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, Senva

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 Senva, Veris Industries 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.

5.20 CURRENT TRANSDUCER (CT)

A. **Clamp-On Design Current Transducer (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**: Veris, Senva

5.21 POWER MONITOR (WHERE REQUIRED)

A. The power monitor shall consist of three split-core CTs and an electronic metering unit.

B. The meter shall measure true (rms) power, instantaneous demand (kW) and consumption (kWh).

C. The meter shall provide data to the BAS using the BACnet protocol. All available points shall be mapped to the BAS.

D. The meter shall be calibrated as a system and be accurate to +/- 1% from 7 % to 100 % of the rated current over a temperature range of 0-60° C.

E. **Acceptable Manufacturer**: Veris.

5.22 CONTINUOUS LEVEL TRANSMITTERS

A. **Ultrasonic Type**

1. Provide a non-contacting, temperature compensating, narrow beam, ultrasonic type level transmitter with adjustable span and zero.
2. **Output**: 4-20 mA.
3. **Transducer Materials**: PC/ABS, Polypropylene, PVC and/or Teflon.
4. **Electrical Enclosure**: NEMA-4X, Type 6.
5. **Approvals**: UL, CE or CSA.
6. **Accuracy**: ±.5% of calibrated span
7. **Acceptable Manufacturers**: Flowline, Siemens.

5.23 INSERTION TYPE TURBINE METER FOR WATER SERVICE

A. **General**: 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. **Installation**: 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, Hersey

5.24 CLAMP-ON ULTRASONIC FLOW METER FOR WATER SERVICE

A. **General**: Provide a clamp-on, transit time ultrasonic flow meter with self-aligning installation hardware and coaxial transducer cables.

B. **Installation**: The flow meter shall be installed without any openings in the pipe wall and shall utilize non-wetted ultrasonic transducers that may be located up to 300 feet from the meter.

C. **Transducers**: Ultrasonic transducers provided must be optimized for the specific pipe & process conditions for each application and the transducer frequency shall be automatically matched to the resonant frequency of the pipe at start-up. An integral auto-zero function shall be provided for zero precision and high accuracy, even at very low flow velocities.

D. **Performance/Accuracy**: The flow meter shall be capable of measuring bi-directional flow. Accuracy shall be within ± 1% of rate from 1 to 40 ft/sec and ± 0.01 ft/sec for velocities below 1 ft/sec. Overall turndown shall exceed 400:1.

E. **Display**: The meter shall display flow rate and flow total with an integral LCD display and support field programming of all parameters. The meter shall also have integral diagnostics to verify installation conditions and the proper operation of the meter. All outputs shall be linear with flow rate.

5.25 VORTEX SHEDDING FLOW METER FOR LIQUID 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 gases.

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

H. **Acceptable Manufacturers**: Foxboro, Rosemount, Onicon

5.26 CO_2 SENSORS/TRANSMITTERS (CO2)

A. **General**: CO_2 sensors shall use silicon based, diffusion aspirated, infrared single beam, dual-wavelength, self-calibrating 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**: Honeywell C7232

5.27 ELECTRIC CONTROL COMPONENTS

A. **Manual Control Switches:**

1. Shall be UL listed for use in NEMA 1 enclosures with contact arrangement and rating suitable for the application

2. Shall be bat handle or knob actuator with nameplate clearly identifying function of each switch position.

B. **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, or equal.

C. **Low Temperature Detector ('Freezestat') (FZ)**:

1. Shall be DPDT (4-wire, 2-circuit) with manual reset.
2. 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).
3. Temperature range 15 to 55°F (-9.4 to 12.8°C), factory set at 38°F.
4. Provide junction box for wiring connections and gasket to prevent air leakage or vibration.

D. **Thermostats:**

1. Thermostats shall have SPDT contacts, switching at an adjustable setpoint with a range of 55 to 85°F
2. Provide separate heating and cooling setpoints with an adjustable deadband
3. Provide automatic heating/cooling changeover.
4. Provide a fan on/off switch for thermostats utilized with fan-coil units.
5. Provide lockable metal guards for all thermostats located in public areas such as lobbies, corridors, lecture halls, gymnasiums, etc.

E. **Aquastats**: Shall be UL listed bi-metal insertion type, manual reset, with contact arrangement and rating as required by application and separable well for water service. Provide with set point limit stops as follows:

1. High limit (hot water) - 220°F maximum
2. Low limit (freeze protection) - 35°F minimum

F. **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 or approved equal.

2. 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 or approved equal.

3. 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.

4. All safety circuits shall be installed to operate individual interposing relays located in the associated equipment control panel. Each safety device (i.e. Freezestat, DP safety, smoke detector, etc.) wiring circuit shall be installed with individual homeruns back to the associated control panel.

G. **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 have replaceable fuses in accordance with the NEC. Transformer shall be properly sized for application, and mounted in minimum NEMA 1 enclosure.

1. Transformers shall be manufactured by Westinghouse, Square ‘D’, or Jefferson.

H. **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 or approved equal.

I. **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 or approved equal.

J. **Alarm Horn**: Panel-mounted audible alarm horn shall be continuous tone, 120 Vac Sonalert solid-state electronic signal, as manufactured by Mallory or approved equal.

K. **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 or approved equal.

5.28 REFRIGERANT MONITOR (WHERE REQUIRED)

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 refrigerants used in chiller equipment installed. The alarm system shall comply with the latest edition of ANSI/ASHRAE 15 and local code requirements and include an alarm light, horn, local digital LED readout. The horn sound level shall be 65 dB or less.

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 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 the latest editions of ANSI/ASHRAE 15 and ASHRAE 34. 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 the latest editions of ANSI/ASHRAE 15 and ASHRAE 34 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 alarm level shall detect the presence of refrigerant approaching dangerous concentrations and energize a relay to signal a intermediate 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

3. ALARM LEVEL THREE - 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.

4. FAULT ALARM – Reports a high level alarm to the BAS operator terminal(s) that there is a fault in the refrigerant monitoring alarm system.

5.29 OXYGEN DEPRIVATION, CARBON DIOXIDE, CARBON MONOXIDE OR NITROGEN DIOXIDE (DIESEL) MONITOR:

A. Design Standard Manufacturer: Honeywell E3Point.

B. General: Wall mounted, polycarbonate enclosure, UL Classified and CSA certified with multi-channel microprocessor-based controller gas monitoring system.

C. Provide visual three-digit display of concentration on front of sensor panel. Alarm shall be silenced by pressing button on wall in vicinity of room. Provide a single calibration kit.

D. Performance:

1. Sensor Power 17 – 27 Vac, 20 – 38Vdc.

2. Relay Output 1 DPDT relay, 5A @ 250Vac; 5A @ 30Vdc.

3. Accuracy: +/-3% of full scale.

4. Range: as required for application. Review with vendor (By Volume).

5. Sensor Life Two Year minimum

6. Communications: BACnet MS-TP

5.30 IDENTIFICATION

A. All control equipment shall be clearly identified by control shop drawing designation as follows:

1. Control valves and damper actuators - brass tags or engraved bakelite tags

2. Other remote control devices - metal tags or laser printed, adhesive backed, metalized polyester film labels

3. Control Panels - engraved nameplate with panel number and system served

4. Number-code or color-code electrical conductors and instrument tubing, excluding those used for individual zone controls. Reflect this tagging or color-coding system on the Project Record Documents

5. Panel Identification. All local control panels shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.

6. Field Devices. All field devices shall be identified by a typed (not handwritten) securely attached tag label

7. Panel Devices. All panel devices shall be identified by a typed label securely fastened to the back plane of the local control panel

5.31 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 VI. EXECUTION

6.01 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 FCPS.

6.02 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 the latest edition of the National Electrical 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. During the bid phase, contractor shall inspect the wiring at representative locations such as at panels and at field devices. Contractor shall assess the type and size and determine adequacy. During the Construction period, Contractor shall inspect and test the wiring and identify any deficiencies. Deficiencies shall be corrected outside the scope of the existing contract.

1. Where extensions are required to existing systems, extend wiring in kind.

a) Exception: Where extension would require splicing of any wiring new wire shall be pulled.

2. For New Systems or branches:

a) Wiring System: Install complete wiring system for electric control systems. Wiring shall be run in EMT conduit for all mechanical rooms, vertical risers, research/laboratory spaces and horizontal runs in exposed ceilings. All other wiring installations shall be concealed except in 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 26 of this Specification. Fasten flexible conductors bridging cabinets and doors, neatly along hinge side, and protect against abrasion. Tie and support conductors every 24 inches, fasten to the structure every 6 feet in a workman like manner to avoid a

conflict with electrical or HVAC installations. Provide pull wire through each conduit installed under this section for future use. Any conduit run inside equipment exposed to outside air conditions shall be sealed tight / weather tight conduit.

b) Control Wiring Conductors: Install control wiring conductors, without splices between terminal points, color-coded. Install in neat, skilful manner, securely fastened. Install in accordance with National Electrical Code.

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 CU end only, unless otherwise recommended by the CU manufacturer.
4. Primary LAN Communication wiring shield shall be terminated as recommended by CU manufacturer.
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, inaccessible locations. Contractor will be fully responsible for noise immunity and rewire with conduit if electrical or RF noise affects performance.

a) Communication and signal wiring may be run without conduit above suspended ceilings provided it is 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. Wiring shall not be laid on the ceiling or duct. Communication wiring shall not be run in the same conduit with other wiring.

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. Temperature Sensor/Thermostat Locations: All room sensors and thermostats shall be mounted 4'-2" above finished floor unless otherwise noted on the drawings.

E. Outside Air Temperature/Humidity Sensors: An aspirated weatherproof and vandal proof enclosure shall be provided for outside air temperature and humidity sensors. These shall be mounted high on a north-facing exposure, clear from any undesirable influence (air intake, exhaust, heat source, etc.).

F. **Averaging Temperature Sensors**: Cover no more than three square feet per linear foot of sensor. The sensor shall be installed according to manufacturer's recommendation and looped and fastened at a minimum of every 36 inches.

G. **Low Temperature Detector ('Freezestat') (FZ)**: Cover no more than one square foot per linear foot of sensor. The sensor shall be installed according to manufacturer's recommendation and looped and fastened at a minimum of every 36 inches.

H. **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.

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

J. **Relative Humidity Sensors**:

1. Provide element guard as recommended by manufacturer for duct probes in high velocity installations.

2. Duct mounted sensors shall be mounted a minimum of 20 duct diameters downstream of any type of humidifiers or evaporative cooling equipment.

3. Provide lockable metal guards for all sensors located in public areas.

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

L. **Flow Switches**: Where possible, install in a straight run of pipe at least 15 diameters in length to minimize false indications. Install per manufacturers recommendations.

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

N. **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 static 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.

O. **Cutting and Patching Insulation**: Repair insulation (ductwork or piping, as applicable) 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.

P. **Test Ports:** Provide test ports in ductwork at each temperature and humidity sensor location to facilitate sensor calibration. Test ports shall be 3/4" diameter

minimum and accessible via a 2” x 4” junction box with insulated cover. Provide a test port for all pressure points in pipe work.

6.03 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

C. Install strobe/horn assembly with identifying placard outside MER door.

END OF SECTION 230901

SECTION 230902 - BAS OPERATOR INTERFACES

PART VII. GENERAL

7.01 RELATED DOCUMENTS

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230903 - BAS Field Panels

D. Section 230904 - BAS Communication Devices

E. Section 230905 - BAS Software and Programming

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

7.02 DESCRIPTION OF WORK

A. Furnish and install all Operator Interfaces as required for the BAS functions specified.

B. Refer to Section 230900 for general requirements.

PART VIII. PRODUCTS

8.01 PORTABLE OPERATOR TERMINAL (POT)

A. Portable Operator Terminal shall support system management by connection to the controllers or by connection via the Internet while serving as the remote workstation.

B. Provide one notebook personal computer (PC) that meets or exceeds the minimum requirements of the BAS software and meets or exceeds the minimum requirements of the Institution. The make and model of notebook PC shall comply with FCPS's current standards for notebook personal computers as of the date of contract completion. Contact FCPS for current computer hardware standards.

C. Provide software, graphics and programming as specified in Section 230905.

D. Provide additional hardware, video drivers, serial ports, etc., to facilitate all control functions and software requirements specified for the building automation system.

E. Provide all controller configuration and interface software and/or plug-ins for all devices applicable. All shall be loaded and functional. Provide all required interface cables required to connect to all networks, routers, controllers, SDs etc.

F. Wherever a POT connection point is not provided accessible in the same room as the device controlled, contractor shall provide a wireless system to permit configuration, testing and operation from within the room. Wireless system shall have the range to reliably communicate with the most remote room

G. Include licensing for all software packages. BAS licensing for this POT shall allow unlimited access to all aspects of the any manufacturer's system including system access, workstations, points, programming, database management, graphics etc. No restrictions shall be placed on the license. 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 FCPS.

8.02 CONTROL SYSTEM SERVER (CSS)

A. This shall be a computer that maintains the system configuration and programming database. 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.

B. For projects where a separate CSS is required, and one or more OWS is required, the CSS may be used in place of one OWS.

C. Provide server computer that meets or exceeds the minimum requirements of the BAS software and meets or exceeds the minimum requirements of the institution. The make and model of the server shall comply with FCPS's current standards for server computers as of the date of contract completion. Contact FCPS for current computer hardware standards.

D. Provide a monitor that complies with FCPS's current standards for desktop personal computers as of the date of contract completion. Contact FCPS for current computer hardware standards.

E. Provide detachable keyboard with standard typewriter layout, function keys, and separate numeric keypad. Provide an optical mouse and mouse pad with the system. Provide one open serial port after configuration of the workstation to meet the requirements of the rest of these specifications.

F. Provide an uninterruptible power supply system providing battery backup for each operator workstation and peripheral devices. UPS shall protect against blackouts, brownouts, surges and noise. UPS shall include LAN port and modem line surge protection. UPS shall be sized for a 7-minute full load runtime, 23-minute ½ load runtime, with a typical runtime of up to 60 minutes. Transfer time shall be 2-4 milliseconds. UPS shall provide a 480-joule suppression rating and current suppression protection for 36,000 amps and provide 90% recharge capability in 2-4 hours. Suppression response time shall be instantaneous. UPS low voltage switching shall occur when supply voltage is less than 94 volts. UPS shall be

provided with modem surge suppression and LAN port connections. Provide all software, cables, peripherals etc. for a complete system.

G. Provide network configuration tool, all programming applications, graphic creation tools and all other software required to configure and operate the system.

H. For CSSs that provide web services for presentation of data across the Internet, all Web components and services shall be installed with required licensing. CSS shall be configured to secure it to the extent practical inside the Local Supervisory LAN. CSS shall always function from behind a firewall provided either by the government network administrators in the case where they provide the LAN infrastructure, or by this contractor where the LAN is provided under this Division of the specifications.

I. Provide network card approved by BAS manufacturer to support Supervisory LAN communications (100 Mbps Ethernet TCP/IP)

J. Provide additional hardware, video drivers, etc., to facilitate all control functions and software requirements specified for the BAS.

K. Provide network card approved by BAS manufacturer to support Supervisory LAN communications (100 Mbps Ethernet TCP/IP)

L. Provide additional hardware, video drivers, etc., to facilitate all control functions and software requirements specified for the BAS.

8.03 ZONE OVERRIDE PANEL

A. Provide a zone override panel located as shown on the drawings. Panel shall include override timers (One for each control zone as shown on the control zone diagram on the mechanical drawings) mounted within the zones on the control zone graphic. The graphic shall show the outline of the entire school with multiple floors shown separately. The Contractor shall provide the size and/or number of panels necessary to include all zones and timers. The control zones, as shown on the drawings, shall be delineated with each zone shown in a different color. The number of each zone shall be shown in its respective areas and the graphic shall be titled "CONTROL ZONES". The graphic shall be made of vinyl with minimum dimensions of 20" x 20” laminated on the face of the panel, and shall be made by a firm specializing in this type of work. Provide shop drawings on this graphic with the automatic temperature control diagram.

B. Provide the necessary software to override each Equipment Zone by override timer. The program shall permit operator selection of zones and shall enable all related equipment for that particular zone. The program shall index the selected zone to the “Occupied” mode in one-hour increments for a period of up to six hours in the override condition. Once overridden, the zone equipment, including interlocked exhaust fans, shall operate in the “Occupied” mode.

PART IX. EXECUTION

9.01 INSTALLATION

A. Set up workstations as indicated. Install all software and peripheral devices. Verify that the systems are fully operational.

B. Ensure licensing is provided for all software. No license, software component, key, etc or any piece of information required for installing, configuring, operating, diagnosing and maintaining the system shall be withheld from FCPS.

C. Install electronic BAS O&M manuals, programming guides, network configuration tools, control shop drawings, etc. on each OWS and CSS.

D. Set up portable operator terminal and configure it as the remote workstation. Install all software and verify that the system is fully operational.

E. Install systems and materials in accordance with manufacturer's instructions.

END OF SECTION 230902

SECTION 230903 - BAS FIELD PANELS

PART X. GENERAL

10.01 RELATED DOCUMENTS:

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230902 - BAS Operator Interfaces

D. Section 230904 - BAS Communication Devices

E. Section 230905 - BAS Software and Programming

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

10.02 DESCRIPTION OF WORK:

A. Furnish and install DDC Control units required to support specified BAS functions.

B. Refer to Section 230900 for general requirements.

PART XI. PRODUCTS

11.01 GENERAL REQUIREMENTS

A. Provide Building Controllers (BC), Advanced Application Controllers (AAC), and Application Specific Controllers (ASC) as required to achieve performance specified in this and related documents.

B. All controller hardware shall be suitable for anticipated ambient conditions. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -20 to 140°F. Controllers used in conditioned spaces shall be mounted in dust-protective enclosures and shall be rated for operation at 32 to 120°F.

C. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

11.02 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. The BAS Contractor shall comply with Section 230900 to select the appropriate controllers.

B. **Functional Boundary**: Provide controllers so that all points associated with and common to one unit or complete system/equipment shall reside within a single control unit. The boundaries of a standalone system shall be as dictated in the contract documents. 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. 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, with the exception of multizone AHUs.

11.03 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 permit multi-user operation from multiple workstations and portable operator terminals connected either locally or over the Primary Controller LAN. 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 an operator workstation, portable operator terminal, or hand held operating 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 Primary Controlling LAN.

4. All BCs shall be protected from any memory loss due to a loss of power by one or a combination of the following:

a) Volatile RAM shall have a battery backup using a lithium battery with a rated service life of fifty (50) hours, and a rated shelf life of at least five years. Self-diagnostic routine shall report an alarm for a low battery condition.

b) EEPROM, EPROM, or NOVROM non-volatile memory

5. In addition, BCs shall provide intelligent, standalone control of HVAC functions. Each BC shall 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 shall 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 Operator Workstation.

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 OWS and/or 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. **BC Input-Output Processing**:

a) Multiplexing of IO Points Unacceptable: Each input and output shall be a discrete input or out put on the BC controller board. The use of supplementary input or output multiplexing boards, or any configuration that combines multiple inputs or outputs into a single point on the controller, is not acceptable.

b) 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. Provide feedback to remotely indicate the HOA is not in the Auto position. If these HOA switches are not provided on the main board they shall be provided via isolation relays within the control enclosure. Provide suppression to limit transients to acceptable levels.

c) 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. A/D converters shall have a minimum resolution of 10 bits.

d) 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.

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

f) 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.

g) 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 terminal shall be provided in each BC. It shall be possible to perform all program and database back-up, system monitoring, control functions, and BC diagnostics through this port. Standalone BC panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or workstations.

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

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 primary controlling network 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. Controller firmware shall always be maintained utilizing flash memory.

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, and connected computer. The system 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 from the operator workstation via the local area network, or the local communications port automatically and manually.

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 last value or a specified value. Peer BCs shall recognize the loss, report alarm and reconfigure the LAN.

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 LAN communications interface functions for controlling secondary controlling LANs Refer to Section 230904 - BAS System Communications Devices for requirements if this function is packaged with the BC.

22. Include multi-level user access control, password protected. At highest level of access, allow operator to select overrides and change database.

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

24. In the last month of the warranty period, all controller firmware, software, drivers, etc. will be upgraded to the latest release (version) in effect at the end of the Warranty Period.

B. **BACnet Building Controller Requirements**:

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

2. BCs shall be connected to and communicate over the Primary Controller LAN.

11.04 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, LAN Interface Device or workstation, any malfunctions or abnormal conditions within the AAC /ASC or alarm conditions of inputs that exceed desired parameters as determined by programming input.

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 five years.

5. All point data, algorithms and application software within an AAC /ASC shall be modifiable from the Operator Workstation.

6. In the last month of the warranty period, all controller firmware, software, drivers, etc. will be upgraded to the latest release (version) in effect at the end of the Warranty Period.

7. AAC and ASC Input-Output Processing:

a) Multiplexing of IO Points Unacceptable: Each input and output shall be a discrete input or out put on the AAC/ASC board. The use of supplementary input or output multiplexing boards, or any configuration that combines multiple inputs or outputs into a single point on the controller, is not acceptable.

b) 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. Provide feedback to remotely indicate the HOA is not in the Auto position. If these HOA switches are not provided on the main board they shall be provided via isolation relays within the control enclosure. Provide suppression to limit transients to acceptable levels.

c) 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. A/D converters shall have a minimum resolution of 10 bits.

d) 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 AAC/ASC and shall be isolated from the main board.

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

f) 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.

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

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 be connected to and communicate over the Primary Controller LAN or the Secondary shall be connected to and communicate over the Primary Controller LAN.

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. When possible the controllers shall perform this function when the supply or exhaust air system is not operating or is unoccupied.

PART XII. EXECUTION

12.01 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.

12.02 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

B. **Mounting**: All controllers shall be mounted in control panels as defined in Section 15951. One exception exists for VAV/CAV box controllers: Section 15953 contractor may furnish ASCs to the terminal unit manufacturer for factory mounting.

12.03 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 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**

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 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**

1. Applications in this category include the following:

a) Fan Coil Units

b) Airflow Control Boxes (VAV and Constant Volume Terminal Units)

c) Unit Ventilators

d) Duct-mounted hot water coils

e) Finned-tube radiation

f) Space Temperature Monitoring

g) Unitary equipment <15 tons (Package Terminal AC Units, Package Terminal Heat Pumps, Split-System AC Units, Split-System Heat Pumps, Water-Source Heat Pumps)

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	Occupied
Morning Warm-Up	Off (cold discharge air)

Summer/Winter	Winter
Trend Data	N/A

4. **LAN Restrictions**: For networks operating at 38.4 kbps or less, limit the number of nodes on the LAN to meet all system performance criteria and to no more than 80% of the maximum recommended by the manufacturer. For networks operating at greater than 38.4 kbps limit the number of nodes on the network to meet all system performance criteria up to the maximum recommended by the manufacturer.

F. **Application Category 2**

1. Applications in this category include the following:

a) Misc. Equipment (Exhaust Fan) Start/Stop

b) Misc. Monitoring (not directly associated with a control sequence and where trending is not critical)

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 AACs/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

5. **LAN Restrictions**: Limit the number of nodes servicing any one of these applications on the Secondary Controller LAN to 32.

G. **Application Category 3**

1. Applications in this category include the following:

a) Chillers

b) Cooling Towers

c) Free Cooling Heat Exchanger

d) Heating Plant

e) Sequenced or Variable Speed Pump Control

f) Rooftop Units (RTUs)

g) Split-System AC Units

h) Heat Pumps (HPs)

i) Constant Volume Air Handlers

j) VAV Air Handlers

k) Critical Monitoring (power monitoring/trending, emergency generators, etc.)

2. BCs shall be used in these applications.

3. **LAN Restrictions**: Comply with 2.02, Stand-Alone Functionality, above.

12.04 CONTROL UNIT REQUIREMENTS

A. Refer to Section 230900 for requirements pertaining to control unit quantity and location.

12.05 CONTROL MODULE INSTALLATION

A. **Building Controller (BC)**:

1. The BAS Contractor shall follow the specifications shown in the manufacturer's hardware installation guide unless stated otherwise herein.
2. Ensure proper shield grounding is applied on any RS485 connections, proper network repeaters are installed if necessary or any other network devices required to achieve the required network performance metric stated in paragraph 3.04.
3. Refer to Section 230900 for power supply requirements. Power shall enter the control panel at an internal junction box that includes a standard receptacle and switch for panel power.

B. **Field Bus Controllers (AAC/ASC)**:

1. The BAS Contractor shall follow the specifications shown in the manufacturer's hardware installation guide unless stated otherwise herein.

2. Controller Power shall have a separate disconnect (or fuse) for each controller.
3. All digital outputs must be equipped with a relay rated to manage the connected load.
4. Only two pair (incoming & outgoing) communication wires shall be connected to the communication terminal on the controller. (No “star” network configurations)

C. **Expansion Modules**:

1. The BAS Contractor shall follow the specifications shown in the manufacturer’s hardware installation guide unless stated otherwise herein.
2. No expansion device shall be used that does not represent itself as a unique physical device within the BAS System Profile.

END OF SECTION 230903

SECTION 230904 – BAS COMMUNICATION DEVICES

PART XIII. GENERAL

13.01 RELATED DOCUMENTS:

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230902 - BAS Operator Interfaces

D. Section 230903 - BAS Field Panels

E. Section 230905 - BAS Software and Programming

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

13.02 DESCRIPTION OF WORK

A. Contractor shall provide all interface devices and software to provide an integrated system connecting BCs, AACs, ASCs and Gateways to FCPS's Wide Area Network (FCPS WAN).

B. Refer to Section 230900, paragraph 2.04 for general requirements connecting third party control sub-systems to the BAS. This would include Power Monitor, Gas Meter, Water Meter, etc.

PART XIV. PRODUCTS

14.01 NETWORK CONNECTION

A. **FCPS WAN**: Internet-based network connecting multiple facilities, accessible via standard web-browser. This is an existing infrastructure and Contractor is not required to configure any components of this WAN. Contractor is however required to provide data and services at the Supervisory LAN via BACnet over IP to the FCPS WAN.

B. **Supervisory LAN**: The Supervisory LAN is an extension of the FCPS WAN. Contractor will be provided specific ports dedicated for control module/interface device connectivity. The LAN is IEEE 802.3 compliant with switches and routers that support 100 Mbps minimum throughput. Contractor may not extend this network without prior approval from FCPS. Refer to Section 230900 for additional requirements.

14.02 SUPERVISORY LAN INTERFACE DEVICE (LANID)

A. The LANID shall be a BC that acts as a gateway/router between the Supervisory LAN CSSs and the Primary LAN.

B. The LANID shall perform information translation between the Primary LAN and the Supervisory LAN, which is 100 Mbps Ethernet TCP/IP and shall use BACnet over IP.

C. The LANID shall contain its own microprocessor, RAM, battery, real-time clock, communication ports, and power supply as specified for a BC in Section 230903. Each gateway shall be mounted in a lockable enclosure.

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

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

14.03 CONTROL SUB-SYSTEM INTEGRATION

A. The LANID shall perform information translation between the Primary LAN, or the Supervisory LAN, and the Installer-Provided Control Sub-System.

B. The LANID and the Installer-Provided Control Sub-System shall use the agreed upon communication protocol required to connect the control sub-system to the BAS. This protocol shall be agreed upon and as defined in Section 230900.

C. The LANID and the Installer-Provided Control Sub-System shall support full bi-directional communication translation as defined by the applicable protocol implementation specification as defined in Section 230900.

D. The Installer-Provided Control Sub-System shall provide all objects, points, variables and any other configuration parameters defined by its protocol implementation conformance specification without any added network protocol

translation devices other than the BAS BC and its own control sub-system components.

PART XV. EXECUTION

15.01 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.

15.02 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. BAS Contractor shall provide leadership as the Integration Coordinator for all Installer-Provided Control Sub-Systems. Contractor to coordinate work progress per Section 230900.

C. BAS Contractor shall coordinate and supervise all interface devices and software to provide an integrated system.

D. Contractor shall closely coordinate with FCPS, or designated representative, to establish IP addresses and communications to assure proper operation of the building control system with the FCPS WAN.

END OF SECTION 230904

SECTION 230905 - BAS SOFTWARE AND PROGRAMMING

PART XVI. GENERAL

16.01 RELATED DOCUMENTS:

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230903 - BAS Field Panels

D. Section 230903 - BAS Field Panels

E. Section 230904 - BAS Communication Devices

F. Section 230993 - Sequences of Operation

G. Section 230995 - BAS Commissioning

16.02 DESCRIPTION OF WORK:

A. Fully configure systems and furnish and install all software and programming defined herein for a complete and fully functioning system as specified.

B. Refer to Section 230900 for general requirements and definitions.

C. Refer to Section 230993 - Sequences of Operation and the control drawings for detailed sequences for controlled equipment.

16.03 LICENSING

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

B. Provide or upgrade all licensing for all software packages at all required workstations. BAS licensing shall allow unlimited simultaneous users for access to all aspects of the system including system access, workstations, points, programming, database management, graphics etc. No restrictions shall be placed on the licensing. All operator interfaces, 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 FCPS. All engineering software shall be provided and installed on a separate FCPS laptop or downloaded to the server.

C. All software should be available on all CSSs, OWSs, and POTs. This includes the permanent installation of any hardware or software keys necessary to provide complete system access.

D. Provide licensing and original software copies for each CSS, OWS, or POT. Include all licensing for workstation operating systems, 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.

PART XVII. PRODUCTS

17.01 SYSTEM SOFTWARE-GENERAL

A. **Functionality and Completeness**: The BAS Contractor shall furnish and install all software and programming necessary to provide a complete and functioning system as specified. The BAS 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. **Online Help**: The software shall support online, context-sensitive help, including an index, glossary of terms, and the capability to search help via keyword or phrase at each workstation user interface.

C. All application software shall be user programmable based upon user access control privileges.

17.02 CONTROLLER SOFTWARE

A. **BC Software Residency**: Each BC as defined below shall be capable of control 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. Distributed Network Interface Communications software

B. **AAC/ASC Software Residency**: Each AAC/ASC as defined below shall be capable of control 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 230904) with the restrictions/exceptions per application provided in Section 230903:

1. Real-Time Operating System software

2. AAC/ASC diagnostic software

3. LAN Communication 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. **Stand Alone Capability**: BC shall continue to perform all functions independent of a failure in other BC/AAC/ASC or other communication links to other BCs/AACs/ASCs. 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 230903 for other aspects of stand-alone 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.

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. Primary LAN shall be a 100MB IEEE 802.3 Ethernet network designed and optimized for control system communication. If a Primary LAN communications trunk is severed, BCs shall reconfigure into two separate LANs and continue operations without interruption or Operator intervention.

2. Controller communication software shall include error detection, correction, and re-transmission to ensure data integrity.

3. Operator/System communication software shall facilitate communications between other BCs, all subordinate AACs/ASCs, Gateways and LAN Interface Devices or Operator Workstations. Software shall allow point interrogation, adjustment, addition/deletion, and programming while the controller is on line 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. **Point Database/Summary Table**: All points included in the typical equipment point list must be represented the FCPS WAN in a common, open protocol format. Naming conventions for these points and network addressing are discussed in Part III of this section. Point/system database creation and modification shall be via a user-friendly, menu-driven program. System software shall support virtual or logic point (points not representing a physical I/O) creation. Software shall support virtual points with all services specified herein. Database software shall support definition of all parameters specified in Part III of this section for a given point type. If database does not support all these parameters software module shall be created and attached to the points which accomplish the respective function.

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

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

I. **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) programming by FCPS, or their designated representative.
2. Line programs shall supply preprogrammed functions to support these energy management and functional block application algorithms.
3. All functions shall be provided with printed narratives and/or flow diagrams to document algorithms and how to modify and use them.

J. **Security**: Controller software shall support multiple level password access restriction as more fully specified below.

K. **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. Boolean Logical Operators
8. Mathematical Operators, Trigonometric Operators

L. **Psychrometric Parameters**: Where required, controller software shall provide preprogrammed functions in accordance with the current edition of ASHRAE "Handbook of Fundamentals", to calculate and report psychometric parameters (given temperature and relative humidity) including the following as a minimum: Enthalpy, Wet Bulb Temperature, Humidity Ratio, Dew Point, and Specific Volume.

M. **Updating/Storing Application Data**: Site-specific programming residing in volatile memory shall be uploadable/downloadable from an OWS or CSS connected locally, to the Primary LAN, to the Supervisory LAN and remotely via

the internet. Initiation of an upload or download shall occur either manually or automatically upon detection of a loss or change.

N. **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 (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.

O. **Time Synchronization**: 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. Automatic time synchronization shall be provided.

P. **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.

Q. **PID Loop Tuning**: Contractor shall provide a software tool for tuning PID loops. This tool shall preferably be provided as an integral part of the system software or graphic software package. Loop response trends shall be used to calculate suggested P, I, and D gains in the units used in the manufacturers PID algorithms. The following are acceptable:

1. Manual Tuning that accepts either automatic or manual amplitude and response time inputs and calculates PID gains for automatic or manual entry into control module.
2. Self-tuning algorithm that periodically upsets the process and automatically adjusts the PID gains.
3. Adaptive Tuning that continuously monitors natural disturbances in the process and adjusts the PID gains accordingly. This algorithm must include a user definable noise band to inhibit adjustments.

17.03 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.

4. **Line Programming**: Text programming in a language similar to BASIC or FORTRAN designed specifically for HVAC control. Subroutines or functions for energy management applications, setpoints, and adjustable parameters shall be customizable, but shall be provided pre-programmed and documented.

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

17.04 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. Lighting/Occupancy Control
10. Dead Band Control
11. Instantaneous kW and Daily, Monthly and Yearly kWh values
12. Instantaneous gas consumption and Daily, Monthly and Yearly gas consumption values
13. Instantaneous water consumption and Daily, Monthly and Yearly water consumption values

B. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization.

17.05 PASSWORD PROTECTION

A. Multiple-level password access protection shall be provided to allow FCPS' authorized BAS Administrator to limit workstation control, display and database manipulation capabilities as deemed appropriate for each authorized user, based upon an assigned user name with a unique password.

B. All passwords for the system shall be provided to FCPS including administrator, dealer, or factory level passwords for the systems provided under this project.

C. Passwords shall restrict access to all Control Units.

D. Each user name shall be assigned to a discrete access level. A minimum of five levels of access shall be supported. Alternately, a comprehensive list of accessibility/functionality items shall be provided, to be enabled or disabled for each user.

E. A minimum of 250 user names shall be supported per FCPS's direction.

F. Operators shall be able to perform only those commands available for the access level assigned to their user name.

G. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving interface device software on-line.

17.06 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. SMS and email notification shall also be supported. The CSS 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 Operator Workstation or local handheld device, or by communications with other panels on the network. All alarms and events shall be routable to all Operator Workstations.

1. **Alarm Descriptor**: Each alarm or point change shall include that point's English language description, and the time and date of occurrence. Provide alarm descriptors tailored for the alarm by building, system type and device type (i.e. "Building 1, AHU-1 High Discharge Air Temperature"). 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 alarm classes. For each alarm class, 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 alarm class. Alarm classes are defined as follows:

a) Default Alarms - All Device Communications Alarms

b) Plant Alarms - All alarms related to the Central Plants

c) Unit Alarms – All alarms related to AHU and FCU operation including Fan Failures, Low Limit Alarms, and Smoke Alarms

d) Temp Alarms - All Zone Temperature alarms

e) Critical Alarms – All Critical alarms as defined below in paragraph 3.07/D

3. **Alarm Acknowledgment**: For alarm classes that are directed to a workstation screen, an indication of alarm receipt shall be displayed immediately regardless of the application in use at the workstation, and shall remain on the screen until acknowledged by a user having a password that allows alarm acknowledgment. Upon acknowledgment, the complete alarm message string (including date, time, and user name of acknowledging operator) shall be stored in the CSS database.

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 event algorithm (e.g., change of value, change of state, out of range, and so on); alarm priority; and notification class.

17.07 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 point and virtual points used in any control algorithm. Analog points/values shall be trended at 10 minute intervals. Digital points/values shall be trended based on a change of state.

2. BACnet Trend Objects are required and all 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 symbols. Displayed trend graphs shall indicate the engineering units for each trended value.

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 CUs, and uploaded to CSS storage when archival is desired. All archived trends shall be

transmitted to the CSS as applicable. 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 devices supporting time synchronization. All trend sample times shall be able to be synchronized. The frequency of time synchronization message transmission shall be selectable by the operator.

17.08 DYNAMIC PLOTTING

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

17.09 DATA ACQUISITION AND STORAGE

A. All points included in the typical equipment point list must be represented in a common, open or accessible format. Naming conventions for these points and network addressing are discussed in the 'Point Naming Conventions' paragraph below.

B. 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.

17.10 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.

17.11 EQUIPMENT SCHEDULING

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

B. Scheduling feature shall include multiple day occupancy schedules, holiday schedules and override schedules, each with start time and stop time. Schedules shall be individually editable for each day and holiday.

C. Scheduling feature shall allow for schedules to be applied to zones only.

D. Schedules shall be hierarchical allowing all devices/systems below a given device/system to follow the same schedule.

E. Timed override feature shall allow an operator to temporarily change the state of scheduled zones. An override command shall be selectable to apply to an individual zone. 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 password 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.

17.12 POINT STRUCTURING AND NAMING

Provide a consistent means of naming points across the FCPS WAN. Contractor shall configure the systems from the perspective of the FCPS WAN, not solely the local project. Consult FCPS for desired point naming convention.

17.13 GRAPHIC SOFTWARE

A. Graphic software shall facilitate user-friendly interface to all aspects of the System Software specified above. Provide 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. Context sensitive help shall be provided within the user interface via a ‘help’ function.

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

C. Graphic software shall provide for multitasking such that third-party programs can be used while the OWS software is on line. Software shall provide the ability to alarm graphically even when operator is in another software package.

D. The software shall allow for FCPS (or designated representative) 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 the mouse.

E. **Screen Penetration**: The operator interface shall allow users to access the various system graphic screens via a graphical penetration scheme by using the mouse 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.

F. **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.

G. **Point Override Feature**: Each displayed point shall be individually enabled/disabled to allow mouse-driven override of digital points or changing of analog points. Such overrides or changes shall occur in the control unit, not just in the workstation software. The graphic point override feature shall be subject to password level protection. A list of points that are currently in an override state shall be available through menu selection.

H. **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 BAS Contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g. fans, cooling coils, filters, dampers, etc.), electro-mechanical system components (e.g., pumps, chillers, cooling towers, boilers, etc.), complete electro-mechanical systems (e.g. constant volume-terminal reheat, VAV, etc.) and electrical symbols.

2. The BAS Contractor shall provide libraries of pre-engineered charting and graphical display objects that can represent reporting output. Such Enhanced Graphical objects must be standard and free to use by all users.

3. The Graphic Development Package shall use a mouse or similar 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.

PART XVIII. EXECUTION

18.01 SYSTEM CONFIGURATION

A. Contractor shall thoroughly and completely configure BAS system software, supplemental software, network communications, CSSs, OWSs, and POTs.

18.02 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. The BAS 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 BAS Contractor's responsibility to request clarification on sequence issues that are unclear or subject to interpretation.

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 FCPS and shall remain on the workstation(s)/server(s) at the completion of the project.

18.03 PASSWORD SETUP

A. Set up the following password levels to include the specified capabilities (FCPS staff will assign users to the desired password levels):

1. Level 1:

a) Level 2 capabilities

b) View, add, change and delete user names, passwords, password levels

c) All unrestricted system capabilities including all network management functions.

2. Level 2:

a) Level 3 capabilities

b) Configure system software

c) Modify control unit programs

d) Modify graphic software

e) Essentially unrestricted except for viewing or modifying user names, passwords, password levels

3. Level 3:

a) Level 4 capabilities

b) Override output points

c) Change setpoints

d) Change equipment schedules

e) Exit BAS software to use third party programs

4. Level 4:

a) Level 5 capabilities

b) Build Reports

c) Acknowledge alarms

d) Temporarily override equipment schedules

5. Level 5:

a) Display all graphic data

b) Trend point data

B. Contractor shall assist FCPS's operators with assigning user names, passwords and password levels.

18.04 POINT PARAMETERS

A. Provide the following minimum programming for each analog input:

1. Name

2. Address

3. Engineering units

4. Offset calibration and scaling factor for engineering units

5. High and low alarm values and alarm differentials for return to normal condition

6. High and low value reporting limits (reasonableness values), which shall prevent control logic from using shorted or open circuit values.

7. 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.

8. 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. Engineering units
4. Offset calibration and scaling factor for engineering units
5. Output Range
6. 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. Engineering units (on/off, open/closed, freeze/normal, etc.)
4. Direct or Reverse action selection
5. Minimum on-time
6. Minimum off-time
7. Status association with a DI and failure alarming (as applicable)
8. Reporting of each change of state, and memory storage of the time of the last change of state.

9. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

10. Default value to be used when the normal controlling value is not reporting.

18.05 TRENDS

A. The BAS Contractor shall create, establish and store trend logs for all trend capable hardware points, virtual points and calculated setpoints. At minimum, all the points indicated on corresponding equipment sequence of operation drawings shall be trended.

B. FCPS, or designated representative, 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. The BAS Contractor shall demonstrate functional trends two weeks prior to functional performance testing.

D. The CSS shall be configured and/or upgraded as necessary to provide historical trend archiving for up to one year for all trend capable points on this project.

18.06 TREND GRAPHS

A. Prepare controller and workstation 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 HVAC 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 HVAC subsystem title, date, and times.

18.07 ALARMS

A. **General**: The BAS Contractor will be responsible for setting initial alarm parameters. No reporting actions will be initiated during construction unless directed by FCPS.

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 for 15 minutes (adj.) during the Occupied mode. 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:

a) Low alarm: 3°F below setpoint

b) Low return-to-normal: 2°F below setpoint

c) Low critical alarm: 50°F

d) High alarm: 3°F above setpoint

e) High return-to-normal: 2°F above setpoint.

f) High critical alarm: 90°F

2. Controlled media temperature other than space temperature (e.g. AHU discharge air temperature, condenser water supply, chilled water supply, etc.): (If controlled media temperature setpoint is subject to a reset algorithm, 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:

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 CO2 Level:

a) High alarm: 1200 ppm

b) High return-to-normal: 1000 ppm

C. **Run/Status Conflict Alarm**: The Sequences of Operation are based on the presumption that motor starter Hand-Off-Auto (HOA) switches are in the ‘Auto’ position. If motorized equipment unit starts without a prior start command from the BAS, as sensed by status sensing device, then BAS shall perform the remaining sequence as specified. BAS shall also enunciate the following alarm message if status indicates a unit is operational for 5 minutes when the run command is not present:

1. *DEVICE XXXX* RUN/STATUS CONFLICT: 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.

D. **Critical Alarms**: In addition to the critical alarms noted in the points list (see control drawings), any of the following alarms on any system shall be critical:

1. Building Fire Alarm
2. Building Power Failure
3. Refrigerant leak detection alarm
4. Room temperature below 50°F or greater than 90°F
5. Boiler failure alarm
6. Chiller failure alarm
7.

E. **Power Usage Alarm**: Generate the following alarm when the power consumption exceeds an operator defined threshold by an adjustable value:

1. *BUILDING POWER USAGE*. The power usage is greater than expected.

F. **Communication Failure Alarms**: Generate the following alarm when a controller has lost communication to the BAS for 15 minutes (adj.):

1. *DEVICE XXXX HAS LOST COMMUNICATION*. Communication with this device has failed.

G. **Maintenance Alarms**: Generate the following alarm when runtime accumulation exceeds a value specified by the operator:

1. *DEVICE XXXX REQUIRES MAINTENANCE*. Runtime has exceeded specified value since last reset.

H. See requirements for additional, equipment-specific alarms specified in Section 230993 – Sequences of Operation.

18.08 GRAPHIC SCREENS

A. **General**:

1. All Graphics shall be visible on all OWS displays in full screen mode without the use of scroll bars.
2. All Graphics must have a unique background graphic, except Terminal Equipment Controllers.
3. All Graphics must contain all setpoints for the system represented.
4. All Graphics must contain all physical points comprising the system.
5. All Graphics shall include outside air sensor data.
6. All relevant Graphics shall contain Dynamic Graphical Links to the contract document As-Built mechanical, electrical and complete BAS drawing(s) for the represented system.
7. All Graphics shall display any points that are currently in alarm. All alarm points must be on a graphic.
8. All animated Graphics shall accurately reflect the state of the equipment/device represented.

B. **Floor Plan Graphics:**

1. Clearly display the building name and floorplan name at the top of each individual building floorplan graphic.

2. Provide floor plan screens for each floor, wing, or tower of the building. Indicate the location of all equipment that is not located on the equipment room screens. Indicate all equipment zones with corresponding ON/OFF status. 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. Display the space temperature point adjacent to each temperature sensor symbol. Use a distinct line or symbol to demarcate each terminal unit zone boundary. Use distinct colors to demarcate each air handling unit zone. Indicate room numbers as provided by FCPS. 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

3. 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.

4. 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. The key here is to assure all graphics can be linked to another and found dynamically by viewing a hierarchical tree like structure that contains all graphics in the system.

C. **System Schematic Screens**:

1. Provide graphic system schematic screen for each controlled and monitored System and Sub-System.
2. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc. as applicable.
3. Operator adjustable points shall be adjustable through the graphic interface.
4. General layout of the system shall be schematically correct and in the point of view as if an Operator were standing beside the most important access point for the system as physically installed.
5. 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.
6. Indicate all adjustable setpoints on the applicable system schematic graphic screen or, if space does not allow, on a supplemental linked-setpoint screen.
7. For each sub-system (i.e. VAV box) provide a link to all other systems serving that system (i.e. HW System, VAV AHU). Include pertinent data from the serving system on the sub-system graphic (i.e. VAV AHU supply temperature at VAV box primary air intake).
8. All valve and damper position indicators should read “xxx % open” or “xxx % closed” as applicable.
9. Indicate occupancy status and temperature on each zone level equipment graphic.

END OF SECTION 230905

SECTION 230993 - SEQUENCES OF OPERATION

PART XIX. GENERAL

19.01 RELATED DOCUMENTS

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230902 - BAS Operator Interfaces

D. Section 230903 - BAS Field Panels

E. Section 230904 - BAS Communication Devices

F. Section 230905 - BAS Software and Programming

G. Section 230995 - BAS Commissioning

19.02 SYSTEM DESCRIPTION

A. This Section defines the manner and method by which the controls operate and sequence the controlled equipment. Included in this section are general requirements and logic strategies that expand on the specific sequences shown on the drawings.

B. Refer to the control drawings for specific sequences of operation. Each control drawing includes the following:

1. Design Intent: A brief outline of the purpose and the design engineer's expectations for the system.
2. Detailed Sequence of Operation: References may be made to specific logic strategies defined in this section.
3. Points List: The points list defines the analog and digital inputs and outputs to the BAS:

a) The points list does not identify field interlocks and may show a single Point that controls multiple field devices. Any required interlocks are identified in the written sequence or the controls schematic.

b) The number of field devices controlled shall be determined by the sizes of equipment scheduled on the mechanical drawings and the type of components selected by the BAS Contractor. An example is damper actuators, the points lists will identify a single analog output point, the schematic may show one or two actuators, but the size of the unit and the actuators may dictate that multiple actuators are required.

PART XX. PRODUCTS – NOT USED

PART XXI. EXECUTION

21.01 GENERAL

A. Sequences specified herein and on the drawings 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. Furthermore, logic diagrams provided on the drawings are provided to more fully communicate the intended sequence 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, without providing additional, superfluous sequences that that are not indicated in the logic.

B. All setpoints and control parameters shall be adjustable from any operator interface, without any required re-programming of software code. Room temperature setpoint offset (i.e. warmer/cooler) shall be additionally adjustable at the room sensor. Provide graphical remote lockout of each room sensor setpoint adjustment dial.

C. All control loops shall utilize PID control algorithms unless otherwise specified in the sequence of operation. 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. Safeties:

1. All HVAC safeties shall be hardwired such that the shutdown will occur both in Automatic and Hand modes at the BAS system and the starter. Software safeties are not acceptable. There shall be no latching software faults that would prevent the normal restart of equipment when physical safety devices have been reset.

E. When air handling units are 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
Outside air damper	Closed	Closed
Exhaust air damper	Closed	Closed
Return air damper	Open	Open

Multizone Dampers	Cooling	Cooling or Last Position
HW Valves	Closed	Open
CHW Valves	Closed	Open
Variable Speed Drive	Off	Minimum Speed

F. 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.

G. Where reset action is specified in a sequence of operation, but a reset schedule is not indicated, 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.

For whichever reset strategy is incorporated, provide a summary of reset operation on the associated system graphic. Information displayed shall include: controlled variable value, compensation variable value, reset ranges, etc.

H. 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 Terminal Controller. A Terminal Controller’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 Terminal Controller’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.

I. Where a supply air temperature, duct pressure, or differential water pressure setpoint is specified to be reset by valve or damper position of the zone or 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, pipe or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g. cooling valve, heating valve, damper position) setpoint of 85% open. The reset increment shall be calculated based on the average position of the quantity of the worst (most open valve/damper) zone(s) as specified. The recalculation time, reset increment and control device position influence shall be chosen to maintain the primary variable within the specified maximum allowable variance while minimizing overshoot and settling time. The BAS analog output value shall be acceptable as indicating the position of the control device.

2. Alternatively to continuously calculating the average of the quantity of worst valve/damper positions, a method similar to the one described above may be employed whereby the “need heat” or “need cool” virtual point shall increment by one unit each time a zone’s valve/damper position rises to greater than 95%. The quantity of “need heat” or “need cool” points shall then be the basis for reset.

J. Where “prove operation” of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the BAS, 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 (de-bounce delay) while the device is commanded to run, an alarm shall be enunciated audibly and via an alarm message at the operator interface . 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.

K. 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. Any 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. Phase and Voltage Protection: Where required, BAS shall monitor incoming electrical power to the building. In the event of a 12% or greater deviation from normal voltage over a 30 second period of time, or a phase loss, the BAS shall generate an alarm and provide an indication on all graphic screens. On a phase loss or an increased deviation from normal voltage by an additional 5%, the BAS shall de-energize all 3-phase motors under BAS control. Once sufficient power has been restored continuously for 10 minutes (adjustable) the system shall perform a sequential re-start of scheduled equipment. Heating pumps and boilers placed on emergency power system shall not be de-energized in response to power irregularities

21.02 DEMAND RESPONSE

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

B. Demand limiting shall be manually enabled by the operator (with appropriate password level) at the OWS. Demand limiting shall remain enabled until manually disabled by the operator at the OWS.

C. On a rise in kW to within 200 kW (adj.) of setpoint, an alarm shall be enunciated and BAS shall begin to globally increase cooling setpoints for non-critical zones at a rate of 2°F/hr (maximum change of 6°F). On a fall below 200 kW (adj.) of setpoint, the reverse shall occur.

D. On a rise in kW to within 50 kW (adj.) of setpoint, an additional alarm shall be enunciated.

21.03 AIR HANDLING UNITS – SCHEDULES AND OPERATING MODES

A. **Scheduling Terminology**: When air handlers are scheduled throughout the day, the following defines the terminology used:

1. **Occupied Period**: The period of time when the building is in use and occupied. Exclude all national holidays. Systems will be fully operational throughout this period and ventilation air shall be continuously introduced. Space temperature setpoints will be in their “normal” range.
2. **Unoccupied Period**: The 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. BAS shall provide an enable/disable software point for zone optimum start.
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. Systems will generally be off except to maintain a “setback” temperature.
5. **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 ASHRAE 62. 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**: the BAS shall de-energize 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. 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.

21.04 AIR HANDLING UNITS – LOGIC STRATEGIES

A. **General**: The BAS shall fully control the air handlers per the Schedules and Operating Modes defined above and the Sequences of Operation shown on the control drawings. The specific logic strategies defined here shall be included by reference, if required, from each air handling unit sequence of operation.

B. **Minimum OA Control:** BAS shall maintain minimum ventilation during the occupied period. The following strategies may apply:

1. **Balanced Position**: During the Occupied Mode, 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 TAB contractor on new projects and shall be the previously set value for existing projects. If the AHU 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 AHUs or units with flow tracking return fan controls.

2. **Reset Balanced Position**: During the Occupied Mode, applicable mixing and OA dampers shall never be positioned at 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 CO_2 setpoint of 1000 ppm (adj.). Loop shall be a "sample and bump" or dynamic proportional only loop tuned for slow response. The balancer shall determine the minimum position outputs at both extreme points. This logic strategy is only applicable to constant volume AHUs.
3. **Damper Controlled Fixed**: During the Occupied Mode, 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 A/E. Flow rate shall be determined in any of the following ways as specified for the particular AH:

a) Measured directly by an OA flow station

b) As determined by CO_2 mixing equations using the SA, OA, and RA CO_2 sensors

4. **Damper Controlled Reset**: During the Occupied Mode, 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 CO_2 setpoint of 900 ppm (adj.). Loop shall be a "sample and bump" or dynamic proportional only loop tuned for 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 AHU:

a) Measured directly by an OA flow station

b) As determined by CO_2 mixing equations using the SA, OA, and RA CO_2 sensors

5. **Mixed Air Temperature Control**: Minimum position of the OA damper shall be set to obtain the design required minimum OA. This balanced minimum position shall remain fixed. Whenever the minimum loop is active BAS shall control the dampers to maintain a mixed air temperature setpoint which will be 2°F below discharge air temperature cooling setpoint (adj.).
6. **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 the 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.

C. **VAV Return Fan Capacity Control**: BAS shall control the output of the return fan as follows:

1. **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:

a) **Fixed Differential**: It shall be fixed at the design minimum OA value plus an adjustable offset for building pressurization.

b) **Differential Reset From RA CO_2**: It shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain a RA CO_2 setpoint of 900 ppm (adj.). Loop shall be a "sample and bump" or dynamic proportional only loop tuned for slow response. Setpoint flow rates shall be provided by A/E.

c) **Differential Reset From Measured OA to Maintain Fixed OA**: The differential shall be reset to maintain the measured minimum OA flow at the design value any time the economizer mode is inactive. Whenever economizer is inactive, the offset value shall be set to the value that existed when the unit became active.

d) **Differential Reset From Measured OA to Maintain Reset OA** When the economizer mode is inactive, offset valve 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 an RA CO_2 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 A/E. Whenever the economizer is active, offset valve shall be set to the value that existed when the unit became active.

2. **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 flow rate is maintained at both maximum and 50% flow conditions. The balancing contractor shall determine the coordinated output.

D. **Airside Economizer:** BAS shall modulate the mixing dampers to provide "free cooling" when conditions merit. The free cooling shall 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 Cool-down Mode where applicable. One of the following strategies shall be used to enable the economizer mode:

1. **Dry Bulb Comparison**: Economizer mode shall be active while the unit is energized AND when outside air temperature falls below return air temperature (with 2°F cycle differential). Economizer mode shall be inactive when outside air temperature rises above return air temperature (with 2°F cycle differential). In either case, dampers shall return to their scheduled minimum positions as specified above. Economizer shall remain enabled during setback cooling.

2. **Dry Bulb Switch**: Economizer mode shall be active while the unit is energized AND when outside air temperature falls below the switching setpoint of 70°F (adj.) (with 5°F cycle differential). Economizer mode shall be inactive when outside air temperature rises above switching setpoint, dampers shall return to their scheduled minimum positions as specified above.
3. **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.

E. **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.

F. **Mixed Air Low Limit Override**: BAS shall override the signal to the economizer dampers 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.

G. **Freeze Safety**: Upon operation of a freezestat, AHU fans shall be de-energized via a hardwired interlock. OA dampers shall close and heating loops shall remain active.

H. **Smoke Safety**: Upon indication of smoke by a smoke detector, AHU fans shall be de-energized via a hard-wired interlock. OA dampers shall close and heating loops shall remain active.

I. **High or Low Pressure Safety**: Upon activation of a high or low pressure safety switch, AHU shall be de-energized, supply and return fans shall be de-energized via a hard-wired interlock. BAS shall annunciate appropriate alarm.

J. **Run Time Limit Diagnostic**: BAS shall accumulate the runtime of the status of associated rotating equipment (fans, coil pumps, etc.) and generate a Maintenance Alarm (see Section 230905) to indicate that the unit is in need of service.

21.05 AIR HANDLING UNITS - DIAGNOSTICS

A. **General**: 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 4 and 5 alarm to indicate that the unit is in need of service. Contractor shall set this interval as directed by the Owner.
2. 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:

"ENERGY WARNING: An unexpected temperature rise is occurring across the heating coil. Please check for leaking valve or faulty controls."

3. 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:

"ENERGY WARNING: An unexpected temperature drop is occurring across the cooling coil. Please check for leaking valve or faulty controls."

4. Cooling Capacity Shortage: BAS shall monitor the output to the cooling valve. If the output exceeds 99% open for 1 hour continuously, enunciate the following alarm:

"CAPACITY WARNING: The cooling valve 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."

5. Economizer Anomaly: If mixed air temperature is less than 45°F or greater than 85°F; 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:

"ENERGY WARNING: An unexpected mixed air temperature indicates a possible problem with the economizer damper controls. Please check for faulty dampers or controls.

6. Fighting Valves: BAS shall monitor the valve positions of the pre-heat and cooling coils and if the valve positions are both over 10% open, enunciate the following alarm:

"FIGHTING VALVES: The pre-heat and cooling valves are opening simultaneously. Verify that the control loops are coordinated."

21.06 AIR HANDLING UNITS - MONITORING AND MANAGEMENT

A. **General**: The BAS shall monitor various aspects of the air handling systems and calculate parameters as specified below to facilitate 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 230905.

C. **Points to be trended**: all points to be trended are indicated on the corresponding drawings.

a)

21.07 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 230905.

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
3. All relative humidity sensors
4. All pressure sensors
5. All run requests and statuses on a change in value
6. All analog loop outputs
7. Calculated wet bulb temperatures
8. Summed cooling and heating requests

END OF SECTION 230993

SECTION 230995 - BAS COMMISSIONING

PART XXII. GENERAL

22.01 RELATED SECTIONS:

A. Section 230900 - Building Automation System (BAS) General

B. Section 230901 - BAS Basic Materials, Interface Devices, and Sensors

C. Section 230902 - BAS Operator Interfaces

D. Section 230903 - BAS Field Panels

E. Section 230904 - BAS Communication Devices

F. Section 230905 - BAS Software and Programming

G. Section 230993 - Sequences of Operation

22.02 GENERAL DESCRIPTION

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

B. Commissioning (Cx) is the process of ensuring that (i) all building systems are installed and perform interactively according to the design intent; (ii) that systems are efficient and cost effective and meet FCPS's operational needs; (iii) that the installation is accurately documented; and (iv) that the Operators are adequately trained. Commissioning serves as a tool to minimize post-occupancy operational problems, and establishes testing and communication protocols to advance the building systems from installation to optimized, fully-dynamic operation.

C. Commissioning Authority (CxA) shall work with the Contractor and the design engineers to direct and oversee the Cx process and perform Functional Performance Testing.

22.03 CONTRACTOR RESPONSIBILITIES

A. Install, thoroughly inspect, startup, test, adjust, balance, complete point-to-point verification, and document all systems and equipment.

B. Assist Commissioning Agent in verification and performance testing. This will include the following:

1. Attend Commissioning (Cx) progress and coordination meetings.
2. Prepare and submit BAS Start-Up Report.
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.

C. **Software Optimization**: Contractor shall provide a control technician to work at the direction of the CxA for software optimization assistance for a minimum of 8 hours during the Acceptance Phase of the project.

22.04 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 background graphic screens, and receive approval.

4. Submit Start-Up Checklists and manufacturer's start-up procedures for all equipment provided by the BAS Contractor. This shall include point-to-point checksheets.

5. Install BAS.

6. Submit BAS Start-Up Test Agenda and Schedule for review.

7. Receive BAS Startup Test Agenda/schedule approval.

8. Submit Training Plan.

9. Simulate sequencing and debug program off-line to the extent practical.

10. Place systems under BAS control where applicable during a scheduled outage.

11. Perform BAS Startup (including point-to-point verification) where applicable during a scheduled outage.

12. Prepare and initiate trend log data storage and format trend graphs.

13. Submit completed BAS Start-Up Reports and initial draft of the O&M Manuals.

14. Receive BAS Startup Report approval and approval to schedule Demonstrations and Commissioning.

15. Demonstrate systems to Commissioning Agent and FCPS.

16. Submit Trend Logs in format specified.

17. Receive demonstration approval and approval to schedule Acceptance Period.
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. Provide Level 1 password access to FCPS.
24. Revise and re-submit as-built record drawings and O&M Manuals.
25. Final Acceptance.
26. Begin Warranty Phase.
27. Schedule and begin Opposite Season acceptance period.
28. Receive Opposite Season acceptance period approval.
29. Submit as-built record drawings and O&M Manuals.
30. Install framed control drawings.
31. End-of-Warranty date/period.

PART XXIII. PRODUCTS

23.01 INSTRUMENTATION

A. Instrumentation required to verify readings and test the system and equipment performance shall be provided by Contractor and made available to Commissioning Agent. 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 year. Certificates of calibration shall be submitted.

23.02 TAB AND COMMISSIONING SYSTEM ACCESS

A. Provide the CxA with all software, connection devices, licenses, passwords, etc. to facilitate connection to the BAS throughout the building. Provide a license to graphic software, and all operating software necessary for testing and configuration of all control elements at all levels. License may be a temporary license that will expire after the completion of the Warranty Period. Options include:

1. A laptop computer provided by BAS Contractor for dedicated use by the CxA throughout the Construction and Acceptance Phases. This would be turned over to FCPS at the end of the Acceptance Phase.

2. Browser access to the full graphic software: CxA will provide laptop, however BAS Contractor shall set up the laptop to successfully connect.
3. Licensed client software to be installed on CxA computer: BAS Contractor shall install the software and ensure it is functional.
4. Terminal Services session access to a graphic server with required CALs to allow use of all required software. BAS Contractor shall configure the CxA computer to connect to the terminal session.

B. Access to the BAS must be provided throughout the building as more fully defined as follows:

1. Full wireless connection to the graphic server throughout the building will be adequate.
2. Network connection for full access to the graphic server within 50’ of any point in the building.
3. Exception to 1 and 2 above: An acceptable alternative to full building access to the graphic server relating to terminal controls shall be providing to the CxA the devices and software required to connect to local terminal controllers through a connection port in the space such as connection to a jack on the temperature sensor (basically what is required by TAB specified below). This does not apply to mechanical rooms as full graphic access is required in mechanical rooms.

C. Provide software required by TAB to calibrate all flow sensors. TAB will provide computer to be used as a portable operator’s terminal. Any manufacturer specific hardware such as connection cables, converters, hand held devices, etc. shall be provided by the BAS Contractor.

D. 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 as well as at the box. Otherwise a wireless system shall be provided to facilitate this local functionality.

PART XXIV. EXECUTION

24.01 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, calibrate, and complete point-to-point verification for 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. Contractor shall provide assistance to the TAB contractor to facilitate testing, adjusting, and balancing of the system. Coordinate with TAB

subcontractor to obtain, program, and record 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

5. 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 Startup Report.

6. Check and set zero and span adjustments for all transducers and transmitters.

7. 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.

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

9. 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.

10. 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.

11. 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.

12. Verify that all safety devices trip at appropriate conditions. Adjust setpoints accordingly.

13. 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 Startup Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows:

a) Duct air temperature: ***±2°F***.

b) Space Temperature: ***±2°F***

c) Chilled Water: ***±2°F***

d) Hot water temperature: ***±2°F***.

e) Duct pressure: ***± 0.25" w.g***.

f) Water pressure: ***±1 psid***

g) Air flow control: ***±5%*** of setpoint velocity

h) Space Pressurization (on active control systems): ***±0.05" wg*** with no door or window movements

14. **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 as-built record drawings.

b) Ensure that terminations are safe, secure and labeled in accordance with the as-built 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 and cycling controller power. Verify the event is annunciated at Operator Interfaces. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection and that controller retains its memory.

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 the memory allocation and loading to ensure adequate and excess capacity is available and that it will not affect control functionality

k) Check for adequate grounding of all DDC panels and devices.

15. **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 CxA for review.

e) Verify alarm enunciation functionality. Verify that real time and historical trends are accessible and viewable in graph format.

f) Verify that SMS/email alarm annunciation is functional.

g) Verify the functionality of remote OIs and that a robust connection can be established consistently.

h) Verify that required third party software applications required with the bid are installed and are functional.

i) Demonstrate open protocol and custom third party interfaces reliably communicate and check response time.

j) Verify schedules are set up and working.

16. Verify proper interface with fire alarm system.

B. **Start-Up Test Report**:

1. Submit Draft Report, which shall consist of all required test sheets and checklists as required for the Pre-commissioning Test Report as specified above.
2. Submit Final Test Report documenting that the BAS has been fully tested, adjusted and calibrated and is ready for demonstration and commissioning. Report shall follow the format of the approved draft report.

24.02 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 230901.

24.03 COIL VALVE LEAK CHECK

A. Verify proper close-off of the valves. Ensure the valve seats properly seat 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 or longer, and the temperature is stable, 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.

24.04 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.

24.05 BAS DEMONSTRATION

A. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the Commissioning Agent and FCPS prior to Substantial Completion. Schedule the demonstration with FCPS'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 to Contract specifications, so as to require scheduling of additional site visits by the Commissioning Agent for re-demonstration, Contractor shall reimburse FCPS for costs of subsequent Commissioning Agent 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 FCPS and CxA.

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 each workstation. 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 communication abilities are in accordance with these Specifications.
4. Demonstrate completed point-to-point verification, including 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 FCPS 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 the Commissioning Authority and by FCPS. Demonstrate that access is sufficient to perform required maintenance.
10. Demonstrate that required trend graphs and trend logs are set up per the requirements.
11. Test each control loop display to verify that it indicates proper percent of scale and correct scaling of engineering units.
12. Alarms: Test each alarm identified in Contract Documents. Verify that control system displays proper indication. Test and verify proper acknowledgement of alarms from supervisory station.
13. For each system, demonstrate:

a) Cold start.

b) Sequence of operation.

c) Seasonal control as applicable.

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.

24.06 BAS ACCEPTANCE PERIOD

A. After approval of the BAS Demonstration and prior to Substantial Completion, 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 performed.

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 Agent for review. Commissioning Agent 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 FCPS'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 Agent 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 FCPS's representative.

24.07 TREND LOGS

A. Contractor shall configure and analyze all trends required under Section 230905.

24.08 TREND GRAPHS

A. Trend graphs as specified in Section 230905 shall 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.

24.09 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 Agent for review upon Commissioning Agent request. Commissioning Agent will review these and notify contractor of any warranty work required.

B. **Opposite Season Testing**: Within 12 months of completion of the Acceptance Phase, Commissioning Agent/FCPS shall schedule and conduct Opposite Season functional performance testing. Contractor shall participate in this testing and remedy any deficiencies identified.

END OF SECTION 230995