SECTION 230923 - INSTRUMENTATION AND CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of Contract, including General and Special Conditions and Division-01 Specification sections, apply to work of this section.

1.2 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Sensors and Transmitters:

1. Airflow stations
2. Flowmeters

B. Control Valves:

1. Control valves

C. Control Dampers:

1. Automated Dampers

1.3 PRODUCTS INTEGRATED WITH THE WORK OF THIS SECTION

A. Communications with 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 or LonMark interface for integration into the Direct Digital Control System described in this section.

1.4 RELATED SECTIONS

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

1.5 CONTROL SYSTEM GENERAL REQUIREMENTS

A. The control system shall be of the electronic microprocessor type employing Direct Digital Control (DDC) Open Protocol technology (LonMark and/or BACnet) technology for all control sequences unless specifically stated otherwise in the Sequence of Operation portion of this specification.

B. All DDC controllers shall be connected via a communications bus to an operators panel. The operators panel may be located on the face of one of the DDC controllers, or at an alternate

location as approved by the Engineers. In addition, a portable operators panel may be connected to the system at any DDC controller location.

C. All DDC controllers shall be connected to a global information handler, which shall send and receive information of a global nature throughout the system. The information handler shall allow each DDC controller and operators panel access to all information contained within the system, regardless of location. The information handler shall also allow commands from any DDC controller or operators panel to be directed to any other DDC controller on either a global or individual basis. The information handler may be furnished as an integral part of one or more DDC controllers. This “Building Network Controller” shall be an Open protocol controller that will allow the simultaneous communication to BACnet and LonMark communication residing on the lower tier controllers (equipment controllers). The building controller shall be capable to be accessed using the majority of internet open protocols such as JAVA, XML, HTTP, etc.

D. Provisions shall be made to allow additional DDC controllers to be added at any point on the communications bus for future expansion.

E. Field Installed Devices (FID) shall be capable of stand-alone operation, as well as interfacing with the networked Building Control System. These controllers shall be LonMark and/or BACnet Protocols. No other protocols for this section will be acceptable.

F. Valve and damper operators shall be of the electronic type.

G. The Building Control System shall be made up of HVAC equipment with factory installed microprocessor-based Product Integrated Controls (PIC), distributed microprocessor-based Field Installed Devices (FID), input/output modules and necessary software.

H. The Product Integrated Controls (PIC) shall be factory installed controls capable of standalone operation. The controller shall be specifically designed to operate and monitor the functions of the HVAC equipment on which it is installed. The PIC shall be capable of interfacing onto the network.

I. The Building Network Controller shall incorporate the GUI (Graphical User Interface) via a standard web browser. Use of hardware keys or special licenses requirements to access the system with a browser is unacceptable. The Building controller will serve up the web pages on a standalone per building application for the intent that if the WAN is not working, an operator can access the system on site via the building internal network using an IP. A server computer will be located at the energy management office to supervise the remote panels and alarm if the communication is lost as well as any control function alarm. This server computer will also be the area of trending archives.

1.6 QUALITY ASSURANCE

A. All equipment or piping used in the conditioned air stream, spaces or return air plenum shall comply with NFPA 90A Flame/Smoke/Fuel contribution rating of 25/50/0 and all applicable local building codes or requirements.

B. All wiring shall conform to the National Electric Code (NEC).

C. Installation of the building Automation System shall be by the manufacturer of the controls or their local authorized agent who has a minimum of five (5) years of experience in the respective field.

D. BACnet systems shall conform to ASHRAE 135; LonWorks systems shall conform to the standards and protocols of the LonMark Interoperability Association.

E. All electrical components 25 V and above shall be UL listed or labeled.

1.7 CODES AND STANDARDS

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

1. National Electric Code (NEC)
2. Underwriters Laborites (UL)
3. Federal Communications Commission (FCC)

1.8 SYSTEM PERFORMANCE

A. Performance Standards: System shall conform to the following minimum standards over network connections.

B. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

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

Table 1
Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±5% of full scale (see Note 1)
Airflow (measuring stations)	±1% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 ppm

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

Table 2
Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.9 SUBMITTALS

A. Product Submittal Requirements: Meet requirements of Division 01 on Shop Drawings, Product Data, and Samples. Provide six copies of shop drawings and other submittals on hardware, software, and equipment to be installed or furnished. Begin no work until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2010 (or newer) compatible files on magnetic or optical disk (file format: .DWF and PDF) and 3 prints of each drawing on 11" x 17" paper. When manufacturer's cutsheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered specification and drawing on each submittal. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal

approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Provide submittals within 12 weeks of contract award on the following:

1. Direct Digital Control System Hardware:

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

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

    c. Wiring diagrams and layouts for each control panel. Show termination numbers.
    d. Floor plan schematic diagrams indicating field sensor and controller locations.
    e. Riser diagrams showing control network layout, communication protocol, and wire types.

2. Central System Hardware and Software:

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

        i. Central Processing Unit (CPU) or web server
        ii. Monitors
        iii. Keyboards
        iv. Power supplies
        v. Battery backups
        vi. Interface equipment between CPU or server and control panels
        vii. Operating System software
        viii. Operator interface software
        ix. Color graphic software
        x. Third-party software

    c. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
    d. Network riser diagrams of wiring between central control unit and control panels.
    e. Submit proposed graphics for each equipment type for approval.
    f. Submit proposed trend log format for approval.
    g. All details for software on how to add / remove / create & modify graphics / configuring and reloading controls, etc.

3. Controlled Systems:

    a. Riser diagrams showing control network layout, communication protocol, and wire types.
    b. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
    c. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
    d. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
    e. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified in Section 230993. Indicate alarmed and trended points.

4. Description of process, report formats, and checklists to be used in Section 230923 Article 3.14 (Control System Demonstration and Acceptance).
5. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules:

1. Schedule of work provided within one month of contract award, indicating:

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

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

C. Project Record Documents: Submit three copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:

1. Project Record Drawings: As-built versions of submittal shop drawings provided as AutoCAD 2010 (or newer) compatible files on magnetic or optical disk (file format: .DWF and PDF) and 6 prints of each drawing on 11" x 17" paper.
2. Testing and Commissioning Reports and Checklists: Completed versions of reports, checklists, and trend logs used to meet requirements of Section 230923 Article 3.14 (Control System Demonstration and Acceptance).
3. Operation and Maintenance (O&M) Manual: Printed, electronic, or online help documentation of the following:

    a. As-built versions of submittal product data.
    b. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
    c. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
    d. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.

e. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
f. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
g. Graphic files, programs, and database on magnetic or optical media.
h. List of recommended spare parts with part numbers and suppliers.
i. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
j. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
k. Licenses, guarantees, and warranty documents for equipment and systems.
l. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

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

E. After the system has operated properly for 90 days following start-up of the final component of the HVAC and DDC systems, an as-built copy of the software shall be transmitted to the Owner for permanent record purposes.

1.10 WARRANTY

A. Warrant work as follows:

1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
3. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.

PART 2 - PRODUCTS

2.1 APPROVED CONTROL SYSTEMS

A. The following is the approved control system supplier and any substitution must be approved by the Architect, Engineer and Owner prior to bidding.

1. ABB
2. Siemens
3. Trane

B. The BCS shall be furnished, installed, and programmed by the control manufacturer or local authorized agent serving the St. Lucie County area. Control systems shall comply with the terms of this specification.

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

2.2 MATERIALS

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

2.3 COMMUNICATION

A. Communication:

1. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a network.
2. Install new wiring and network devices as required to provide a complete and workable control network.
3. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

2.4 OPERATOR INTERFACE – CENTRAL SERVER AND HARDWARE/TERMINAL NOT REQUIRED

A. Operator Interface: Web server shall reside on high-speed network using Owner provided IP address with building controllers. Each standard browser connected to server shall be able to access all system information using user ID and password from any District computer.

B. Central Site: If the contractor does not already have a central server system in place, the contractor shall provide a central site system configuration that includes, as a minimum, the following components: Placement of computer/docking station to be determined by the Owner's Facilities Management.

1. Central Server Components:

    a. The central server shall consist of the following (minimum):

        i. System shall utilize a server class PC, tower or rack mounted
        ii. Two Xeon 2.8GHz, 1MB L3 cache processors
        iii. 2GB, DDR266 SDRAM memory
        iv. DVD+R/W or CD ROM
        v. Microsoft Windows Server 2003 (IIS 6.0) Or Server 2008, IIS V7 +
        vi. Microsoft SQL Server 2005
        vii. .NET Framework 1.1 BJE: .NET 3.5
        viii. Furnish all required serial, parallel, and network communication ports, and all cables for proper system operation. The server shall include a minimum 17", color monitor with 1024 x 768 screen resolution.

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

1. Hardware Base: Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified in Section 230923 Paragraph 1.8. Hard disk shall have sufficient memory to store system software, one year of data for trended points specified, and a system database at least twice the size of the existing database at system acceptance. Configure computers and network connections if multiple computers are required to meet specified memory and performance. Web server or workstations shall be Dell or equal PCs with a minimum of:

    a. Intel i7 processor 3ghz
    b. 6 GB RAM
    c. 1 TB hard disk providing data at 100 MB/sec
    d. 24x CD-RW/DVD drive
    e. 24” LCD Monitor
    f. Windows 7 Ultimate 32 bit Operating System
    g. Serial, parallel, and network communication ports and cables required for proper system operation

D. Operator Functions: Operator interface shall allow each authorized operator to execute the following functions as a minimum:

1. Log In and Log Out: System shall require user name and password to log in to operator interface.
2. Point-and-click Navigation: Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
3. View and Adjust Equipment Properties: Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.
4. View and Adjust Operating Schedules: Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.
5. View and Respond to Alarms: Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.
6. View and Configure Trends: Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.

7. View and Configure Reports: Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.
8. Manage Control System Hardware: Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.
9. Manage Operator Access: Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.
10. Create and modify control sequences.
11. Add or remove control points.

E. System Software:

1. Operating System: Web server shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows.
2. Software shall be provided in these five categories:

    a. System executive software
    b. Software for user control over system configuration through the main controller via internet access (“Central site”), and by Maintenance Personnel in the field
    c. Facility monitoring functions
    d. Direct digital control
    e. Application software

3. Central site must be able to generate standard ASCII file formats to allow use with third-party software (e.g. Microsoft Excel) to generate and store owner-designed reports.
4. Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. It shall also provide a current status of all I/O points being controlled and applicable to each piece of equipment including analog readouts in appropriate engineering units at appropriate locations on the graphic representation. Programming, scheduling and set-point changes shall be accessible for modification on each menu for the associated equipment. Operator shall be able to automatically download changes from the central site to the appropriate program for the equipment being controlled. Operator shall be able to upload information from the field modules to the central site.
5. All operator commands shall be in graphics data base and menu driven. After the operator selects the desired object item or menu, the system shall display either the status of selected object item or the allowable options available. Upon entry of a command to the point or points desired as described above, the system shall, before performing any command requested and any entered data, ask the operator to verify his intent (e.g. “are you sure?”). System shall include error monitoring software for user's input error.
6. Output Format:

    a. The system shall operate on a System Format basis, regardless of the manner or hardware configuration in which the data is acquired. A "system" shall consist of a logical grouping of data points, related to a piece of mechanical equipment, an energy distribution system, or an architectural area. For example, in some cases, it may be desired to display, as a single system, a space temperature with its associated air handling unit, and in other cases to display all space temperatures on a floor or in a building. The DDC shall allow such determinations to be made without regard to the physical hardware locations of a point or group of points. Likewise, the system shall accommodate future changes of system grouping and operations without field hardware changes.

b. All displays and logs shall contain a header line indicating date, day-of-week, and time.
c. All output displays or logs of a point or group of points shall contain, as a minimum, the following information:

    i. Graphic presentation of the System
    ii. User name of point
    iii. Point descriptor
    iv. Current value/status
    v. Associated engineering units
    vi. Alarm description

d. User names, point descriptors, and engineering units shall be operator definable on a per point basis.
e. Set points:

    i. All alarm colors shall be in red.
    ii. System shall be capable of utilizing the operator interface to change individual zone temperature setpoints.
    iii. System shall be capable of globally changing all or groups of set points.

f. Graphic Structure:

    i. Software graphics will ensure the operator is always aware of his position within the system as well as how to logically progress through the graphical hierarchy to select any desired graphic or other source of information.
    ii. System shall be programmed to provide a color graphic for:

        a) Each piece of equipment monitored or controlled
        b) Each floor and zone controlled - both HVAC and lighting.
        c) Each trend
        d) Each report

g. User Access Restriction. Operator sign-on shall require an assignable password. Access security shall have multiple levels, starting at ‘view only’ to full access, including ability to program. Designer shall coordinate with Owner’s representative for access to be included at each level. A typical progression would include: readout only, local room set point; local schedule; system set points; system schedules; building set points, schedules, and sequences; campus set points, schedules, and sequences; district set points, schedules, and sequences.
h. Power Failure/Automatic Restart:

    i. Power failures shall cause the system to go into an orderly shutdown with no loss of program memory.
    ii. Upon resumption of power, the system shall automatically restart and record the times and dates of the power failure and restoration at the Central Site.
    iii. “Restart” program shall automatically restart affected field equipment. Operator shall be able to define an automatic power up time delay for each piece of equipment under control.

7. User Control Over System Configuration:

    a. Database Creation and Modification. All changes shall be done utilizing standard procedures and be capable of being done while the system is on-line and operational. The system shall allow changes to be made through the portable

operator terminal and from the central site. To aid the user, instructive prompting software shall be provided.

b. System shall permit the operator, with proper password, to perform as a minimum the following:

   i. Add and delete points
   ii. Modify point parameters
   iii. Create and modify control sequences
   iv. Reconfigure application programs
   v. Add and/or modify graphics

c. All data points within the database shall be completely accessible as independent or dependent variables for custom programming, calculation, interlocking, or manipulation.

d. Graphics software shall be fully implemented and operational to accomplish the following:

   i. Create a new graphic picture
   ii. Modify a portion of a graphic picture
   iii. Delete a graphic picture, or any portion thereof
   iv. Call up a graphic picture
   v. Cancel the display of a graphic picture
   vi. Assign conditions which automatically initiate the display
   vii. Overlay alphanumeric and graphics
   viii. Save the graphic picture
   ix. Display latest process data fully integrated with the graphic display

8. Facility Management Functions:

   a. Trend Logging:

      i. System shall be able to trend and display either numerically or graphically any analog or digital points in the system.
      ii. System shall be able to simultaneously, graphically display any two trended points within a module function block or any point in the module with respect to the outside air temperature, enthalpy, or relative humidity.
      iii. Each field module shall be capable of storing the most recent 60 samples for each single trend point or the most recent 30 samples for each of two trended points from one module function block.
      iv. Each module shall be capable of automatically uploading on a daily basis all accumulated trend data to the central site for permanent storage on non-volatile memory.

   b. Run Time:

      i. System shall provide run time information for all digital output and input points on command from the operator. Maximum run time limits shall be operator definable and shall be capable of automatically issuing an alert when the run time maximum is exceeded. Operator shall be able to reset the run time accumulator.
      ii. Run time hours and start time date shall be retained in non-volatile module memory.
      iii. Each module shall be capable of automatically uploading all accumulated data to the central site for permanent storage on non-volatile memory.

c. Alarm Conditions and Maintenance Messages:

   i. Central site shall allow receipt of alarms and messages while in a functional mode other than energy management. i.e., Incoming alarms shall be displayed, and generate an audible alarm when deemed appropriate by the operator, while the operator is using other functions of the system. The operator shall be able to return to his prior operation after the alarm is received and acknowledged.
   ii. System shall distinguish between alarms and messages with alarms having a higher priority.
   iii. System shall be capable of delivering an alarm or message directly to up to three different remote locations, in addition to the central site, through E-Mail, E-Page, alphanumeric page, or other appropriate method. Operator shall determine if alarms or messages are to be based on temperature limit, status, off-normal reporting, or other condition. Coordinate with Owner to determine what alarm condition(s) merit direct delivery of alarm messages. Typically, any condition, or set of conditions, that would cause the plant to shut down or have the potential to damage equipment or injure personnel would merit such direct reporting.
   iv. System shall be capable of generating maintenance messages when run time accumulation maximum limits are exceeded.
   v. Text for operator alarm and messages shall be operator definable. System shall be capable of storing at least 100 messages each of any length. Generic messages used for multiple points throughout the system shall only count as one message. In the event the central site is powered down, alarms shall be stored in the modules until the central site is restored.
   vi. Central site shall be capable of transferring all alarms to non-volatile memory for storage.

d. Reports and Archiving:

   i. Field modules shall be capable of calling the central site to automatically upload all current and accumulated data. This shall be delivered to the central site for permanent storage on non-volatile memory. All reports and stored data shall be transferable to other sites or media.
   ii. System shall be capable of reporting and archiving the following information as a minimum:

      a) Outside air temperature history and degree day history
      b) Electric demand and usage history
      c) All trended points
      d) All alarms and messages
      e) Equipment runtime information

   iii. The system shall also provide the following additional reports for which archiving is not applicable:

      a) All points summary
      b) Building operating schedules
      c) Printout of any graphic screen

   iv. All systems reports shall be capable to being viewed via the central site and printed at the operator's discretion

9. Direct Digital Control Software:

    a. System shall continuously perform DDC functions at the local DDC controller in a stand-alone mode. The operator shall be able to design and modify the control loops to meet the requirements of the system being operated. Operators shall use system provided displays for tuning of PID loops. These displays shall include the past three input variable values, the set point for the loop as well as the sample interval and the results of the proportional, integral and derivative effects of the final output.
    b. Each Controller shall perform the following functions:

        i. Identify and report alarm conditions
        ii. Execute DDC algorithms
        iii. Execute all application programs indicated on the I/O Summary table
        iv. Trend and store data

    c. In the event of a Controller failure, all points under its control shall be commanded to the failure mode.
    d. All DDC software shall reside in the respective DDC controller.

10. Application Software:

    a. Application software shall be as required to produce and implement the sequences of operation.

F. Portable Operator's Terminal – NOT PROVIDED

1. Provide all necessary software to configure a Dell or equal laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

    a. Minimum Requirements:

        i. Dell XT Tablet PC
        ii. 12.1” Touch screen
        iii. 2 GB RAM
        iv. 64GB SSD Harddrive
        v. Intel WiFi Link 5300 (802.11a/g/n 3x3)
        vi. Bluetooth Module
        vii. 6-cell 42W/Hr Li-ion primary battery
        viii. Spare 6-cell battery
        ix. Windows 7 Ultimate 32 bit operating system

2.5 CONTROLLER SOFTWARE

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. Scheduling: See Paragraph 2.4.C.4 (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:

1. Weekly: Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).

2. Exception: Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
3. Holiday: Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

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

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

E. Maintenance Management: System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as recommended by manufacturer for following equipment:

1. Chillers

F. Sequencing: Application software shall sequence chillers and pumps as specified in control sequences.

G. PID Control: System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.

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

I. Energy Calculations:

1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.
3. System shall communicate with all electrical sub metering equipment and gather data on the sub system electrical consumption characteristics (i.e. lighting, mechanical equipment, etc.).

J. Anti-Short Cycling: Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

K. On and Off Control with Differential: System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

L. Runtime Totalization: System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Sequence of Operation.

M. Software required to provide the initial operation routines shall not consume more than 70% of programmable capability of the controller.

2.6 CONTROLLERS

A. General: Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 230923 Article 1.8 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet or LonMark Device profile.

B. The main, or central, controller shall have non-volatile memory for all system sequences, setpoints, trended data, etc., for proper system operation, to support restart upon power loss, and to prevent loss of historical data. The main, or central, controller shall have a human interface device mounted on the front surface of its panel for data read-out and control input.

C. Communication:

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

    a. AHU.
    b. FCU.
    c. VAV.

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

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

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

F. Serviceability:

1. Controllers shall have diagnostic LEDs for power, communication, and processor.
2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

G. Memory:

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

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

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

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

J. All control panels shall have wiring diagrams for the devices contained within. Wiring within the panel should be labeled for the device to which it goes from the controller (valve, damper, etc.).

2.7 INPUT AND OUTPUT INTERFACE

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

B. Protection: 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.

C. Binary Inputs: Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

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

E. Analog Inputs: Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary Outputs: Binary outputs shall send an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs: Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

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

I. Universal Inputs and Outputs: Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.8 POWER SUPPLIES AND LINE FILTERING

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

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

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

B. Power Line Filtering:

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

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

2.9 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers:

1. Type: Control dampers shall have linear flow characteristics and shall be parallel- or opposed-blade type as specified below or as scheduled on drawings.

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

2. Frame: Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (1/8 in.) extruded aluminum with reinforced corner bracing.
3. Blades: Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).
4. Shaft Bearings: Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals: Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall

leak no more than 50 L/s·m^2 (10 cfm per ft^2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).

6. Acceptable manufacturer is Ruskin CD – 50, or approved equal.

B. Electric Damper and Valve Actuators:

1. Stall Protection: Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
2. Spring-return Mechanism: Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range: Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range.
4. Wiring: 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning: Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.
6. All actuators are to provide position feedback to system.
7. Acceptable manufactures Belimo, or approved equal.

C. Control Valves:

1. General: Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.
2. Type: Provide two- or three-way control valves for two-position or modulating service as shown.
3. Water Valves:

   a. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball.
   b. Close-off (Differential) Pressure Rating: Valve actuator and trim shall provide the following minimum close-off pressure ratings.

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

   c. Ports: Valves providing modulating service shall be pressure independent characterized control.
   d. Sizing:

      i. Two-position service: line size.
      ii. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 35 kPa (5 psi).
      iii. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi).

   e. Fail Position: Water valves shall fail normally open or closed as follows unless otherwise specified.

      i. Water zone valves: normally open.
      ii. Heating coils in air handlers: normally open.
      iii. Chilled water control valves: normally closed.

iv. Other applications: as scheduled or as required by sequences of operation.

4. Acceptable manufactures Belimo Energy Valve.

D. Butterfly Valves – High Performance:

1. Valve body shall be full lugged carbon steel ANSI Class 150 [300] body with a 316 stainless steel disc without a nylon coating, RTFE seat, and be ANSI Class 150300 flange standards. Blowout-proof shaft shall be 17-4ph stainless steel and shall be supported at four locations by glass-backed TFE bushings. Valve packing shall be Chevron TFE and shall include fully adjustable packing flange and separable packing gland. Valve body shall have long stem design to allow for 2" insulation (minimum). Valve face-to-face dimensions shall comply with API 609 and MSS-SP-68. Valve assembly shall be completely assembled and tested, ready for installation
2. Industrial Actuators *(ONLY TO BE USED WITH 2.16.I Butterfly Valves)*
3. Manufactured, brand labeled or distributed by BELIMO
4. The combination of valve and actuator shall meet the close-off requirements as specified
5. Coupling: ISO 5211 mounting standards
6. Overload Protection: A self resetting thermal switch embedded in the motor
7. Manual Override: Actuator shall be equipped with a hand wheel or shaft for manual override to permit operation of the actuator in the event of an electrical power failure
8. Power Requirements: 24VAC control power.
9. Auxiliary Switches: 2 SPDT rated 3A at 250 VAC
10. Temperature Rating: -22 to +150ºF -30 to +65ºC.
11. Housing: Minimum requirement NEMA type 4X/ IP67 with an industrial quality coating. Actuator shall have an internal heater to prevent condensation within the housing. A visual indication beacon shall indicate position status of the device
12. Agency Listing: ISO, CE, CSA
13. The manufacturer shall warrant for 2 years from the date of production

E. Low-Voltage Space Thermostats: Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

1. Line-Voltage Space Thermostats: Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
2. Low-Limit Thermostats: Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

F. Temperature Sensors:

1. Type: Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
2. Duct Sensors: Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2(10 ft^2) of duct cross-section.
3. Immersion Sensors: Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.

4. Space Sensors:

    a. Space sensors shall have no display.
    b. Space sensors shall have setpoint adjustment, override switch and communication port.

5. Differential Sensors: Provide matched sensors for differential temperature measurement.

G. Humidity Sensors:

1. Duct and room sensors shall have a sensing range of 20%-80%.
2. Duct sensors shall have a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 20%-95% RH and shall be suitable for ambient conditions of 40°C-75°C (40°F-170°F).
4. Humidity sensors shall not drift more than 1% of full scale annually.
5. Room Humidity sensors shall be integral to the room temperature sensor so that there is only one sensor per room.

H. Air Flow Monitor Stations:

1. Furnish and coordinate the installation of Air Flow Measuring Stations according to the Contract Documents.
2. Include manufacturer's recommended number of probes for the proper traverse of the air duct, and required mounting hardware.
3. Provide all cabling required for connection to probe assemblies and transmitter electronics.
4. Where these stations serve as primary signals for airflow control loops, verify location and installation to assure that accurate primary signals are obtained.
5. Acceptable manufacturer is Ebtron (Gold Series).

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

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

J. Relays:

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

K. Override Timers:

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

L. Current Transmitters:

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

M. Current Transformers:

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

N. Voltage Transmitters:

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

O. Voltage Transformers:

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

P. Power Monitors:

1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

Q. Current Switches:

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

R. Pressure Transducers:

1. Transducers shall have linear output signal and field-adjustable zero and span.

2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

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

T. Flow Meter / BTU Meter:

1. Provide insertion electromagnetic type flow meters.

    a. Minimum pressure: 150 psig
    b. Minimum temperature rating: 250 deg F
    c. Stainless steel probe of length to span inside of pipe.
    d. Equal to Onicon F-3500

U. BTU Meter:

1. Where BTU meters are called out, provide companion BTU meter system along with flow meter equal to Onicon F-3500 flow meter with System 10 BTU meter or approved equal.

    a. Temp reading accuracy: +/- 15 deg F over calibrated range.
    b. Temp reading range: 32 deg F to 200 deg F.

V. Pressure-Electric (PE) Switches: PE switches shall be UL listed, pilot duty rated (125 VA minimum) or motor control rated, metal or neoprene diaphragm actuated, operating pressure rated for 0-175 kPa (0-25 psig), with calibrated scale minimum setpoint range of 14-125 kPa (2-18 psig).

1. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application.
2. Switches shall be open type (panel-mounted). Exception: Switches shall be enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
3. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

W. Local Control Panels:

1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

2.10 WIRING AND RACEWAYS

A. General: Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

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

PART 3 - EXECUTION

3.1 EXAMINATION

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer 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 to Engineer and obtain written instructions for changes necessary to accommodate Section 230923 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

A. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.

B. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

A. Site:

1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Submittals: See Section 230923 Article 1.9 (Submittals).

C. Test and Balance:

1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
2. Train Test and Balance Contractor to use control system interface tools.
3. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

D. Life Safety:

1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in Sequence of Operation.

E. Coordination with Other Controls: Integrate with and coordinate controls and control devices furnished or installed by others as follows.

1. Communication media and equipment shall be provided as specified in Section 230923 Article 2.3 (Communication).
2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

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

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

D. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

E. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

3.5 FIELD QUALITY CONTROL

A. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 230923 Article 1.7 (Codes and Standards).

B. Continually monitor field installation for code compliance and workmanship quality.

C. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.6 WIRING

A. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26, and manufacturer's recommendations. Where the requirements of Section 230923 differ from Division 26, Section 230923 shall take precedence.

B. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC and Division 26.

C. Low-voltage wiring shall meet NEC Class 2 requirements. Subfuse low-voltage power circuits as required to meet Class 2 current limit.

D. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed for the intended application.

E. Install wiring in raceway where subject to mechanical damage and at levels below 3 m (10ft) in mechanical, electrical, or service rooms.

F. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.

G. Do not install wiring in raceway containing tubing.

H. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 3 m (10 ft) intervals.

I. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

J. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.

K. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

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

M. Use color-coded conductors throughout.

N. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.

O. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment such as steam pipes or flues.

P. Adhere to requirements in Division 26 where raceway crosses building expansion joints.

Q. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.

R. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.

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

T. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.7 COMMUNICATION WIRING

A. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.6 (Wiring).

B. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.

C. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

D. Verify entire network's integrity following cable installation using appropriate tests for each cable.

E. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.

F. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.

G. Label communication wiring to indicate origination and destination.

H. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.8 FIBER OPTIC CABLE

A. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.9 INSTALLATION OF SENSORS

A. Install sensors according to manufacturer's recommendations.

B. Mount sensors rigidly and adequately for operating environment.

C. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

D. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.

E. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

F. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2 (1 ft^2) of coil area.

G. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

H. Install outdoor air temperature sensors on north wall at designated location with sun shield.

I. Differential Air Static Pressure:

1. Supply Duct Static Pressure: Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
2. Return Duct Static Pressure: Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
3. Building Static Pressure: Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

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

3.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

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

3.11 ACTUATORS

A. General: Mount actuators and adapters according to manufacturer's recommendations.

B. Electric and Electronic Damper Actuators: Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.

1. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
2. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, then tighten linkage.
3. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
4. Provide necessary mounting hardware and linkages for actuator installation.

C. Valve Actuators: Connect actuators to valves with adapters approved by actuator manufacturer.

3.12 PROGRAMMING

A. Point Naming: Name points as shown on the equipment points list provided with each sequence of operation. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.

B. Software Programming: Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.

1. Application Programming: Provide application programming that adheres to sequences of operation specified. Program documentation or comment statements shall reflect language used in sequences of operation.
2. System Programming: Provide system programming necessary for system operation.

C. Operator Interface:

1. Standard Graphics: Provide graphics as specified. Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List in and sequences shown on the plans. Point information on graphics shall dynamically update.
2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation).

3.13 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup Testing: Complete startup testing to verify operational control system before notifying Owner of system demonstration. Provide Owner with schedule for startup testing. Owner may have representative present during any or all startup testing.

1. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 230923.
2. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
3. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
4. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
5. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
6. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
7. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
8. Alarms and Interlocks:

    a. Check each alarm with an appropriate signal at a value that will trip the alarm.
    b. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
    c. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.14 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration: Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified in Article 3.13 (Control System Checkout and Testing). Provide Engineer with log documenting completion of startup tests.

1. Owner/Engineer may be present to observe and review system demonstration. Notify Owner/Engineer at least 10 days before system demonstration begins.
2. Demonstration shall follow process submitted and approved under Section 230923 Article 1.9 (Submittals). Complete approved checklists and forms for each system as part of system demonstration.
3. Demonstrate actual field operation of each sequence of operation as specified in Section 230993. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Engineer. Provide and operate test equipment required to prove proper system operation.
4. Demonstrate compliance with Section 230923 Part 1 (System Performance).
5. Demonstrate compliance with sequences of operation through each operational mode.
6. Demonstrate complete operation of operator interface.
7. Demonstrate each of the following:

    a. DDC loop response: Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Engineer will require further tuning of each loop that displays unreasonably under- or over-damped control.

b. Demand limiting: Supply trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
c. Building fire alarm system interface.
d. Trend logs for each system: Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified in.
e. Minimum Trend Log Requirements:

    i. Control Stability Trend Logs:

        a) Each digital or analog output to valves, dampers, adjustable frequency drives and other control devices shall be included.
        b) Scan time shall be at five second intervals for a duration of ten minutes.
        c) Start of the sets shall be immediately after change from one mode to another, i.e., unoccupied to occupied, no economizer to economizer, off to on, etc. Only one log will be required for each output as long as it addresses all controlled elements.
        d) Where control of a piece of equipment is by factory furnished packaged controls, then the controlled temperature which is monitored shall be included. For instance, where a chiller is controlled by its own control system and control is from leaving chilled water temperature, then leaving chilled water temperature shall be included in the log set.

    ii. System Operation Trend Logs:

        a) Each measured value (temperature, pressure, amps, etc.), equipment status (on-off, percent speed or position, etc.), each mode (unoccupied, cool-down, occupied, etc.), each setpoint and each alarm shall be included.
        b) Scan time shall be at operation adjustable intervals with a duration of 24 hours.
        c) Sets shall be included for cooling only, cooling plus economizer and heating only. Where start up occurs at a defined season and both heating and cooling cannot be logged, then the system will be accepted subject to a final demonstration of the other season, when weather permits.

    iii. Load Profile Trend Log Sets:

        a) The total campus load in tons shall be calculated using flow and temperature difference between supply and return water.
        b) Chiller plant load shall be calculated using chiller flow and temperature difference between supply and return water.
        c) Heat rejection load on water cooled equipment shall be calculated based on condenser water flow and temperature difference between supply and return water.
        d) Compressor power input (KWH) shall be calculated based on measured KW or volts and amps and a look-up table provided by the compressor supplier. This shall be logged and converted to tons (KW x 3414 divided by 12,000) and compared to the compressor tons obtained by subtracting chiller tons from condenser tons.

e) Tonnage shall be calculated by averaging six instantaneous readings per hour taken at ten minute intervals. Tonnage for each of the 24 hours shall be listed.

iv. Energy Use Trend Log Sets:

a) Energy use (KWH) of each chiller compressor shall be calculated using KWH or measured volts, amps and a look-up table provided by the manufacturer.
b) Energy use of each dedicated primary chilled water pump, condenser water pump and cooling tower fan shall be calculated using measured KWH or volts and amps prorated to motor nameplate data to convert to KW. Chiller auxiliary power use (KWH) shall be added to the chiller power use to get each individual chiller system power use.
c) Energy use of the secondary chilled water distribution pumps shall be obtained in a similar manner and added to the chiller system energy use to get central plant total energy use. This shall be compared to the measured central plant KWH where available.
d) Energy use of each fan shall be calculated using measured amps and a look-up table provided by the motor manufacturer to convert to KW.
e) Energy use of constant flow exhaust fans, small pumps, etc. shall be estimated based on input data of KW taken from the test and balance data and added based on fan on or off status.
f) The sum of all HVAC power use shall be totaled and listed.
g) KWH shall be calculated by averaging six instantaneous KW readings per hour taken at the same ten-minute intervals as the load measurements. Each chiller, central plant and total building energy use shall be converted to KW/ton and listed.
h) Energy consumption of the entire building shall be taken from the power company meters and listed.
i) Outdoor air wetbulb shall be listed.
j) Data shall be presented for each of the 24 hours each day.
k) Energy use shall be presented in bar graph form.

v. Custom Trend Log Sets:

a) The operator shall have the ability to customize all trend logs by adjusting both sampling time and duration.
b) After the initial graph data is accepted, the print-out shall be changed from a fixed interval to a change of value.

8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

B. Acceptance:

1. After tests described in this specification are performed to the satisfaction of both Engineer and Owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control.
2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 230923 Article 1.9 (Submittals).
3. After start-up and calibration, Building Controls Contractor shall submit to the Engineer trend logs of all points on each system demonstrating stable and proper operation. The trend logs shall be as follows:

a. 24 hour period at 15 minute intervals.
b. 3 hour start-up period at 5 minute intervals.
c. A total of two sets covering two days during each period are required.

3.15 TRAINING – **NOT PROVIDED**

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

B. Provide as part of this contract on site training for four facility operators (two advanced and two basic level) as designated by the Owner.

C. A total of 40 hours of on the job owner training conducted by a technician or technicians fully qualified to conduct such training shall be provided. Instruction or Training shall include, but not be limited to:

1. Instructions in the manufacturers recommended maintenance and operating procedures.
2. Instructions in the detailed sequence of operation of the mechanical equipment controls.
3. Instructions in reading and using the control wiring diagrams.
4. Instructions in control setpoint adjustment as relating to each specific system provided under this section.
5. Performance testing as described in Part 3.

END OF SECTION 230923