SECTION 23 09 00

BUILDING AUTOMATION AND TEMPERATURE CONTROL SYSTEM - REVISED

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes fully integrated building automation system, incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified:

1.3 COMMISSIONING

A. All building energy-related systems shall be commissioned in order to verify and ensure that fundamental building elements and systems are installed, constructed, calibrated to operate, and perform according to the Owner's Project Requirements, Basis of Design, and Construction Documents.

B. Refer to Divisions 1 and 23 commissioning specifications for additional information.

1.4 SCOPE

A. The Building Automation System (BAS) manufacturer shall furnish and install a fully integrated building automation system, incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified.

B. The primary desktop and laptop interface will be via a standard Web Browser such as Internet Explorer or Chrome. BAS contractor shall provide software license(s) for BAS WEB access for a minimum of twenty concurrent users.

C. The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation or identification number and sequence of operation all bearing the name of the manufacturer. The installing manufacturer shall certify in writing, that the shop drawings have been prepared by the equipment manufacturer and that

the equipment manufacturer has supervised their installation. In addition, the equipment manufacturer shall certify, in writing, that the shop drawings were prepared by their company and that all temperature control equipment was installed under their direct supervision.

D. All materials and equipment used shall be standard components, regularly manufactured for this and/or other systems and not custom designed especially for this project. All systems and components shall have been thoroughly tested and proven in actual use for at least two years.

E. BAS manufacturer shall be responsible for all BAS and Temperature Control wiring for a complete and operable system. All wiring shall be done in accordance with all local and national codes.

F. Air handling unit control/end devices shall be furnished by the BAS manufacturer and factory installed by the air handling unit manufacturer. Controls contractor shall provide data sheets on all components to be mounted, indicating component dimensions, mounting hardware, and methods, as well as wiring and piping diagrams for each application identified by unit tag per the schedule in the drawings.

G. BAS provider shall provide IT cabling and network between devices, controllers and building controllers so that a complete BAS is installed, functional and accessible via tie into the BAS network from a single location during TAB and commissioning. BAS network and cabling shall be compliant with and compatible with the Owner's IT department requirements so that BAS may be connected to an Owner's switch(s) once that system is complete.

1.5 INTERFACE REQUIREMENTS

A. The new system shall be an extension of and connected to the existing Siemens management system which is used for energy management.

B. The BAS contractor shall provide all necessary hardware and software to integrate the new control system with the existing Siemens BAS without additional hardware or gateways. Integration means the ability to monitor, override, change set points, and provide real-time bi-directional dynamic data exchange between the new control system and the existing BAS hardware and software.

C. The existing BAS is a Siemens system. The BAS is comprised of multiple supervisory controllers, monitoring and communicating with various building control systems over the Ethernet LAN system. The new building control system will be connected to, and communicate with, the existing campus BAS server via the Ethernet LAN

D. All new control points, monitoring points and software points shall be added to the existing Siemens BAS database and shall be available for monitoring and adjustment at any computer, with current copy of Microsoft Internet Explorer software (Release 6.0 or later), that is connected to the CCTC LAN.

E. All new building software and databases shall be archived on the hard drive at the BAS server. In the event that any building controller should lose its program that controller's archived software program shall be downloaded across the BAS network from the BAS server to the respective building controller.

F. The BAS contractor will provide all necessary hardware, software, and labor to allow communication with all any computer, with current copy of Microsoft Internet Explorer (Release 6.0 or later), that is connected to the LAN.

G. Integrity of the existing BAS shall be maintained during installation.

H. The new building control system shall be compatible in every respect with existing Siemens BAS hardware and software. All new controllers shall be compatible with Siemens database and software development tools.

1.6 WORK BY OTHERS

A. Electrical Contractor provides:
   1. 120V power to all BAS and/or Temperature control panels. Where not shown on plans, locations shall be determined by the BAS contractor and coordinated with the Architect and electrical contractor.
   2. Wiring of all power feeds through all disconnect starters to electrical motor.
   3. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by BAS manufacturer.
   4. Wiring of electrical sub-metering devices furnished by BAS manufacturer.

B. Control Devices for Installation by Installers
   1. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.
   2. Deliver the following to duct fabricator and installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
      a. Airflow sensors, switches and stations
      b. Pressure sensors.
   3. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
      a. DDC control valves
      b. Pipe-mounted flow meters
      c. Pipe-mounted sensors, switches and transmitters.
      d. Tank-mounted sensors, switches and transmitters.
      e. Pipe- and tank-mounted thermowells.
   4. Deliver the following to electrical installers for installation. Include installation instructions to Installer and supervise installation for compliance with requirements.
      a. Meters/Sub-Metering Devices

C. Communication Interface to Equipment with Integral Controls

1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.
2. Equipment to Be Connected:
   a. Acid neutralization system
   b. Air-cooled chillers
   c. Air-terminal units
   d. Boiler controllers
   e. Commercial Kitchen Hoods (alarm contacts only)
   f. Computer-room air-conditioning units
   g. Cooling Towers
   h. Domestic water booster pumps.
   i. Dust Collector
   j. Emergency engine generators
   k. Fan array controllers
   l. Fan coil units
   m. Kitchen coolers and freezers (alarm contacts only)
   n. Motor control centers
   o. Packaged air handling unit controllers
   p. Refrigerant monitoring
   q. Split-system air-conditioners
   r. Sump pump unit controllers
   s. Unit ventilators
   t. Variable-frequency controllers
   u. Water-cooled chiller controllers

D. Communication Interface to Other Building Systems:
   1. DDC system shall have a communication interface with systems having a communication interface.
   2. Systems to Be Connected:
      a. Access controls.
      b. Elevators.
      c. Fire-alarm system
      d. Lighting controls. BAS shall connect to all Lighting Control panels and contactors for lighting control. Refer to the electrical drawings for location and quantity.
      e. Power monitoring.

E. Test, Adjust and Balance:
   1. The BAS contractor shall cooperate with the air and water testing, adjusting and balancing (TAB) contractor in the performance of their work as required or directed, including calibration of all sensors and devices.
   2. The BAS contractor shall work with the air and water testing, adjusting and balancing (TAB) contractor and commissioning agent (CxA) to utilize the TAB certified measuring instruments to verify BAS temperature and humidity readings as applicable and provide any adjustments in the BAS programming to modify the reading of the BAS sensor to match the TAB reading.

F. Commissioning

1. BAS contractor shall work with the Commissioning Agent in the performance of their work as required or directed.
2. Each system upon completion shall be tested in the presence of the Commissioning Agent and shall be shown to be in satisfactory condition.
3. During this test period, the BAS Contractor shall make all necessary adjustments.
4. General operating tests shall cover such time as is necessary to demonstrate that the entire equipment is functioning in accordance with specifications.
5. BAS Contractor shall furnish all instruments, test equipment and personnel that are required for tests.
6. It will be the BAS Contractor's responsibility to schedule the above tests with the Architect and Commissioning Agent.
7. Refer to PART 3 – EXECUTION for additional requirements.

1.7 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at Project site.
   1. Conduct a pre-installation walk through at the Project site with owner, architect and engineer prior to BAS rough-in to coordinate and confirm all device locations.

1.8 ACTION SUBMITTALS

A. Product Data: For each type of product include the following:
   1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
   2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
   3. Product description with complete technical data, performance curves, and product specification sheets.
   4. Installation, operation and maintenance instructions including factors effecting performance.
   5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
      a. Gateways.
      b. Routers.
      c. DDC controllers.
      d. Enclosures.
      e. Electrical power devices.
      f. UPS units.
      g. Accessories.
      h. Instruments.
      i. Control damper actuators.
      j. Control valves and actuators.

6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

B. Shop Drawings:
   1. General Requirements:
      a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
      b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
      c. Drawings Size: 11x17.
   2. Include plans, elevations, sections, and mounting details where applicable.
   3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   4. Detail means of vibration isolation and show attachments to rotating equipment.
   5. Plan Drawings indicating the following:
      a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
      b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
      c. Each desktop workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
      d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
      e. Network communication cable and raceway routing.
      f. Information, drawn to scale, of ¼”=1’-0”.
      g. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.
   6. Schematic drawings for each controlled HVAC system indicating the following:
      a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
      b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
      c. A graphic showing location of control I/O in proper relationship to HVAC system.
      d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
      e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
      f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
      g. Narrative sequence of operation.
      h. Graphic sequence of operation, showing all inputs and output logical blocks.
   7. Control panel drawings indicating the following:

a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
c. Front, rear, and side elevations and nameplate legend.
d. Unique drawing for each panel.

8. DDC system network riser diagram indicating the following:
   a. Each device connected to network with unique identification for each.
   b. Interconnection of each different network in DDC system.
   c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
   d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.
9. DDC system electrical power riser diagram indicating the following:
   a. Each product requiring power with associated requirements (volts/phase//hertz/amperes/connection type) listed for each.
10. Monitoring and control signal diagrams indicating the following:
    a. Control signal cable and wiring between controllers and I/O.
    b. Point-to-point schematic wiring diagrams for each product.
    c. Control signal tubing to sensors, switches and transmitters.
    d. Process signal tubing to sensors, switches and transmitters.
11. Color graphics indicating the following:
    a. Itemized list of color graphic displays to be provided for each system.
    b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
    c. All visible points to be displayed.
    d. Intended operator access between related hierarchical display screens.

C. System Description:
   1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
   2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
   3. System and product operation under each potential failure condition including, but not limited to, the following:
      a. Loss of power.
      b. Loss of network communication signal.
      c. Loss of controller signals to inputs and outpoints.
      d. Operator workstation failure.
      e. Server failure.
      f. Gateway failure.
      g. Network failure
      h. Controller failure.
      i. Instrument failure.
      j. Control damper and valve actuator failure.
   4. Complete bibliography of documentation and media to be delivered to Owner.
   5. Description of testing plans and procedures.

6. Description of Owner training.

1.9 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
   1. In addition to items specified in Section 01 78 23 "Operation and Maintenance Data," include the following:
      a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
      b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
      c. As-built versions of submittal Product Data.
      d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
      e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
      f. Programming 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.
      g. Engineering, installation, and maintenance manuals that explain how to:
         1) Design and install new points, panels, and other hardware.
         2) Perform preventive maintenance and calibration.
         3) Debug hardware problems.
         4) Repair or replace hardware.
      h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
      i. Backup copy of graphic files, programs, and database on electronic media such as digital media.
      j. List of recommended spare parts with part numbers and suppliers.
      k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
      l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
      m. Licenses, guarantees, and warranty documents.
      n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
      o. Owner training materials.

1.10 QUALITY ASSURANCE

A. The BAS system shall be designed and installed, commissioned and serviced by manufacturer employed, factory trained personnel. Manufacturer shall have an in-place support facility within 20 miles of the site with technical staff, spare parts inventory and necessary test and diagnostic equipment.

B. The manufacturer shall provide onsite, experienced project manager for this work, responsible for direct supervision of the design, installation, start up and commissioning of the BAS.

C. The Bidder shall be regularly engaged in the manufacturing, installation and maintenance of BAS systems and shall have a minimum of ten (10) years of demonstrated technical expertise and experience in the manufacture, installation and maintenance of BAS systems similar in size and complexity to this project.

D. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

E. This system shall have a documented history of compatibility by design for a minimum of 15 years. Future compatibility shall be supported for no less than 10 years. Compatibility shall be defined as the ability to upgrade existing field panels to current level of technology and extend new field panels on a previously installed network.

F. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
   1. Flame-Spread Index: 25 or less.
   2. Smoke-Developed Index: 50 or less.

1.11 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.
   1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
   2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
      a. Install updates only after receiving Owner's written authorization.
   3. Warranty service shall occur during normal business hours and commence within 24 hours of Owner's warranty service request.
   4. Warranty Period: From date of Substantial Completion.
      a. One-year parts and labor.
      b. Three-year parts.
      c. For Gateway: One-year parts and labor warranty for each.

B. The on-line support services shall allow the local BAS subcontractor to dial out over telephone lines to monitor and control the facility's building automation system. This

remote connection to the facility shall be within 2 hours of the time that the problem is reported. This coverage shall be extended to include normal business hours, after business hours, weekends and holidays.

1.12 IDENTIFICATION

A. Identify control wires with a distinctive number on a nonconducting tag attached to each end or at junction points or by color coding of that wire or tube. Designate on control diagram the identifying color and/or number or other identifying designation used.

B. Identify all control equipment and devices, including panels, controllers, valves, and automatic dampers, firestats, etc., by a method approved by the Architect. Designations shall match those used on control diagrams and shop drawings.

PART 2 PRODUCTS

2.1 MANUFACTURER

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Automated Logic Corporation
   2. Hoffman Building Technologies
   3. Johnson Controls Inc. (Metasys).
   4. Siemens Building Technologies, Inc.
   5. Trane

B. System must extend and connect to the existing Siemens network control systems installed at Central Carolina Technical College.

2.2 GENERAL DESCRIPTION

A. The Building Automation System (BAS) shall use an open architecture. The system shall be designed for use on the Internet, or intranets using off the shelf, industry standard technology compatible with other owner provided networks.

B. The Building Automation shall consist of the following:
   1. Standalone Network Control Engine (NCE)
   2. Field Equipment Controller(s)
   3. Input/Output Module(s)
   4. Local Display Device(s)
   5. Distributed User Interface(s)
   6. Network processing, data storage and communications equipment
   7. Other components required for a complete and working BAS

C. The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, controllers and operator devices, while re-using existing controls equipment.

D. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

2.3 PERFORMANCE REQUIREMENTS

A. Delivery of Selected Control Devices: Deliver to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

B. Delegated Design, Qualified Professional: Engage a qualified professional to design BAS system to satisfy requirements indicated.
   1. System Performance Objectives:
      a. BAS system manages HVAC systems.
      b. BAS system operates HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
      c. BAS system responds to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
      d. BAS system operates while unattended by an operator and through operator interaction.
      e. BAS system records trends and transactions of events and produces report information such as performance, energy, occupancies, and equipment operation.

C. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths complying with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
   1. Flame-Spread Index: 25 or less.
   2. Smoke-Developed Index: 50 or less.

D. BAS System Speed:
   1. Response Time of Connected I/O:
      a. Update AI point values connected to BAS system at least every five seconds for use by DDC controllers. Points used globally to also comply with this requirement.
      b. Update BI point values connected to BAS system at least every five seconds for use by DDC controllers. Points used globally to also comply with this requirement.
      c. AO points connected to BAS system to begin to respond to controller output commands within two second(s). Global commands to also comply with this requirement.
      d. BO point values connected to BAS system to respond to controller output commands within two second(s). Global commands to also comply with this requirement.

2. Display of Connected I/O:
    a. Update and display analog point COV connected to BAS system at least every 10 seconds for use by operator.
    b. Update and display binary point COV connected to BAS system at least every 10 seconds for use by operator.
    c. Update and display alarms of analog and digital points connected to DDC system within 45 seconds of activation or change of state.
    d. Update graphic display refresh within eight seconds.
    e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations to not exceed graphic refresh rate indicated.

E. Network Bandwidth: Design each network of BAS system to include spare bandwidth with BAS system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions. Minimum spare bandwidth as follows:
    1. Level 1 Networks: 20.
    2. Level 2 Networks: 20
    3. Level 3 Networks: 10.

F. BAS Data Access:
    1. When logged into the system, operator able to also interact with any BAS controllers connected to BAS system as required for functional operation of BAS system.
    2. Use for application configuration; for archiving, reporting, and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.

G. Future Expandability:
    1. BAS system size shall be expandable to an ultimate capacity of at least 1.25 times total I/O points indicated.
    2. Design and install system networks to achieve ultimate capacity with only addition of BAS controllers, I/O, and associated wiring and cable. Design and install initial network infrastructure to support ultimate capacity without having to remove and replace portions of network installation.
    3. Operator interfaces installed initially do not require hardware and software additions and revisions for system when operating at ultimate capacity.

H. Input Point Values Displayed Accuracy: Meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.
    1. Energy:
        a. Thermal: Within 5 percent of reading.
        b. Electric Power: Within 5 percent of reading.
        c. Requirements indicated on Drawings for meters not supplied by utility.
    2. Flow:
        a. Air: Within 2 percent of design flow rate.

b. Air (Terminal Units): Within 10 percent of design flow rate.
c. Natural Gas: Within 5 percent of design flow rate.
d. Water: Within 2 percent of design flow rate.

3. Gas:
   a. Carbon Dioxide: Within 50 ppm.
4. Moisture (Relative Humidity):
   a. Air: Within 5 percent RH.
   b. Space: Within 5 percent RH.
   c. Outdoor: Within 5 percent RH.
   d. Level: Within 2 percent of reading.
5. Pressure:
   a. Air, Ducts and Equipment: 1 percent of instrument range.
   b. Space: Within 1 percent of instrument range.
   c. Water: Within 1 percent of instrument range.
6. Speed: Within 5 percent of reading.
7. Temperature, Dew Point:
   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.
   c. Outdoor: Within 3 deg F
8. Temperature, Dry Bulb:
   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.
   c. Outdoor: Within 1 deg F.
   d. Chilled Water: Within 1 deg F.
   e. Heating Hot Water: Within 1 deg F.
   f. Temperature Difference: Within 0.25 deg F
9. Temperature, Wet Bulb:
   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.
   c. Outdoor: Within 1 deg F.

I. Precision of I/O Reported Values: Values reported in database and displayed to have following precision:
   1. Current:
      a. Milliamperes: Nearest 1/100th of a milliampere.
      b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.
   2. Energy:
      a. Electric Power:
         1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
         2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
         3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.
      b. Natural Gas (Usage): Nearest 1/10th of a unit (cubic feet, MCF, therm) up to 100 units; nearest unit for above 100 units.
      c. Thermal, Rate:

1) Heating: For British thermal units per hour, nearest British thermal unit per hour up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For MBh, round to nearest MBh up to 1000 MBh; nearest 10 MBh between 1000 and 10,000 MBh; nearest 100 MBh above 10,000 MBh.
2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons.

d. Thermal, Usage:
1) Heating: For British thermal unit, nearest British thermal unit up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For MBtu, round to nearest MBtu up to 1000 MBtu; nearest 10 MBtu between 1000 and 10,000 MBtu; nearest 100 MBtu above 10,000 MBtu.
2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons.

3. Flow:
a. Air: Nearest 1/10th of a cubic feet per minute through 100 cfm; nearest cubic feet per minute between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm.
b. Fuel Oil: Nearest 1/10th of a gallon per minute through 100 gpm; nearest gallon per minute between 100 and 1000 gpm.
c. Natural Gas: Nearest 1/10th of a cubic feet per hour through 100 cfh; nearest cubic feet per hour between 100 and 1000 cfh; nearest 10 cfh between 1000 and 10,000 cfh; nearest 100 cfh above 10,000 cfh.
d. Water: Nearest 1/10th of a gallon per minute through 100 gpm; nearest gallon per minute between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm.
4. Gas:
a. Carbon Dioxide (ppm): Nearest ppm.
5. Moisture (Relative Humidity):
a. Relative Humidity (Percentage): Nearest 1 percent.
6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches.
7. Speed:
a. Rotation (rpm): Nearest 1 rpm.
b. Velocity: Nearest 1/10th of feet per minute through 100 fpm; nearest feet per minute between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm.
8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
9. Pressure:
a. Air, Ducts and Equipment: Nearest 1/10th of an inch water closet.
b. Space: Nearest 1/100th of an inch water closet.
c. Water: Nearest 1/10 of a pound per square inch gauge through 100 psig; nearest pound per square inch gauge above 100 psig.
10. Temperature:
a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
b. Outdoor: Nearest degree.
c. Space: Nearest 1/10th of a degree.
d. Chilled Water: Nearest 1/10th of a degree.

e. Heating Hot Water: Nearest degree.

11. Vibration: Nearest 1/10th of an inch per second.
12. Voltage: Nearest 1/10 V up to 100 V; nearest volt above 100 V.

J. Environmental Conditions for Controllers, Gateways, and Routers:
1. Products shall operate without performance degradation under ambient environmental temperature, pressure, and humidity conditions encountered for installed location.
   a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure to be internally insulated, electrically heated, cooled, and ventilated as required by product and application.
2. Protect products with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. House products not available with integral enclosures complying with requirements indicated in protective secondary enclosures. Installed location dictates the following NEMA 250 enclosure requirements:

K. Environmental Conditions for Instruments and Actuators:
1. Instruments and actuators to operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
2. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled, and/or ventilated as required by instrument and application.

L. Electric Power Quality:
1. Power-Line Surges:
   a. Protect susceptible BAS system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.1 and IEEE C62.41.2.
   b. Do not use fuses for surge protection.
   c. Test protection in the normal mode and in the common mode, using the following two waveforms:
      1) 10-by-1000-microsecond waveform with a peak voltage of 1500 V and a peak current of 60 A.
      2) 8-by-20-microssecond waveform with a peak voltage of 1000 V and a peak current of 500 A.
2. Ground Fault: Protect products from ground fault by providing suitable grounding. Products to not fail due to ground fault condition.

M. Backup Power Source:
1. Serve BAS system products that control HVAC systems and equipment served by a backup power source also from a backup power source.

N. UPS:
1. BAS system products powered by UPS units are to include the following:

a. Servers.
b. Gateways.
c. DDC controllers.
d. Desktop workstations.

O. Continuity of Operation after Electric Power Interruption:
1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems are to automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.4 BAS ARCHITECTURE

A. Automation Network
1. The BAS shall network multiple user interface clients, automation engines, system controllers and application-specific controllers. Utilize existing application and data server as required for systems operation.
2. The automation network shall be capable of operating at a communication speed of 100 Mbps, with full peer-to-peer network communication.
3. Network Control Engine (NCE) shall reside on the automation network.
4. The automation network will be compatible with other campus-wide networks. Where indicated, the automation network shall be connected to the campus network and share resources with it by way of standard networking devices and practices.

B. Control Network
1. Network Control Engine (NCE) shall provide supervisory control over the control network.
2. Control networks shall provide either “Peer-to-Peer,” Master-Slave, or Supervised Token Passing communications, and shall operate at a minimum communication speed of 38,400 baud.
3. DDC Controllers shall reside on the control network
4. Wireless communication between DDC controllers is acceptable. All sensors shall be wired.

C. Dedicated Web Based User Interface
1. The BAS Contractor shall provide and install a personal computer for command entry, information management, network alarm management, and database management functions. Real-time control functions, including scheduling, history collection and alarming, shall be resident in the BAS Network Engines and Data Server to facilitate greater fault tolerance and reliability.
2. Dedicated User Interface Architecture – The architecture of the computer shall be implemented to conform to industry standards, so that it can accommodate applications provided by the BAS Contractor and by other third-party applications

suppliers, including but not limited to Microsoft Office Applications. Specifically, it must be implemented to conform to the following interface standards.

a. Edge or Google Chrome or Safari for user interface functions.
b. Microsoft Office Professional for creation, modification and maintenance of reports, sequences and other necessary building management functions.
c. Microsoft Outlook or other e-mail programs for supplemental alarm functionality and communication of system events, and reports.
d. Required network operating system for exchange of data and network functions such as printing of reports, trends and specific system summaries.

3. PC Hardware/Software – The personal computer(s) shall be configured as specified in the Computing Hardware and Software section.
4. Provide one operational device as herein specified and located on plans.
5. Mobile, Web Based, User Interface (MUI) General
   a. All functionality as outlined within this section shall be provided as a standard catalog product software suite from the BAS manufacturer. Custom functionality development to meet these requirements is not acceptable.
   b. The mobile, web-based, user interface shall be HTML5-compliant and provide access to the system from smartphones, tablets, portable and desktop computers. User Interfaces that require software installation on the client device (e.g. Java, MicrosoftSilverlight®, Adobe® Flash®), or software downloads from an online app store shall not be acceptable for these purposes.
   c. The mobile user interface shall provide system operators with a simple space/zone/location-based navigation approach to finding information, including the ability to search for any location by name and to bookmark a location in a standard browser.
   d. The mobile user interface shall organize and display information using customer specific locations and spaces. At a minimum, the user interface shall provide:
      1) Organization of all space, equipment and point information in a familiar way (using standard equipment names and location descriptions), reducing the need for extensive training prior to use.
      2) A navigation mechanism or tree for users to select the specific location or space for accessing information – only spaces and locations in the navigation tree or equipment serving that space, nothing more.
      3) The ability to search for and/or bookmark any location, space, or equipment by name for quick access to critical or troublesome areas.
      4) Application of the same navigation mechanisms across any client device (e.g. Smart phone, tablet, personal computer) for consistency and ease of use.
   e. The same user interface elements shall be accessible from any type of personal computer or mobile device running any type of operating system supported (e.g. iOS, Android, Windows®). It shall automatically adapt and optimize the display for the screen size and touch screen navigation.
   f. Navigation Trees
      1) A dedicated location-based navigation tree shall be provided as part of the user interface in order to navigate to specific places within the facility on a hierarchical basis (typ. Campus, Facility, Building, Wing, Floor, Room.)

2) The location-based tree shall use place names familiar to the operator without training or familiarization regarding special codes and conventions utilized in the generation of the BAS.
3) Clicking or tapping on a location name in the tree shall display the home page associated with the space and simultaneously expand the tree to display the next level of spaces below the one selected.
4) Provide a means for qualified users to view an all hardware items navigation tree of devices connected to the BAS network in order to enable troubleshooting of equipment and communications.
5) A click or tap on a device in the network tree shall display a dashboard for that device including information regarding related equipment and access to a separate focus view of commandable points associated with the piece of hardware. A click or tap on such a point shall display a control dialogue box allowing the user to modify or command that point as indicated. The dialog box shall contain an annotation box for describing why the action was taken or special circumstances that apply.
6) Specific hardware and software types in the Network tree shall also include access to one or more the following views in their dashboard depending on hardware type or network element (e.g. MS/TP trunk):
    a) Summary View
    b) Diagnostic View
    c) Network View
    d) Trend View
7) Provide a means to hide the Network Tree and return to the Spaces Tree at any time by clicking on the Spaces Icon above the tree.
8) Provide a means to restrict user access to any space in the Spaces Tree and thereby prevent manipulation of equipment associated with the space.

g. Dashboard Displays
1) The user interface shall provide the ability to view equipment visualizations, floor plans, and/or other graphics on mobile or desktop client devices in a browser environment, without the need for additional plugins or software. Graphics shall be accessible via a space (for floorplans, campus maps, etc.) or equipment dashboard.
2) Standard dashboards shall be configured for each defined space including one of the following predefined or custom elements:
    a) Equipment Serving Space
    b) Potential Problem Areas
    c) Equipment Summary
    d) Graphic Display (if specified)
    e) Schedule
3) Standard dashboards shall be configured for each system or device (typ. mechanical or electrical equipment) including the following predefined or custom elements:
    a) Trend
    b) Equipment Activity Summary
    c) Equipment Relationships Summary
    d) Equipment Data
    e) Graphic Display

f) Schedule

4) Users with appropriate permissions shall have access to a Dashboards Manager that can change the display order of Summaries and Data elements, add or remove elements and apply custom dashboards layouts to equipment and space by type.
5) Dashboard Manager shall apply dashboards to spaces or equipment based on the viewing platform (Desktop/Tablet or Phone) in order to tailor the user experience to the needs of the specific user base.
6) Default dashboard displays by space and equipment type shall be created per the guidelines in this specification or by mutual agreement with the Owner's representative.

h. Alarm Management
1) The user interface shall provide a single display of all potential issues in a facility including items currently in alarm, warning, override, out-of-service and offline.
2) The user interface shall provide notification of new alarms, visually and audibly.
3) The user interface shall provide the ability to view a summary of alarms, including a chart of the number of alarms in each of the defined alarm priority ranges. The priority ranges should be filterable.
4) The user interface shall provide the capability to view multiple occurrences of the same alarm, ultimately providing the ability to acknowledge or discard all occurrences of the alarm in a single action.
5) The user interface shall provide the capability to view, and filter on, all alarms present in a well-defined mechanical system using the equipment serving equipment relationships.
6) The user interface shall provide the capability to acknowledge and discard all occurrences of at least 1000 alarms in one operation.
7) The user interface shall provide the user with the understanding of what physical space is being affected when an alarm occurs. The user interface shall provide the ability to filter alarms by physical space affected when the alarm occurred.
8) The user interface shall provide the capability to monitor alarms 24/7 without requiring an active login to the system, accessible via segregated web page. The user interface shall provide the capability to enabled or disable the 24/7 alarm monitor mode if desired.
9) The user interface shall provide the capability to annotate alarms using a pre-defined selection list or by providing custom text.
10) The user interface shall provide the capability to filter down alarm list and bookmark the filtered list, allowing automatic filtering to be applied when the bookmark is accessed.
11) Provide a means to export a .csv or .pdf copy of the currently displayed alarm list.
12) Provide a means to set up an alarm escalation feature. If an alarm is not acknowledged or discarded by recipients within a user-selected time, the alarm shall be escalated to an additional set of recipients.

i. Send Announcement
1) Administrative users should have the ability to alert staff of planned outages in advance. The communication avenues should include:

a) Email
b) A message shown on the login screen
c) A banner shown to logged in users

j. Equipment Activity Summary
   1) The user interface shall provide a filterable, single display, of all activity related to a specific piece of equipment including user changes, discarded user changes, pending alarms, discarded alarms, and acknowledged alarms for at least one year of historical data.
   2) Items shall be listed in timed order with the latest activity at the top of the list.
   3) Filters shall allow only specific activities for specific data points occurring within a specific time and date window to be displayed.
   4) Provide a means to export a .csv copy of the currently displayed summary by clicking or tapping on the export icon.
   5) Provide a means to create a custom trend graph containing the data shown in the currently displayed summary by tapping or clicking on the trend icon in the header bar and selecting the specific points to trend in the resulting selection panel.
   6) Clicking on the information icon in front of any displayed activity listed in the summary shall expand the display to include the name of the user, server time, value prior to the activity, the ability to annotate the activity and a user selectable icon for displaying a trend graph of the point.

k. Equipment Relationships Summary
   1) The user interface shall provide a summary of all equipment and spaces related to the operation of the system or device currently selected for viewing.
   2) The user interface shall include the capability to navigate to the home page of any related piece of equipment or space with a single click or tap on the desired element.

l. Equipment Data Summary
   1) The user interface shall provide a summary of all data pertaining to a particular piece of mechanical or electrical equipment in a tabular format. Clicking or tapping on any value in the summary shall display a related command panel allowing the user to command, override, or change service condition of the point selected and to annotate such actions for future reference.
   2) Provide a means to export a .pdf copy of the report with a single click on the associated export icon.

m. Equipment Serving Space Summary
   1) The user interface shall provide a summary of all mechanical and electrical equipment as defined in the points list that serves a selected space from the navigation tree.
   2) The summary shall be capable of including a subset of the viewable points for each system representing the key elements of interest to operators without subjecting them to long lists of points irrelevant to basic operation.
   3) Clicking or tapping on any item in the summary shall navigate to the item’s assigned home page in the user interface.

4) Provide a means to view a custom trend of information contained in the summary with a single click of the trend icon residing in the title header.
5) Provide a means to display specific systems and points by filtering equipment types desired.
6) Because the data is intended to be a snapshot of the current conditions in the space it shall not dynamically update but a click or tap on the update icon at any time performs that function.

n. Potential Problem Areas Summary
1) The user interface shall provide a summary of all points in the system related to the space that are not operating correctly (e.g. alarm, off normal or not communicating correctly) in order to provide the operator with a quick update on current conditions.
2) The information shall include:
a) Point status (via color)
b) Point name
c) Value of the point when the summary was taken
d) Equipment that contains the offending point
e) Space that is served by that equipment
3) Data points in the summary may be filtered by one or more types of off-normal condition (e.g. above setpoint, offline and overridden).
4) The summary may be exported in .csv format for inclusion in spreadsheets or other documents.

o. Equipment Summary
1) The user interface shall provide a summary that allows the user to compare all similar equipment that serves the space as well as downstream (child) spaces in order to evaluate conditions quickly and determine patterns for troubleshooting purposes.
2) Each unique equipment type shall be selectable and display a representative set of values along with the space(s) being served by the device. Equipment types can be selected from a dropdown menu in the summary.
3) Clicking or tapping on a selected device in the summary shall navigate to the home page for that piece of equipment while clicking or tapping a data point shall display the command panel for that point.
4) Provide a means to export a .pdf copy of the currently displayed summary by clicking or tapping on the export icon.
5) Provide a means to create a custom trend graph containing the data shown in the currently displayed summary by clicking on the trend icon in the header bar and selecting the specific points to trend in the resulting selection panel.
6) Provide a means to sort data within the summary by clicking on the desired column heading, allowing to sort from lowest to highest value or vice versa.
7) Provide a means to edit the column types and column order within the summary to provide relevant information in accordance with Operators' preferences.
8) Provide a means to link to an advanced search and reporting function directly from the Equipment Summary that will pre-populate the advanced report with the data from the Equipment Summary.

p. User Defined Summaries
   1) Provide the capability to view, command, and modify large quantities of similar data in summaries without the use of a secondary application (e.g. a spreadsheet). These summaries shall be generated automatically or user defined.

q. Trend
   1) The user interface shall provide the capability to view historical trend data from multiple pieces of equipment in both bar and line formats.
   2) The user shall have the ability to navigate to a selection list of frequently viewed trends.
   3) Trend graphs shall have to ability to be smartly auto-generated based on equipment and space relationships.
   4) The user shall have the ability to view up to 3 graphs of differing units of measurement in a single screen and select which data points to plot on each to help with readability.
   5) Each graph shall include a dedicated selection icon to export a copy of the graphic and data in .pdf format or the data only as a .csv file.
   6) Trend graphs shall allow the plotting of non-trended point's default values.
   7) The user shall have the ability to add any trended to point a custom trend graph.
   8) The user shall have the ability to save trend graphs for reference later.
   9) The user shall be able to specify the duration of time and aggregation period for each trend line.
   10) The user shall have the ability to decide whether to show raw or aggregate trend data.

r. Operator Access
   1) The user interface shall provide the ability to segment access to building data based on the space(s) or location(s) the user is physically located in and/or manages. The user interface shall provide the capability to assign "inherited" space permissions and the ability to assign user's space based access in bulk.
   2) The user interface shall provide the ability to segment access to building data based on the space(s) or location(s) the user is physically located in and/or manages. The user interface shall provide the capability to assign "inherited" space permissions and the ability to assign user's space based access in bulk.

s. Graphics
   1) The user interface shall display an equipment visualization or graphic within the context of its associated space (building, floor, room, etc.) or equipment dashboard.
   2) Graphics shall include the ability to define individual information layers for operator selection in order to clarify systems status and simplify operation on mobile devices. Where desired a master layer may be defined to include important information about the facility on all graphic screens.
   3) Graphics shall support the use of photo-realistic symbols as well as color change and animation to match the status of the related system control point.

4) Provide a means to export a time stamped .pdf file of the graphic being viewed in order to communicate the current conditions in the space or the equipment being viewed and to provide a historic record.
5) An integral graphic manager shall be provided including the following features and capabilities:
    a) Creation and modification of graphics from any HTML5 capable browser without the need for additional plug-ins or software packages.
    b) Access to a full suite of pre-defined templates for air and water sourced HVAC applications as well as the ability to add custom templates as created for other use. Pre-aliased graphic templates may be defined and saved for repetitive representations of common mechanical and electrical equipment.
    c) A full suite of pre-defined three dimensional symbols for mechanical and electrical systems as well as all line, text and shape tools required for integration into a graphic with zoom and pan capabilities on multiple platforms and in multiple browsers.
    d) The ability to search and replace items in multiple graphics with a single command.
    e) The ability to import and insert photos and images into the graphic.
    f) The ability of the graphics manager to create and edit graphics including the ability to bind graphic elements to the values and conditions of system points in both an on-line and off-line mode.
    g) The ability to create and import custom SVG symbols that can be selectable from the graphical palette and rendered at runtime.
6) As required, the BAS Contractor shall provide software licenses in the name of the owner for programming, configuration and graphics building tools to allow designated representatives to make changes, modifications or additions to the system. While future updates or revisions may require an update fee, the owner shall incur no additional cost if they choose not to update. Systems that require any annual or time-limited licensing fees shall not be permitted.

t. Scheduling
    1) The user interface shall provide the capability to display, in a singular view, all of the effective schedules in the context of the space (building/floor/room, etc.) or equipment that the schedule effects. The software should have the ability to display an effective schedule, for the present, or a future date.
    2) The user interface shall provide a report of all schedules affecting a space or equipment. The report shall provide the user details of events that comprise the weekly schedule and exception schedule(s). The report shall provide a means of viewing individual breakout scheduling elements for Weekly Schedule, Exceptions and Default Commands.
    3) The user interface shall provide the capability to efficiently change or modify schedules in mass quantities. This includes the capability to add, in bulk, exceptions to schedules, in addition to assigning, in bulk, weekly schedules.

u. Command and Control

1) Provide a means to command system analog and binary points via a dropdown menu accessed by clicking or tapping on the value shown in any equipment summary or graphic display and completing the task in the resultant menu including an optional annotation.
2) Commanding multiple points shall be possible on displays where multiple like system elements can be chosen.
3) The user interface shall support users adding notes on their commands.
4) The user interface shall support a choice of either permanent or temporary commands.

v. Involvement
1) The user interface shall provide in a single screen, a way to visualize all interactions (I.e. - commands, writes, references) with a single object.
2) The interface shall provide the ability to filter out any interactions (i.e. commands, writes, references) that are not pertinent.
3) The user interface shall allow seamless navigation between one object's Involvement view to another object's.

w. System-Level Activity
1) The user interface shall provide a timeline view of all audits that occur in the system, including:
a) Logins attempts with user specified
b) Add, delete, modification of objects
c) Commands

x. Search
1) Typing a text string in the Search box shall display a list of all occurrences of that string in the mobile user interface. When a string is represented in the description of a space or network element, selecting it shall display its default dashboard.
2) Clicking or tapping on the Advanced Search Icon shall display the Advanced Search dialog box permitting the following:
a) Search by Space and Equipment, Equipment Definition or Network Reference
b) Filter the search by wildcard name or object type
c) Multi-selection of objects for commanding or the creation of reports including Trend, Alarm, Audit and Activity for a specific period of time
d) Creation of reports in PDF or CSV formats which can be instantaneously downloaded or emailed, or scheduled to be sent at Operator-selected intervals (daily/weekly/monthly)

y. Software Updates
1) Users shall be notified when new software becomes available for download.
2) Users shall be given brief information on what's to be expected in the update.

z. Offline Operation
1) The mobile user interface shall have the ability to operate in an offline mode in order to create or edit graphics and dashboard elements.
2) Content created offline shall be available to all authorized users for inclusion of an operating user interface later.

aa. Fault Detection

1) Fault detection functionality shall be provided that identifies and displays building system-related faults and lists them color coded in order of severity. This software shall leverage defined rules and a semantic data model to ease configuration.
    a) The building system fault engine shall run periodically against a minimum of seven days of historical data.

bb. Fault Triage
1) Provide a means to display additional information on a particular fault along with corrective actions in the order of their likeliness to resolve the issue, a description of the fault, charting of supporting data, and an activity log to track progress of triage attempts. Functionality shall enhance the sorting order and information in the Faults display to introduce fault occurrences and durations to better drive the most problematic issues to the top of the list.

D. Associated Application Components
1. Security/Passwords
    a. Multiple-level passwords access protection shall be provided via roles and permissions. The feature will allow the system to base access on a user's job title or role and allow the user/manager access interface control, display, and database manipulation capabilities based on an assigned password.
    b. Roles may be copied and altered to meet specific roles and permissions based on the particular policies.
    c. The system shall allow each user to change his or her password at will.
    d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
    e. A maximum of 150 categories may be used to determine or assign areas of responsibilities to each user account.
    f. A minimum of 100 unique passwords shall be supported.
    g. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
    h. Operators shall be further limited to only access, command, and modify those buildings, systems, and subsystems for which they have responsibility. Provide a minimum of 100 categories of systems to which individual operators may be assigned.
    i. The system shall automatically generate a report of log-on/log-off and system activity for each user.
    j. The system shall have the ability to provide a Department of Defense (DoD) specific warning banner for applicable sites that warns the user they are accessing a restricted site.
    k. After successful login the last time and date that user name was previously logged in is shown on the screen.
    l. Each login attempt is recorded in the system Audit Log with the option to record the IP address of the PC that made the login.
2. Screen Manager
    a. The system will allow a customized image on the login screen (e.g. organization name, logo).

b. User View navigations can be displayed as either a set of tabs or a drop down list.
c. Allows user preference for assigning of a background color for when an object is Out of Service which will enable the operator to quickly distinguish points that have been commanded to this state.
d. The User Interface shall be provided with screen management capabilities that allow the user to activate, close, and simultaneously manipulate a minimum of 4 active display windows plus a network or user defined navigation tree.

3. Historical trending and data collection
   a. Each Network Engine shall store trend and point history data for all analog and digital inputs and outputs, as follows:
      1) Any point, physical or calculated, may be designated for trending. Two methods of collection shall be allowed:
         a) Defined time interval
         b) Upon a change of value
   b. Each Network Engine shall have the capability to store multiple samples for each physical point and software variable based upon available memory, including an individual sample time/date stamp. Points may be assigned to multiple history trends with different collection parameters.

2.5 NETWORK CONTROL ENGINE (NCE)

A. Network Control Engine (NCE)
   1. The Network Control Engine shall be a fully user-programmable, supervisory controller. The NCE shall monitor the network of equipment controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Engines.
   2. The NCE shall also be a fully user-programmable, equipment controller that includes a minimum of 28 I/O points.
   3. Automation Network – The NCE(s) shall reside on the automation network and shall support a subnet system controllers via an integral Control network connection.
   4. Automation network temporary cellular connection – The BAS shall be provided with a temporary connection via a “master” control engine whereby the Automation network and connected “slave” engines can be accessed remotely before Owner’s IT network is operational. This project shall include at least one connected control engine.
      a. The connected control engine shall be a standard catalog product of the BAS manufacturer. Non-standard or custom applications are not acceptable.
      b. This connected control engine shall be panel mounted with a cellular modem, remote antenna and antenna cables, 5 port Ethernet switch, and a power supply with convenience outlet,
      c. The “master” control engine shall communicate with a temporary Automation Data Server which can be used to remotely load graphics, generate and load database, program, commission and demonstrate the BAS.

d. A one-year cellular contract shall be included within this contract at no additional cost to the Owner. Multiple cellular services shall be made available to choose from to allow for best connection strength at the jobsite. The costs of the remote server shall be included within this contract at no additional cost to the Owner.

5. User Interface – Each Network Control Engine shall have the ability to deliver a web-based User Interface previously described. All computers connected physically or virtually to the automation network shall have access to the web-based user interface.
6. Processor – The NCE(s) shall be microprocessor-based with a minimum word size of 32 bits. The Network Control Engine shall be a multi-tasking, multi-user, and real-time digital control process. Standard operating systems shall be employed. NCE(s) size and capability shall be sufficient to fully meet the requirements of this Specification.
7. Memory – Each NCE shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all control level devices.
8. Secure Boot – The NCE shall prevent malicious or unauthorized software applications from loading during the system startup process.
9. Background File Transfer – The NCE shall provide the capability to download a new image and database to a network engine while the engine is still running and controlling the building.
10. User Authentication – The NCE shall support local user authentication.
11. Password Security – Access to the Network Control Engines' embedded user interface shall require a password of 8 to 50 characters including a minimum of one lower case letter, one upper case letter, one number, and one special character. An alarm shall be generated after three unsuccessful attempts within 15 minutes and the user shall be denied access until permission is renewed by a system administrator.
12. Network Security – Communication between the NCE and other system networked devices including additional Network Engines, Application and Data Servers, Open Data Servers (BACnet listed OWS), and user interface clients shall be encrypted and support HTTPS with Transport Level Security (TLS) Version 1.2. Self-signed certificates are to be provided with the option of configuring trusted certificates. Engines shall also be equipped to optionally support FIPS 140-2 Federal Government encryption standard.
13. Hardware Real Time Clock – The Network Control Engine shall include an integrated, hardware-based, real-time clock, with a supercapacitor to maintain time for a minimum of 72 hours during a power loss. Controllers using a battery to maintain time during a power loss shall not be acceptable.
14. Diagnostics – The NCE(s) shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The NCE(s) shall provide both local and remote annunciation of any detected component failures or repeated failures to establish communication.
15. Power Failure – In the event of the loss of normal power, the NCE(s) shall continue to operate for a user adjustable period of up to 10 minutes after which there shall be an orderly shutdown of all programs to prevent the loss of database or operating system software.

a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions. All critical configuration data shall be saved into Flash memory.
b. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.

16. Certification – The NCE(s) shall meet and be listed to the UL 916 Standard for Energy Management Equipment and be FCC Compliant to CFR47, Part 15, Subpart B, Class A.
17. Device Integration – The NCE(s) shall support integrating and supervising networked devices using the following communication protocols on the device/controller network:
    a. The NCE (s) shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135 on the controller network.
        1) The NCE (s) shall support Remote Field Bus integration via a BACnet IP to MS/TP router.
        2) The NCE (s) shall be tested and BTL listed/certified as a BACnet Building Controller (B-BC).
        3) A BACnet Protocol Implementation Conformance Statement shall be provided for the NCE(s).
    b. The NCE(s) shall optionally support integration of networked devices using the following networking protocols:
        1) BACnet
        2) Johnson Controls N2 or third party N2 Open devices.
        3) LonTalk
        4) MODBUS RTU
        5) MODBUS TCP
        6) KNX
        7) M-Bus
        8) OPC UA
18. The NCE shall employ a finite state programming to eliminate unnecessary conflicts between control functions at crossover points in their operational sequences. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.
19. The NCE shall be factory programmed with a continuous adaptive tuning algorithm that senses changes in the physical environment and continually adjusts loop tuning parameters appropriately. Controllers that require manual tuning of loops or perform automatic tuning on command only, shall not be acceptable.
20. The NCE shall support the following types of inputs and outputs:
    a. Universal Inputs – shall be configured to monitor any of the following for Analog inputs: Voltage Mode, Current Mode, Resistive Mode. For Binary Inputs: Dry Contact Maintained Mode, Pulse Counter Mode
    b. Analog Outputs – shall be configured to output either of the following: Voltage Mode, Current Mode
    c. Binary Outputs – shall output the following: 24VAC Triac
    d. Configurable Outputs – shall be configured to output either of the following:
        1) Analog Output Voltage Mode
        2) Binary Output 24 VAC Triac Mode

e. The NCE shall have the ability to monitor and control a network of sensors and actuators over a Sensor Actuator (SA) Bus dedicated to the controller. This bus shall be a MS/TP Bus supporting BACnet Standard protocol SSPC-135 supporting no less than 9 devices with a maximum distance of 1,200 Ft. between the NCE and the furthest connected device.

21. The NCE shall provide removable, labeled, screw terminal blocks for 24 VAC power, communication bus and I/O point field wiring.
22. The NCE shall include the following multi-color, flashing LEDs to indicate important operating conditions and status
23. Communications Ports – The NCE(s) shall provide the following ports for connecting networkable devices:
    a. Two (2) USB ports
    b. One (1) RS-485 port
    c. Two (2) Ethernet ports
24. The NCE shall support an integrated user interface featuring a display and keypad in lieu of on-board HOA switches for output overrides.
    a. The integrated user interface shall allow viewing and monitoring points, alarms, and trends.
    b. The integrated user interface shall allow viewing and changing setpoints, modes of operation, and parameters.
    c. The integrated user interface shall provide password protection with user-adjustable password timeout.
    d. The information presented by the integrated user interface shall be organized into folders for easy navigation.
    e. The integrated user interface shall support textual descriptions in English for each point.
    f. The display shall be, at minimum, a 2.4-inch, color display with 320x240 resolution.
    g. The display shall support adjustable contrast and brightness.
    h. The keypad shall include no more than seven (7) keys.
25. The NCE shall support up to 50 supervised devices across all supported integrations.

2.6 DDC EQUIPMENT CONTROLLERS

A. General Purpose Application Controller (GPAC)
    1. The General Purpose Application Controller (GPAC) shall be a fully programmable, digital controller that communicates via the BACnet MS/TP protocol over the FC Bus.
        a. The GPAC shall support BACnet Standard ANSI/ASHRAE 135.
            1) The GPAC shall be BTL listed/certified.
            2) The GPAC shall be tested and certified as a BACnet Advanced Application Controller (B-AAC).
            3) A BACnet Protocol Implementation Conformance Statement shall be provided for the GPAC.
    2. The GPAC shall employ finite state programming to eliminate unnecessary conflicts between control functions at crossover points in their operational sequenc-

es. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.

3. GPAC shall be factory programmed with a continuous adaptive tuning algorithm that senses changes in the physical environment and continually adjusts loop tuning parameters appropriately. Controllers that require manual tuning of loops or perform automatic tuning on command only shall not be acceptable.
4. The GPAC shall be assembled in a plastic housing with protection class IP20 (IEC529) and flammability rated to UL94-5VB.
5. The GPAC shall include an integral real-time clock and support time-based tasks which enables these field controllers to monitor and control schedules, calendars, alarms, and trends.
6. The GPAC can continue time-based monitoring when offline for extended periods of time from a network.
7. The GPAC can operate as a stand-alone controller in applications that do not require a networked supervisory device or for network applications where it is preferred to have the scheduling, alarming, and/or trending performed locally in the equipment controllers.
8. The GPAC shall include troubleshooting LEDs to indicate the following conditions normal or abnormal operation of power, controller fault, SA bus communications, FC Bus communications, and end of line on/off.
9. The GPAC shall have the ability to transfer and apply firmware files to all SA Bus devices (EOIM, IOM, and networked zone sensors) connected to it.
10. The GPAC shall include removable and labeled screw terminal blocks for all I/O, FC and SA Bus communication, and power wiring connections.
11. The GPAC shall accommodate the direct wiring of analog and binary I/O field points with the following resolution.
    a. Inputs – 24-bit analog-to-digital converter
    b. Outputs – +/- 200 mV accuracy in 0-10 VDC applications
12. The GPAC shall support the following types of inputs and outputs supplied in the amounts required for the specified applications:
    a. Universal Inputs – 0-10 VDC analog input, 4-20 mA analog input, 0-600k ohms analog input, Dry contact binary input
    b. Binary Inputs – Dry Contact Maintained Mode, Pulse Counter Mode
    c. Analog Outputs – 0-10 VDC analog output, 4-20 mA analog output
    d. Binary Outputs – 24 VAC Triac
    e. Configurable Outputs – 0-10 VDC analog output, 24 VAC Triac binary output
13. The GPAC shall have the ability to monitor and control a network of sensors and actuators over a SA Bus.
14. The GPAC shall include three (3) decimal rotary dial switches for setting the BACnet MS/TP device address.
15. The GPAC shall have the capability to execute complex control sequences involving direct wired I/O points as well as input and output devices communicating over a MS/TP Bus.
16. The GPAC shall support a Local Controller Display as a remote device communicating over the SA Bus.
    a. The Display shall use a BACnet Standard SSPC-135 MS/TP protocol.
    b. The Display shall allow the user to view monitored points without logging into the system.

c. The Display shall allow the user to view and change setpoints, modes of operation, and parameters.
d. The Display shall provide password protection with user adjustable password timeout.
e. The Display shall be menu driven with separate paths for:
    1) Input/Output
    2) Parameter/Setpoint
    3) Overrides
f. The Display shall use easy-to-read English text messages.
g. The Display shall allow the user to select the points to be shown and in what order.
h. The Display shall support a back lit LCD with adjustable contrast and brightens and automatic backlight brightening during user interaction.
i. The Display shall have a keypad.
j. The Display shall be panel mountable.

2.7 FIELD DEVICES

A. Expansion Input/Output Module (EIOM)
1. The EIOM provides additional input and output interfaces for use in digital controllers.
2. The EIOM shall communicate with controllers over the FC Bus or the SA Bus.
3. The EIOM shall support BACnet Standard ANSI/ASHRAE 135.
    a. The EIOM shall be BTL listed/certified and carry the BTL Label.
    b. The EIOM shall be tested and certified as a BACnet Smart Actuator (B-SA).
    c. A BACnet Protocol Implementation Conformance Statement shall be provided for the IOM.
4. The EIOM shall include removable screw terminal blocks for all I/O, SA/FC bus communication, and power wiring connections.
5. The EIOM shall include three (3) decimal rotary dial switches for setting the BACnet MS/TP device address.
6. The IOM shall accommodate the direct wiring of analog and binary I/O field points with the following resolution:
    a. Inputs – 24-bit analog-to-digital converter
    b. Outputs – +/- 200 mV accuracy in 0-10 VDC applications
7. The EIOM shall support the following types of inputs and outputs:
    a. Universal Inputs – 0-10 VDC analog input, 4-20 mA analog input, 0-600k ohms analog input, Dry contact binary input
    b. Binary Inputs – Dry Contact Maintained Mode, Pulse Counter Mode
    c. Analog Outputs – 0-10 VDC analog output, 4-20 mA analog output
    d. Binary Outputs – 24 VAC Triac
    e. Configurable Outputs – 0-10 VDC analog output, 24 VAC Triac binary output
8. The EIOM shall include troubleshooting LEDs to indicate the following conditions normal or abnormal operation of power, controller fault, SA bus communications, FC Bus communications, and end of line on/off.

B. Networked Thermostat (TEC)

1. The Networked Thermostat shall include an intuitive User Interface providing plain text messages.
    a. Two-line, 8 character backlit display
    b. LED indicators for Fan, Heat, and Cool status
    c. Five (5) User Interface Keys
        1) Mode
        2) Fan
        3) Override
        4) Degrees C/F
        5) Up/Down
2. The Networked Thermostats shall provide the flexibility to support the following inputs:
    a. Integral Indoor Air Temperature Sensor
    b. Duct Mount Air Temperature Sensor
    c. Remote Indoor Air Temperature Sensor with Occupancy Override and LED Indicator.
    d. Two configurable binary inputs
3. The Networked Thermostats shall provide the flexibility to support the following outputs:
    a. Three Speed Fan Control
    b. On/Off Control
    c. Floating Control
    d. Proportional (0 to 10V) Control

C. Network Sensors (NS)
1. The Network Sensors (NS) shall have the ability to monitor the following variables all within a single wall-mounted enclosure (no exceptions) as required by the systems sequence of operations:
    a. Zone temperature
    b. Zone humidity
    c. Zone carbon dioxide
    d. Zone set point
2. The NS shall transmit the zone information back to the controller on the Sensor-Actuator Bus (SA Bus) using BACnet Standard protocol SSPC-135.
3. The NS shall be BTL listed/certified and carry the BTL Label.
    a. The NS shall be tested and certified as a BACnet Smart Sensors (B-SS).
4. The Network Zone Temperature Sensors shall include the following items:
    a. A backlit LCD to indicate the temperature, humidity and setpoint
    b. An LED to indicate the status of the Override feature
    c. A button to toggle the temperature display between Fahrenheit and Celsius
    d. A button to program the display for temperature or humidity
    e. A button to initiate a timed override command
    f. Available in either surface mount, wall mount, or flush mount
    g. Available with either screw terminals or phone jack

D. VAV Box Controller (VBC)
1. The VAV Box Controller (VBC) shall provide both standalone and networked DDC of pressure independent, VAV terminal units.

2. The VBC controller shall be a fully programmable, digital controller that communicates via BACnet MS/TP protocol over the FC Bus.
    a. The VBC shall support BACnet Standard ANSI/ASHRAE 135.
        1) The VBC shall be BTL listed/certified.
        2) The VBC shall be tested and certified as a BACnet Advanced Application Controller (B-AAC).
        3) A BACnet Protocol Implementation Conformance Statement shall be provided for the VBC.
3. The VBC shall include 14 preloaded single duct VAV box control applications to allow the VBC to be made fully operational without the need to create a custom program.
4. The VBC shall employ finite state programming to eliminate unnecessary conflicts between control functions at crossover points in their operational sequences. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.
5. The VBC shall be factory programmed with a continuous adaptive tuning algorithm that senses changes in the physical environment and continually adjusts loop tuning parameters appropriately. Controllers that require manual tuning of loops or perform automatic tuning on command only shall not be acceptable.
6. The VBC shall be assembled in a plenum-rated plastic housing with protection class IP20 (IEC529) and flammability rated to UL94-5VB.
    a. The VBC shall include an integral real-time clock and support time-based tasks which enables these equipment controllers to monitor and control schedules, calendars, alarms, and trends
7. The VBC can continue time-based monitoring when offline for extended periods of time from a network.
8. The VBC shall include an integral differential pressure transducer and damper actuator. An additional configuration option shall be available that also includes an integral potentiometer for actual damper position feedback. All components shall be connected and mounted as a single assembly, removable as one piece.
9. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 60 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.
10. The VBC shall determine airflow by a state-of-the-art, digital, non-flow pressure sensor that supports automatic correction for polarity on high- and low-pressure DP tube connections to eliminate high- and low-pressure connection mistakes.
11. The VBC shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.
12. The VBC can operate as a stand-alone controller in applications that do not require a networked supervisory device or for network applications where it is preferred to have the scheduling, alarming, and/or trending performed locally in the equipment controllers.
13. The VBC shall include troubleshooting LEDs to indicate the following conditions normal or abnormal operation of power, controller fault, SA bus communications, FC Bus communications, and end of line on/off.
14. The VBC shall have the ability to transfer and apply firmware files to all SA Bus devices (EOIM, IOM, and Networked zone sensors) connected to it.

15. The VBC shall include removable screw terminal blocks for all I/O, FC and SA Bus communication, and power wiring connections.
16. The VBC shall accommodate the direct wiring of analog and binary I/O field points with the following resolution.
    a. Inputs – 24-bit analog-to-digital converter
    b. Outputs – +/- 200 mV accuracy in 0-10 VDC applications
17. The VBC shall support the following types of inputs and outputs supplied in the amounts required for the specified applications:
    a. Universal Inputs – 0-10 VDC analog input, 4-20 mA analog input, 0-600k ohms analog input, Dry contact binary input
    b. Binary Inputs – Dry Contact Maintained Mode, Pulse Counter Mode
    c. Analog Outputs – 0-10 VDC analog output, 4-20 mA analog output
    d. Binary Outputs – 24 VAC Triac
    e. Configurable Outputs – 0-10 VDC analog output, 24 VAC Triac binary output
18. The VBC shall have the ability to monitor and control a network of sensors and actuators over a SA Bus.
19. The VBC shall include three (3) decimal rotary dial switches for setting the BACnet MS/TP device address.
20. The VBC shall have the capability to execute VAV box control sequences involving direct wired I/O points as well as input and output devices communicating over the SA or FC buses.
21. The controller shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.
22. Each controller shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.
23. The controller shall provide the ability to download and upload VAV box control application configuration files, both locally and via the FC Bus. Controllers shall be able to be loaded individually or as a group.
24. Control setpoint changes initiated over the network shall be written to VBC nonvolatile memory.
25. The VBC controller firmware shall be flash-upgradeable remotely via the FC bus.
26. The VBC controller shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.
27. The VBC controller shall interface with balancer tools that allow automatic recalculation of box flow pickup gain ("K" factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.
28. The VBC controller shall have on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop's sample interval, which may be used to continuously monitor and document system performance. The VBC shall calculate Exponentially Weighted Moving Averages (EWMA) for each of the following metrics, which shall be available to the end user for efficient management of the VAV terminals.
29. The controller shall detect system error conditions to assist in managing the VAV zones.
30. The controller shall provide a flow test function to view damper position vs. flow in a graphical format. The information would alert the user to check damper posi-

tion. The VBC would also provide a method to calculate actuator duty cycle as an indicator of damper actuator runtime.

31. The VBC controller shall provide a compliant interface for ASHRAE Standard 62-1989 (indoor air quality) and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.
32. The VBC controller shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

E. System Tools
    1. One software copy of each system tool shall be provided with the BAS.
    2. System Configuration Tool
        a. The Configuration Tool shall be a software package enabling a computer platform to be used as a stand-alone engineering configuration tool for a Network Engine.
        b. The configuration tool shall provide an archive database for the configuration and application data.
        c. The configuration tool shall provide a site discovery feature to automatically discover field devices on connected buses and networks. Automatic discovery shall be available for the following field devices:
            1) BACnet Devices
            2) LonWorks devices
            3) Johnson Controls N2 Bus devices
        d. A wireless access point shall allow a wireless enabled portable PC to make a temporary Ethernet connection to the automation network.
        e. Provide Johnson Controls SCT or approved equal.
    3. Controller Configuration Tool (CCT)
        a. As part of the single software tool environment including system and controller elements, the Controller Configuration Tool (CCT) shall be used to configure, simulate and commission equipment controllers and NCE controllers.
        b. The CCT shall operate in distinct modes to facilitate efficiency at various steps in the steps leading to project completion as well as future upgrades and maintenance
        c. The configuration tool shall be capable of programming the Equipment Controllers.
            1) The configuration tool shall provide the capability to configure, simulate, and commission the Equipment Controllers.
            2) The configuration tool shall allow the equipment controllers to be run in Simulation Mode to verify the applications.
            3) The configuration tool shall contain a library of standard applications to be used for configuration.
        d. The CCT shall provide multiple options for downloading files to the controllers including direct wired, wireless and Ethernet pass thru as dictated by controller type and location.

2.8 INPUT DEVICES

A. General Requirements
   1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors
   1. General Requirements:
      a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
      b. The temperature sensor shall be of the resistance type and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.
      c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:
   2. Room Temperature Sensors
      a. Room sensors shall be constructed for either surface or wall box mounting.
      b. Room sensors shall have the following options when specified:
         1) Set point reset providing a +3 degree (adjustable) range.
         2) Individual heating/cooling set point slide switches.
         3) A momentary override request push button for activation of after-hours operation.
      c. Provide digital display of sensed temperature.
   3. Thermo wells
      a. When thermo wells are required, the sensor and well shall be supplied as a complete assembly, including wellhead and Greenfield fitting.
      b. Thermo wells shall be pressure rated and constructed in accordance with the system working pressure.
      c. Thermo wells and sensors shall be mounted in a threadolet or 1/2” NFT saddle and allow easy access to the sensor for repair or replacement.
      d. Thermo wells shall be constructed of 316 stainless steel.
   4. Outside Air Sensors
      a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
      b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
      c. Temperature transmitters shall be of NEMA 3R construction and rated for ambient temperatures.
   5. Duct Mount Sensors
      a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
      b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
      c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.
   6. Averaging Sensors
      a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.

b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Humidity Sensors
1. The sensor shall be a solid-state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
2. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
3. The humidity transmitter shall meet the following overall accuracy, including lead loss and Analog to Digital conversion. 3% between 20% and 80% RH @ 77 Deg F unless specified elsewhere.
4. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA 3R enclosure with sealtite fittings and stainless steel bushings.
5. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
6. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

D. Carbon Dioxide Sensors
1. Duct Mounted
a. Sensor shall be remote-mounted diffusion-aspirated, single-beam dual-wavelength sensor type with Infrared (IR) source, sample cell, tunable-interference filter, and IR detector. .
b. Sensing cell shall be provided with thirty (30) inch cable for duct mounting.
c. Sensor shall produce linear analog 0-1 Volt DC, 4-20 MA, and binary adjustable switch point form C outputs.
d. Range shall be 0-2000 parts per million with accuracy of two (2) percent.
e. Sensor shall be mounted in weather tight enclosure with forty-one (41) degree Fahrenheit to 104 degree Fahrenheit operating temperature.
f. Sensor shall be capable of maintaining calibration within 2% for a one year period of operation.
2. Wall Mounted
a. Sensor shall be wall-mounted diffusion-aspirated, single-beam dual-wavelength sensor type with Infrared (IR) source, sample cell, tunable-interference filter, and IR detector. .
b. Sensing cell shall be provided with thirty (30) inch cable for duct mounting.
c. Sensor shall produce linear analog 0-1 Volt DC, 4-20 MA, and binary adjustable switch point form C outputs.
d. Range shall be 0-2000 parts per million with accuracy of two (2) percent.
e. Sensor shall be mounted in weather tight enclosure with forty-one (41) degree Fahrenheit to 104 degree Fahrenheit operating temperature.
f. Sensor shall be capable of maintaining calibration within 2% for a one year period of operation.

E. Differential Pressure Transmitters
   1. General Air and Water Pressure Transmitter Requirements:
      a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
      b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
      c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.
      d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.
   2. Low Differential Water Pressure Applications (0” - 20” w.c.)
      a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
      b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      c. .01-20” w.c. input differential pressure range.
      d. 4-20 mA output.
      e. Maintain accuracy up to 20 to 1 ratio turndown.
      f. Reference Accuracy: +0.2% of full span.
   3. Medium to High Differential Water Pressure Applications (Over 21” w.c.)
      a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
         1) Differential pressure range 10” w.c. to 300 PSI.
         2) Reference Accuracy: +1% of full span (includes non-linearity, hysteresis, and repeatability).
      b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
   4. Building Differential Air Pressure Applications (-1” to +1” w.c.)
      a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
      b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
         1) -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
         2) 4-20 mA output.
         3) Maintain accuracy up to 20 to 1 ratio turndown.
         4) Reference Accuracy: +0.2% of full span.
   5. Low Differential Air Pressure Applications (0” to 5” w.c.)

a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
    1) (0.00 - 1.00” to 5.00”) w.c. input differential pressure ranges. (Select range appropriate for system application.)
    2) 4-20 mA output.
    3) Maintain accuracy up to 20 to 1 ratio turndown.
    4) Reference Accuracy: +0.2% of full span.

6. Medium Differential Air Pressure Applications (5” to 21” w.c.)
    a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
        1) Zero & span: (c/o F.S./Deg. F): .04% including linearity, hysteresis and repeatability.
        2) Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
        3) Thermal Effects: <+.033 F.S./Deg. F. over 40□F. to 100□F. (calibrated at 70□F.).
    b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

F. Power Monitoring Devices
    1. Current Measurement (Amps)
        a. Current measurement shall be by a combination current transformer and a current transducer. The current transformer shall be sized to reduce the full amperage of the monitored circuit to a maximum 5 Amp signal, which will be converted to a 4-20 mA DDC compatible signal for use by the Facility Management System.
        b. Current Transformer – A split core current transformer shall be provided to monitor motor amps.
            1) Operating frequency – 50 - 400 Hz.
            2) Insulation – 0.6 Kv class 10Kv BIL.
            3) UL recognized.
            4) Five amp secondary.
            5) Select current ration as appropriate for application.
    2. Current Transducer – A current to voltage or current to mA transducer shall be provided. The current transducer shall include:
        a. 6X input over amp rating for AC inrushes of up to 120 amps.
        b. Manufactured to UL 1244.
        c. Accuracy: +.5%, Ripple +1%.
        d. Minimum load resistance 30kOhm.
        e. Input 0-20 Amps.

f. Output 4-20 mA.
g. Transducer shall be powered by a 24VDC regulated power supply (24 VDC +5%).

G. Power and Energy Meters:
1. Power meters shall be furnished by BAS contractor, installed and wired by the electrical contractor. Communication trunk from the BAS and integration with the BAS shall be provided by the BAS contractor. Power meter(s) shall be compatible with the Building Automation System (BAS) provided under Division 23. Refer to Electrical
2. The power meter shall be fully electronic with multi-line backlit LCD display showing measured parameters as well as alarm functions and pulse output.
3. The power meter shall perform the following measurements:
   a. Accumulated Real Energy (kWh) for each phase and total of all phases
   b. Accumulated Reactive Energy (kVARh) and Apparent Energy (kVAh) totals for all phases
   c. Net Present Demand for Real (kW), Reactive (kVAR) and Apparent (kVA) Power over a user-specified interval (block or sliding window)
   d. Maximum (Peak) Real (kW), Reactive (kVAR) and Apparent (kVA) Demand Intervals
   e. Instantaneous Real (kW), Reactive (kVAR) and Apparent Power (kVA), by phase and in total
   f. Current (amps) for each phase and average of all phases
   g. Phase-to-phase voltage for each phase and average of all phase pairs
   h. Phase-to-neutral voltage for each phase pair and average of all phases
   i. Power factor for each phase and average of all phases
   j. AC frequency
4. The power meter shall communicate using the BACnet MS/TP protocol at speeds from 9600 to 115,200 baud (no parity). The meter shall provide a BACnet Device object, a set of writable Analog Value objects for remote configuration, a set of Analog Input objects to provide access to scaled 32-bit measurement values and their unit types, and a set of Binary Input objects for indicating individual alarm conditions.
5. The meter shall be UL/CUL listed to the latest applicable safety standards.
6. Power meter models shall accept voltage input over the range of 90 to 600 VAC (50 or 60 Hz).
7. The power meter shall accept 0 to 0.333VAC input from up to three current transducers (U018 Rope Style CTs only) from 20 to 5000 amps.
8. The measured energy consumption shall be retained in non-volatile memory for the life of the product warranty.
9. The power meter shall have demand measurement programmable for up to 6 sub-intervals of 10 seconds to 546 minutes duration.
10. Meter shall be optionally available in an outdoor NEMA 4X enclosure.
11. The power meter shall operate from -30°C to +70°C.
12. The power meter shall have dimensions not exceeding 4.2” x 3.6” x 2.3”.
13. The power meter shall meet both ANSI C12.20 .5% and IEC 62053-22 Class .5S real power and energy accuracy specifications.
14. The power meter shall meet IEC 62053-22 Class 2 reactive power and energy accuracy specifications.

15. The power meter shall be configurable for operation on Single Phase (AN or AB), Split Phase (ABN), Delta (ABC), and Wye (ABCN) systems.
16. The power meter shall have automatic phase reversal compensation such that it is insensitive to the CT's load orientation.
17. The power meter shall have separate control power inputs such that is may be powered from a different service than it measures.
18. The power meter shall have Phase Loss Alarm contacts with a user configurable phase loss threshold.
19. The power meter shall have a user-configurable Pulse Contact input to support measurement of other related energy (Gas, Water, Steam, etc.) via BACnet using a simple pulse-output transducer.
20. The power meter shall be configurable for use with Potential Transformers to 5000 volts.
21. The power meter shall support warnings for low power factor (phase current or voltage miss-wired), current over range, voltage over range, and frequency out of range.
22. The product shall have a 5-year warranty.
23. The power meter shall be Veris E50H2 or equivalent.

H. Status and Safety Switches
   1. General Requirements
      a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BAS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.
   2. Current Sensing Switches
      a. The current sensing switch shall be self-powered with solid-state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept overcurrent up to twice its trip point range.
      b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.
      c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   3. Air Filter Status Switches
      a. Differential pressure switches used to monitor air filter status shall be of the automatic reset type with SPDT contacts rated for 2 amps at 120VAC.
      b. A complete installation kit shall be provided, including: static pressure tops, tubing, fittings, and air filters.
      c. Provide appropriate scale range and differential adjustment for intended service.
   4. Air Flow Switches
      a. Differential pressure flow switches shall be bellows actuated mercury switches or snap acting micro-switches with appropriate scale range and differential adjustment for intended service.

5. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120VAC.
    a. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.
6. Low Temperature Limit Switches
    a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
    b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
    c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.

2.9 OUTPUT DEVICES

A. Actuators
1. General Requirements
    a. Damper and valve actuators shall be electronic. Controls submittals shall indicate actuator fail position as normally open or closed.
2. Electronic Damper Actuators
    a. Electronic damper actuators shall be direct shaft mount.
    b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized Based on actuator manufacturer’s recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in either direction, and a gear release to allow manual positioning.
    c. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
    d. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop associated fan. Two-position actuators, as specified in sequences of operations as “quick acting,” shall move full stroke within 20 seconds. All smoke damper actuators shall be quick acting.
3. Electronic Valve Actuators

a. Electronic valve actuators shall be manufactured by the valve manufacturer.
b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
c. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized Based on valve manufacturer's recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.
d. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal, and may be used to parallel other actuators and provide true position indication. The feedback signal of each valve actuator (except terminal valves) shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated pump or chiller.

B. Control Relays
1. Control Pilot Relays
a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
b. Mounting Bases shall be snap-mount.
c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
d. Contacts shall be rated for 10 amps at 120VAC.
e. Relays shall have an integral indicator light and check button.

2.10 MISCELLANEOUS DEVICES

A. Local Control Panels
1. All control panels shall be factory constructed, incorporating the BAS manufacturer's standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance. Control panels shall be fully enclosed, with perforated sub-panel, hinged door, and slotted flush latch.
2. In general, the control panels shall consist of the DDC controller(s), display module as specified and indicated on the plans, and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the con-

trol panel due to function. Where specified the display module shall be flush mounted in the panel face unless otherwise noted.

3. All I/O connections on the DDC controller shall be provide via removable or fixed screw terminals.
4. Low and line voltage wiring shall be segregated. All provided terminal strips and wiring shall be UL listed, 300-volt service and provide adequate clearance for field wiring.
5. All wiring shall be neatly installed in plastic trays or tie-wrapped.
6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

B. Thermostats
1. Electric room thermostats of the heavy-duty type shall be provided for unit heaters, cabinet unit heaters, and ventilation fans, where required. All these items shall be provided with concealed adjustment. Finish of covers for all room-type instruments shall match and, unless otherwise indicated or specified, covers shall be manufacturer’s standard finish.

2.11 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS

A. Furnish local UPS units, of type indicated, installed with DDC system.

B. DIN Rail Mounted UPS:
1. Provide continuous, regulated output power without using batteries during brown-out, surge, and spike conditions.
2. Performance:
   a. Capacity: Load not to exceed 75 percent of rated capacity.
   b. Efficiency: Minimum 94 percent.
   c. Input Voltage: Single phase, 120 V ac, compatible with field power source.
   d. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
   e. Output Voltage: 101 to 132 V ac, while input voltage varies between 89 and 152 V ac.
   f. On Battery Output Voltage: Sine wave.
   g. Inverter Overload Capacity: Minimum 150 percent for 30 seconds.
   h. Battery Backup: Five minutes of operation at full load with battery power.
   i. Battery Recharge Time: Maximum of six hours to 90 percent capacity after full discharge.
   j. Transfer Time: 6 ms.
   k. Surge Voltage Withstand Capacity: IEEE C62.41.1 and IEEE C62.41.2, Categories A and B.
3. Automatic bypass operation during fault or overload conditions.
4. Integral line-interactive, power condition topology to eliminate all power contaminants.
5. Include power switch and visual indication of power, battery, fault, and temperature.
6. Include audible alarm of faults with silence feature.
7. Include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure) and connect points to BAS system.

8. Batteries: Sealed; maintenance free; replacement without dropping load.

C. Tower UPS Models through 1000 VA:
   1. Provide continuous, regulated output power without using batteries during brown-out, surge, and spike conditions.
   2. Performance:
      a. Capacity: Load not to exceed 75 percent of rated capacity.
      b. Efficiency: Complying with ENERGY STAR requirements; minimum 91 percent.
      c. Input Voltage: Single phase, 120 V ac, compatible with field power source.
      d. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
      e. Output Voltage: 101 to 132 V ac, while input voltage varies between 89 and 152 V ac.
      f. On Battery Output Voltage: Sine wave.
      g. Inverter Overload Capacity: Minimum 150 percent for 30 seconds.
      h. Battery Backup: Five minutes of operation at full load with battery power.
      i. Battery Recharge Time: Maximum of four hours to 90 percent capacity after full discharge to cutoff.
      j. Transfer Time: 0 ms.
      k. Surge Voltage Withstand Capacity: IEEE C62.41.1 and IEEE C62.41.2, Categories A and B; 6 kV/200 and 500 A; 100 kHz ring wave.
   3. Automatic bypass operation during fault or overload conditions.
   4. Integral line-interactive, power condition topology to eliminate all power contaminants.
   5. Include power switch and visual indication of power, battery, fault, and temperature.
   6. Include audible alarm of faults and front panel silence feature.
   7. Receptacles: Minimum four>, NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
   8. Remote Alarms: Include dry contacts (digital output points) or serial communication interface for low battery condition and battery-on (primary utility power failure) and connect points to BAS system.
   9. Batteries: Sealed type; maintenance free. Battery replacement is to be front accessible by user without dropping load.
   10. Install tower models in enclosures rated for location.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
   1. Verify compatibility with and suitability of substrates.

B. Examine roughing-in for products to verify actual locations of connections before installation.

1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.

C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.

D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

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

3.2 BAS SPECIFIC REQUIREMENTS

A. Graphic Displays
   1. Provide a color graphic system flow diagram display for each system with all points as indicated on the point list. All terminal unit graphic displays shall be from a standard design library.
   2. User shall access the various system schematics via a graphical penetration scheme and/or menu selection.

B. Actuation / Control Type
   1. Primary Equipment
      a. Controls shall be provided by equipment manufacturer as specified herein.
      b. All damper and valve actuation shall be electric.
   2. Air Handling Equipment
      a. All air handers shall be controlled with a HVAC-DDC Controller
      b. All damper and valve actuation shall be electric.
   3. Terminal Equipment:
      a. Terminal Units (VAV, FCU etc.) shall have electric damper and valve actuation.
      b. All terminal units shall be controlled with HVAC-DDC Controller.

3.3 INSTALLATION

A. BAS Wiring
   1. All conduit, wiring, accessories and wiring connections required for the installation of the Building Automation, as herein specified, shall be provided by the BAS Contractor unless specifically shown on the Electrical Drawings under Division 26 Electrical. All wiring shall comply with the requirements of applicable portions of Division 26 and all local and national electric codes, unless specified otherwise in this section.
   2. All BAS wiring materials and installation methods shall comply with BAS manufacturer recommendations.
   3. The sizing, type and provision of cable, conduit, cable trays, and raceways shall be the design responsibility of the BAS Contractor. If complications arise, however, due to the incorrect selection of cable, cable trays, raceways and/or conduit

by the BAS Contractor, the Contractor shall be responsible for all costs incurred in replacing the selected components.

4. Class 2 Wiring
    a. All Class 2 (24VAC or less) wiring shall be installed in conduit.
    b. Concealed, inaccessible wiring shall be installed in conduit and routed to above nearest accessible ceiling.
    c. Concealed, accessible wiring does not need to be installed in conduit but shall be plenum rated.
    d. Conduit shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements.
5. Class 2 signal wiring and 24VAC power can be run in the same conduit. Power wiring 120VAC and greater cannot share the same conduit with Class 2 signal wiring.
6. Provide for complete grounding of all applicable signal and communications cables, panels and equipment so as to ensure system integrity of operation. Ground cabling and conduit at the panel terminations. Avoid grounding loops.

B. BAS Raceway
1. All wiring shall be installed in blue conduit or raceway except as noted elsewhere in this specification. Minimum control wiring conduit size 1/2”.
2. Where it is not possible to conceal raceways in finished locations, surface raceway (wiremold) may be used as approved by the Architect.
3. All conduits and raceways shall be installed level, plumb, at right angles to the building lines and shall follow the contours of the surface to which they are attached.
4. Flexible Metal Conduit shall be used for vibration isolation and shall be limited to 3 feet in length when terminating to vibrating equipment. Flexible Metal Conduit may be used within partition walls. Flexible Metal Conduit shall be UL listed.

C. Penetrations
1. Provide fire stopping for all penetrations used by dedicated BAS conduits and raceways.
2. All openings in fire proofed or fire stopped components shall be closed by using approved fire resistive sealant.
3. All wiring passing through penetrations, including walls shall be in conduit or enclosed raceway.
4. Penetrations of floor slabs shall be by core drilling. All penetrations shall be plumb, true, and square.

D. BAS Panel Installation
1. The BAS panels and cabinets shall be located as indicated at an elevation of not less than 2 feet from the bottom edge of the panel to the finished floor. Each cabinet shall be anchored per the manufacturer’s recommendations.
2. The BAS contractor shall be responsible for coordinating panel locations with other trades and electrical and mechanical contractors.

E. Input Devices
1. All Input devices shall be installed per the manufacturer recommendation.

2. Locate components of the BAS in accessible local control panels wherever possible.

F. HVAC Input Devices – General
   1. All Input devices shall be installed per the manufacturer recommendation.
   2. Locate components of the BAS in accessible local control panels wherever possible.
   3. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, airflow stations, etc.
   4. Input Flow Measuring Devices shall be installed in strict compliance with ASME guidelines affecting non-standard approach conditions.
   5. Outside Air Sensors
      a. Sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air conditions accurately.
      b. Sensors shall be installed with a rain proof, perforated cover.
   6. Water Differential Pressure Sensors
      a. Differential pressure transmitters used for flow measurement shall be sized to the flow-sensing device.
      b. Differential pressure transmitters shall be supplied with tee fittings and shut-off valves in the high and low sensing pick-up lines.
      c. The transmitters shall be installed in an accessible location wherever possible.
   7. Medium to High Differential Water Pressure Applications (Over 21” w.c.):
      a. Air bleed units, bypass valves and compression fittings shall be provided.
   8. Building Differential Air Pressure Applications (-1” to +1” w.c.):
      a. Transmitters exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind.
      b. The interior tip shall be inconspicuous and located as shown on the drawings.
   9. Duct Temperature Sensors:
      a. Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement.
      b. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate.
      c. For ductwork greater in any dimension than 48 inches or where air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor.
      d. The sensor shall be mounted to suitable supports using factory approved element holders.
   10. Space Sensors:
      a. Shall be coordinated with Architectural plans and mounted per ADA requirements.
      b. In public areas and/or where indicated on plans, provide sensors without controls interface, and/or a lockable interface.
      c. Space air temperature sensors shall be provided in all Electrical, AV, IT, Data, Telecom (TR) and Server rooms. Sensors shall be provided with digital display of sensed temperature.

11. Low Temperature Limit Switches:
    a. Install on the discharge side of the first water or steam coil in the air stream.
    b. Mount element horizontally across duct in a serpentine pattern insuring each square foot of coil is protected by 1 foot of sensor.
    c. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.
12. Air Differential Pressure Status Switches:
    a. Static pressure tips, tubing, fittings, and air filter.
13. Water Differential Pressure Status Switches:
    a. with shut off valves for isolation.
14. Do not cover or conceal sensors with insulation.

G. HVAC Output Devices
1. All output devices shall be installed per the manufacturer's recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, airflow stations, pressure wells, etc.
2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke. When any pneumatic actuator is sequenced with another device, pilot positioners shall be installed to allow for proper sequencing.
3. Control Valves:
    a. Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI.
    b. Install valves in piping with stems as vertical as possible but in no case less than forty-five (45) degrees from vertical. For soldered or welded connections, remove valve internals before installation.
    c. Wire electric valves in accordance with NFPA 70 with not less than two (2) feet of flexible liquidtight connector with watertight bushings at the valve actuator and conduit termination. Brace conduit to the building structure to prevent movement and damage.
4. Electronic Signal Isolation Transducers: Whenever an analog output signal from the Building Automation is to be connected to an external control system as an input (such as a chiller control panel), or is to receive as an input a signal from a remote system, provide a signal isolation transducer. Signal isolation transducer shall provide ground plane isolation between systems. Signals shall provide optical isolation between systems.

H. Label Installation
1. Install or permanently fasten labels on each major item of temperature control equipment.
2. Locate labels where accessible and visible.
3. For equipment, devices, sensors, etc. located above the ceiling, in addition to a label on the equipment, labels are to be permanently affixed to the ceiling grid framing as near to the item as possible using epoxy glue. Where hard ceilings are used, the label is to be affixed to the frame of the access panel for the unit.

3.4 TRAINING

A. The manufacturer shall provide a factory trained instructor to give not less than 8 hours of full instruction to designated personnel in the operation of the system installed. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach.

B. Provide training for Owner's designated operating personnel. Training shall include:
   1. Explanation of drawings, operations and maintenance manuals
   2. Walk-through of the job to locate control components
   3. Operator workstation and peripherals
   4. DDC controller and ASC operation/function
   5. Operator control functions including graphic generation and field panel programming
   6. Explanation of adjustment, calibration and replacement procedures
   7. Electronic Catalog and Materials

C. Since the Owner may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Manufacturer. If such training is required by the Owner, it will be contracted at a later date.

3.5 COMMISSIONING, TESTING AND ACCEPTANCE

A. BAS contractor to the review of the commissioning test scripts, pre-test all system prior to the commissioning functional testing, participate in the commissioning functional testing, be on-site in the Warranty phase during the off-season HVAC testing for heating and cooling functional max load testing.
   1. Prior to system program commissioning, verify that each control panel has been installed according to plans, specifications, and approved shop drawings. Test, calibrate and bring online each control sensor and device.
   2. Pre-testing to include, but not be limited to:
      a. Sensor accuracy at 10, 50 and 90% of range.
      b. Sensor range.
      c. Verify analog limit and binary alarm reporting.
      d. Point value reporting.
      e. Binary alarm and switch settings.
      f. Actuator ranges.
      g. Fail safe operation on loss of control signal, electric power, network communications.

B. BAS contractor shall submit a written "Certificate of Readiness" that indicates all systems have been pre-tested using the Approved Commissioning Functional Test Scripts and resolved all issues with sequences and devices, confirming the BAS is ready for Commissioning Functional Testing.
   1. Certificate of Readiness should be submitted one week prior to the start of the Commissioning Functional Testing and the GC/CM should factor this timing into their Master Construction Schedule.

C. The BAS contractor shall supply all instruments for testing.
   1. Test Instrument Accuracy:
      a. Temperature: ¼ °F or ½% full scale, whichever is less.
      b. High Pressure: ½ psi or ½% full scale, whichever is less.
      c. Low Pressure: ½% full scale
      d. Humidity: 2% RH
      e. Electrical: ¼% full scale

3.6 TEMPERATURE CONTROL

A. The control sequence of operations describe the general operational intent of the control systems. Provide all hardware, software, devices, equipment and wiring as required to perform the operational intent described by the various control sequences and to fully interface with the building automation system (BAS).

B. The control diagrams indicate the general arrangement of system components to the extent that they affect process flow or control. Not all required components are shown on the control diagrams. The contractor shall thoroughly review all contract documents to ascertain the full scope of their work.

C. A full communication interface and complete interoperability with the BAS shall be provided to perform the functions herein described or indicated in the contract documents.

D. For equipment with factory controllers:
   1. The BAS provider and the equipment manufacturer shall provide a complete list of all BACNET points available to be accessed from within the manufacturer's factory controllers and, specifically, identify what points can be read from the BAS, which points can be written too and which points cannot be accessed at all.
   2. The BAS submittal, sequences and points list shall indicate routines that are controlled completely from the manufacturer's controllers, which routines are controlled partially by the manufacturer's controllers and BAS and which routines are controlled completely by the BAS.
   3. The BAS provider and equipment manufacturer, in collaboration, shall provide coordinated submittals that indicate anything that has to be set, reset or accessed in a manufacturer's controller at the piece of equipment as opposed to being accessed at or from the BAS user interface/controller console. This coordination and collaboration shall occur at the submittal phase and well before equipment and controls are delivered to the site.

E. Unless otherwise noted, size all automatic control valves for maximum ten (10) feet water pressure drop at maximum design flow rate.

F. Refer to drawings for locations of all terminal units, room sensors, panels, dampers, valves, and equipment; where such devices are not indicated, however are required by the control sequences to achieve the intended operation, they shall be provided and located in the field where directed by the engineer.

G. Division 26 shall provide all detection devices (heat/smoke) as required by the contract documents. Division 23 shall install all detection devices including required control and power wiring required for mechanical systems. Detection devices shall provide automatic shutdown of the HVAC systems in accordance with the International Mechanical Code.

H. All pumps and fans shall be provided with a differential pressure sensor installed around the pump or fan. Sensor shall provide status indication for pump or fan operation. Current sensors with VA memory may be used instead of differential pressure sensors where indicated or noted.

I. Adjustable freezestats shall be provided at all preheat and heating coils and shall de-energize their respective air handling system when their setting of 35°F is reached. Freezestats for water coils shall be installed in the coil leaving air stream. Freezestats shall be hard wired in the motor starter circuit and send an alarm signal to the BAS when they are activated.

J. All temperature, humidity, pressure, time, etc. set points shall be fully adjustable through the BAS. Final system setpoints will be confirmed through system commissioning and fixed prior to building occupancy. Thereafter setpoints shall be adjustable through the BAS by trained maintenance staff.

K. All two position dampers and valves shall be proven open by the use of end switches.

L. All control devices located within chemical storage areas shall be explosion proof suitably rated for each specific application.

M. Refer to individual input/output summary schedules for additional control devices not specifically described in the control narratives. Input/output summary schedules are minimum requirements; provide all required points for complete operation of the systems.

N. All variable frequency drives (VFD) for fans and pumps shall be soft started at minimum speed and increased to required operating speed by the BAS.

O. Refer to drawings for fans that shall be equipped with an inlet air monitoring device (AMD). Where provided, the BAS shall continuously monitor the airflow rate for the fan. AMD’s for exhaust fans shall be of a material suitable for the intended airstream.

P. Upon failure of any direct digital control (DDC) unit, an alarm shall be indicated on the BAS and the system shall automatically revert to the default cycle. All motors and fans shall remain in their last commanded state. When emergency power is available, the BAS shall monitor each essential power transfer switch and ramp the VFD’s of selected fans and pumps to their lower limits until the emergency generator is stable and online; at which time the normal sequence of operations shall resume for selected fans and pumps.

Q. In general and unless otherwise noted, heating control valves shall fail open, specialist area heating control valves shall fail closed, steam control valves shall fail closed,

chilled water control valves shall fail closed. Isolation dampers at fans and air units shall fail open.

R. Standby chillers, boilers, heat pumps, fans and pumps shall be alternated into operation every 500 hours. The BAS shall alarm for change over; actual change over shall be initiated by trained maintenance personnel through the BAS.

S. HVAC system controls shall not fail and lock out upon loss of power (such as under emergency conditions) and loss of power shall not be alarmed to the BAS.

T. Where used to control both comfort heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 5ºF within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum. Variable air volume (VAV) terminal units shall be programmed to operate at the minimum airflow setting without addition of reheat when the zone temperature is within the set dead band.

END OF SECTION