SECTION 23 0900
BUILDING AUTOMATION AND TEMPERATURE CONTROL SYSTEM

PART 1 GENERAL

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

1.02 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.

1.03 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 BAS shall be a Web based system communicating over the building owners Local Area Network (LAN). Contractor shall be responsible for coordination with the owner’s IT staff to ensure that the BAS will perform in the owner’s environment without disruption to any of the other activities taking place on that LAN. TCP/IP connections and addresses shall be provided by the owner for connection of supervisory panels to the USC network.

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

D. 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.

E. 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.
F. 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.

G. Control contractor shall furnish and field install all air handling unit end devices. Control 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.

H. Air handling unit variable frequency drives shall be furnished and installed by the air handling unit manufacturer. Power wiring shall be provided under Division 26. Refer to Section 230550 "Variable Frequency Drives (VFDs)".

I. Air handling unit end devices shall be furnished by the BAS manufacturer and field installed by the control contractor.

J. Lighting Panel BAS Scope of Work
   1. BAS Controls Contractor shall provide all necessary materials and labor to integrate with the lighting panels (LP) as shown on the electrical drawings.

K. 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 [Agency] IT department requirements so that BAS may be connected to a [Agency] switch(s) once that system is complete. In no case shall [Agency] IT system completion be justification for delay in completing, testing and commissioning BAS system.

1.04 INTERFACE REQUIREMENTS

A. The new system shall be an extension of and connected to the existing [insert existing system] 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 [insert existing system] 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 [insert existing system] 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 [insert existing system] 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 USC 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 [insert existing system] BAS hardware and software. All new controllers shall be compatible with [insert existing system] database and software development tools.

1.05 WORK BY OTHERS

A. Mechanical contractor installs all wells, valves, taps, dampers, flow stations, etc. furnished by BAS manufacturer.

B. 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.

C. 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. DDC control dampers
      b. Airflow sensors, switches and stations
      c. 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

D. 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. Packaged air handling unit controllers

b. Variable-frequency controllers

E. 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.

F. The control manufacturer shall cooperate with the air and water balancing agency in the performance of their work as required or directed.

1.06 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.


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. Workstations.
   b. Servers.
   c. Gateways.
   d. Routers.
   e. DDC controllers.
   f. Enclosures.
   g. Electrical power devices.
   h. UPS units.
   i. Accessories.
   j. Instruments.
   k. Control dampers and actuators.
   l. 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.
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 point of connection to field power with requirements (volts/phase/hertz/amperes/connection type) listed for each.

b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.

c. Each product requiring power with requirements (volts/phase/hertz/amperes/connection type) listed for each.

d. Power wiring type and size, race type, and size 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.
   b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
   c. 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.

1.07 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 017823 "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 DVDs.
   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.

1.08 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 full time, on site, experienced project manager for this work, responsible for direct supervision of the design, installation, start up and commissioning of the BAS.

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.

1.09 PERFORMANCE REQUIREMENTS

A. Comply with the following performance requirements:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.

2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.

3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.

4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.

5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.

6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
7. Performance: Programmable controllers shall execute DDC PID control loops, and scan
and update process values and outputs at least once per second.

8. Reporting Accuracy and Stability of Control: Report values and maintain measured
variables within tolerances as follows:
   a. Water Temperature: Plus or minus 1 deg F.
   b. Water Flow: Plus or minus 2 percent of full scale.
   c. Water Pressure: Plus or minus 2 percent of full scale.
   d. Space Temperature: Plus or minus 1 deg F.
   e. Ducted Air Temperature: Plus or minus 1 deg F.
   f. Outside Air Temperature: Plus or minus 2 deg F.
   g. Dew Point Temperature: Plus or minus 3 deg F.
   h. Temperature Differential: Plus or minus 0.25 deg F.
   i. Relative Humidity: Plus or minus 5 percent.
   j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
   k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
   l. Airflow (Terminal): Plus or minus 10 percent of full scale.
   m. Air Pressure (Space): Plus or minus 0.01-inch wg.
   n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
   o. Carbon Dioxide: Plus or minus 50 ppm.
   p. Electrical: Plus or minus 5 percent of reading.

B. 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.

1.10 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: Five year(s) from date of Substantial Completion.
a. For Gateway: Five-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.

### 1.11 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

2.01 MANUFACTURER

A. Basis-of-Design Product: Subject to compliance with requirements, provide a building automation and temperature control system by iNTREO as provided by Delta Controls.

B. System must extend and connect to the existing network control system.

2.02 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 Automation Engine(s)
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.

2.03 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 Automation Engines (NAE) 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 Automation Engines 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 9600 baud.
3. DDC Controllers shall reside on the control network
4. Wireless communication between DDC controllers is acceptable. All sensors shall be wired.

C. Distributed Web Based User Interface
1. All features and functions of the dedicated user interface previously defined in this document shall be available on any computer connected directly or via a wide area or virtual private network (WAN/VPN) to the automation network and conforming to the following specifications.

2. Alarms
   a. Alarms shall be routed directly from Network Automation Engines to PCs and servers. It shall be possible for specific alarms from specific points to be routed to specific PCs and servers. The alarm management portion of the user interface shall, at the minimum, provide the following functions:
      1) Log date and time of alarm occurrence.
2) Generate a “Pop-Up” window, with audible alarm, informing a user that an alarm has been received.

3) Allow a user, with the appropriate security level, to acknowledge, temporarily silence, or discard an alarm.

4) Provide an audit trail on hard drive for alarms by recording user acknowledgment, deletion, or disabling of an alarm. The audit trail shall include the name of the user, the alarm, the action taken on the alarm, and a time/date stamp.

5) Provide the capability to direct alarms to an e-mail address or alphanumeric pager. This must be provided in addition to the pop up window described above. Systems that use e-mail and pagers as the exclusive means of announcing alarms are not acceptable.

6) Any attribute of any object in the system may be designated to report an alarm.

b. The BAS shall annunciate diagnostic alarms indicating system failures and non-normal operating conditions

3. Reports and Summaries
   a. Reports and Summaries shall be generated and directed to the user interface displays, with subsequent assignment to printers, or disk. As a minimum, the system shall provide the following reports:
      1) All points in the BAS
      2) All points in each BAS application
      3) All points in a specific controller
      4) All points in a user-defined group of points
      5) All points currently in alarm
      6) All points locked out
      7) All BAS schedules
      8) All user defined and adjustable variables, schedules, interlocks and the like.
   
b. Summaries and Reports shall be accessible via standard UI functions and not dependent upon custom programming or user defined HTML pages.
   c. Selection of a single menu item, tool bar item, or tool bar button shall print any displayed report or summary on the system printer for use as a building management and diagnostics tool.
   d. The system shall allow for the creation of custom reports and queries via a standard web services XML interface and commercial off-the-shelf software such as Microsoft Access, Microsoft Excel, or Crystal Reports.
   e. Energy Essentials Software: Provide a focused set of reports that includes essential information required for effective management of energy resources. Required includes but shall not be limited to:
1) Energy Overview
2) Load Profile
3) Simple Energy Cost
4) Consumption
5) Equipment Runtime
6) Electrical Energy
7) Energy Production

- Reports shall be selectable by date, time, area and device. Each report shall include a graphical color visual summary of essential energy information.

4. Schedules
   a. A graphical display for time-of-day scheduling and override scheduling of building operations shall be provided. At a minimum, the following functions shall be provided:
      1) Weekly schedules
      2) Exception Schedules
      3) Monthly calendars.
   b. Weekly schedules shall be provided for each group of equipment with a specific time use schedule.
   c. It shall be possible to define one or more exception schedules for each schedule including references to calendars.

5. Password
   a. Multiple-level password access protection shall be provided to allow the user/manager to user interface control, display, and database manipulation capabilities deemed appropriate for each user, based on an assigned password.
   b. A minimum of five levels of access shall be supported individually or in any combination as follows:
      1) Level 1 = View Data
      2) Level 2 = Command
      3) Level 3 = Operator Overrides
      4) Level 4 = Database Modification
      5) Level 5 = Database Configuration
      6) Level 6 = All privileges, including Password Add/Modify
   c. 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.

6. Dynamic Color Graphics
a. The graphics application program shall be supplied as an integral part of the User Interface. Browser or Workstation applications that rely only upon HTML pages shall not be acceptable.

b. The graphics applications shall include a create/edit function and a runtime function. The system architecture shall support an unlimited number of graphics documents (graphic definition files) to be generated and executed.

c. The graphics shall be able to display and provide animation based on real-time data that is acquired, derived, or entered.

7. Historical trending and data collection

a. Each Automation 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. Three methods of collection shall be allowed:
      
      a) Defined time interval
      b) Upon a change of value
   
   2) Each Automation 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.

b. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in either Microsoft Access or SQL database format.

8. Trend data viewing and analysis

a. Provide a trend viewing utility that shall have access to all database points.

b. It shall be possible to retrieve any historical database point for use in displays and reports by specifying the point name and associated trend name.

c. The trend viewing utility shall have the capability to define trend study displays to include multiple trends

d. Displays shall be able to be single or stacked graphs with on-line selectable display characteristics, such as ranging, color, and plot style.

e. Display magnitude and units shall both be selectable by the operator at any time without reconfiguring the processing or collection of data. This is a zoom capability.

f. Display magnitude shall automatically be scaled to show full graphic resolution of the data being displayed.

g. Trend studies shall be capable of calculating and displaying calculated variables including highest value, lowest value and time based accumulation.

2.04 NETWORK AUTOMATION ENGINES (NAE)

A. Network Automation Engine (NAE)
1. The Network Automation Engine (NAE) shall be a fully user-programmable, supervisory controller. The NAE shall monitor the network of distributed application-specific controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Automation Engines.

2. Automation network – The NAE shall reside on the automation network and shall support a subnet of system controllers.

3. Processor – The NAE shall be microprocessor-based with a minimum word size of 32 bits. The NAE shall be a multi-tasking, multi-user, and real-time digital control processor. Standard operating systems shall be employed. NAE size and capability shall be sufficient to fully meet the requirements of this Specification.

4. Memory – Each NAE shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all control level devices.

5. Diagnostics – The NAE shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The Network Automation Engine shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

6. Power Failure – In the event of the loss of normal power, The NAE 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.

2.05 DDC SYSTEM CONTROLLERS

A. Field Equipment Controller (FEC)

1. The Field Equipment Controller (FEC) shall be a fully user-programmable, digital controller that communicates via BACnet MS/TP protocol.

2. Controllers 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.

3. The FEC shall be assembled in a plenum-rated housing with flammability rated to UL94-5VB.

4. The FEC shall include a removable base to allow pre-wiring without the controller.

5. The FEC shall accommodate the direct wiring of analog and binary I/O field points.

6. The FEC shall support the following types of inputs and outputs:
a. Universal Inputs - shall be configured to monitor any of the following:
   1) Analog Input, Voltage Mode
   2) Analog Input, Current Mode
   3) Analog Input, Resistive Mode
   4) Binary Input, Dry Contact Maintained Mode
   5) Binary Input, Pulse Counter Mode

b. Binary Inputs - shall be configured to monitor either of the following:
   1) Dry Contact Maintained Mode
   2) Pulse Counter Mode

c. Analog Outputs - shall be configured to output either of the following
   1) Analog Output, Voltage Mode
   2) Analog Output, current Mode

d. Binary Outputs - shall output the following:
   1) 24 VAC Triac

e. Configurable Outputs - shall be capable of the following:
   1) Analog Output, Voltage Mode
   2) Binary Output Mode

7. The FEC shall have the ability to reside on a Field Controller Bus (FC Bus).
   a. The FC Bus shall be a Master-Slave/Token-Passing (MS/TP) Bus supporting BACnet
   b. The FC Bus shall support communications between the FECs and the NAE.
   c. The FC Bus shall support a minimum of 100 IOMs and FEC in any combination.
   d. The FC Bus shall operate at a maximum distance of 15,000 Ft. between the FEC
      and the furthest connected device.

8. The FEC shall have the ability to monitor and control a network of sensors and actuators
   over a Sensor-Actuator Bus (SA Bus).
   a. The SA Bus shall be a Master-Slave/Token-Passing (MS/TP) Bus supporting BACnet
   b. The SA Bus shall support a minimum of 10 devices per trunk.
   c. The SA Bus shall operate at a maximum distance of 1,200 Ft. between the FEC and
      the furthest connected device.

9. The FEC shall support, but not be limited to, the following:
   a. Hydronic water applications
   b. Built-up air handling units for special applications
   c. Terminal units
   d. Special programs as required for systems control.
2.06 OPERATOR INTERFACE

A. Basic Interface Description

1. Operator interface software shall minimize operator training through the use of English language prompting, 30 character English language point identification, on-line help, and industry standard PC application software. The software shall provide, as a minimum, the following functionality:

   a. Real-time graphical viewing and control of environment.
   b. Scheduling and override of building operations.
   c. Collection and analysis of historical data.
   d. Point database editing, storage and downloading of controller databases.
   e. Alarm reporting, routing, messaging, and acknowledgment.

B. Dynamic Color Graphic Displays

1. The BAS interface and color graphics shall be standard and consistent for all similar systems (system to system) [and for all buildings (building to building) within the campus/district]. Graphics to be created include, but are not limited to:

   a. Landing page
   b. Building floor plan
   c. Hydronic equipment and associated loops
   d. Air handling units
   e. Terminal units
   f. Split system air-conditioning units
   g. Fan coil units
   h. Exhaust fans.
   i. Computer room air conditioning units.

2.07 FIELD DEVICES

A. Input/Output Module (IOM)

1. The Input/Output Module (IOM) provides additional inputs and outputs for use in the FEC.

2. The IOM shall communicate with the FEC over either the FC Bus or the SA Bus using BACnet Standard protocol SSPC-135, Clause 9.

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
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. VAV Modular Assembly (VMA)

1. The VAV Modular Assembly shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units. It shall address both single and dual duct applications.

2. The VAV Modular Assembly shall communicate over the FC Bus using BACnet Standard protocol SSPC-135, Clause 9.

3. The VAV Modular Assembly shall have internal electrical isolation for AC power, DC inputs, and MS/TP communications. An externally mounted isolation transformer shall not be acceptable.

4. The VAV Modular Assembly shall be a configurable digital controller with integral differential pressure transducer and damper actuator. All components shall be connected and mounted as a single assembly that can be removed as one piece.

5. The VAV Modular Assembly shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.

6. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

7. The controller shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.
8. Each controller shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

9. The controller shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

10. 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.

11. The controller shall provide the ability to download and upload VMA configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

12. Control set point changes initiated over the network shall be written to VMA non-volatile memory to prevent loss of set point changes and to provide consistent operation in the event of communication failure.

13. The controller firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

14. The controller shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

15. The 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 set points.

16. Controller performance shall be self-documenting via 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 VMA shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
   a. Absolute temperature loop error.
   b. Signed temperature loop error.
   c. Absolute airflow loop error.
   d. Signed airflow loop error.
   e. Average damper actuator duty cycle.

17. The controller shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
   a. Unreliable space temperature sensor.
   b. Unreliable differential pressure sensor.
   c. Starved box.
   d. Actuator stall
e. Insufficient cooling.

f. Insufficient heating.

18. 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 position. The VMA would also provide a method to calculate actuator duty cycle as an indicator of damper actuator runtime.

19. The 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.

20. The 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.

21. Inputs:
   a. Analog inputs with user defined ranges shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
      1) 0-10 VDC Sensors
      2) 1000ohm RTDs
      3) NTC Thermistors
   b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
   c. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.
   d. Provide side loop application for humidity control.

22. Outputs
   a. Analog outputs shall provide the following control outputs:
      1) 0-10 VDC
   b. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
   c. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

23. Application Configuration
   a. The VAV Modular Assembly shall be configured with a software tool that provides a simple Question/Answer format for developing applications and downloading.

24. Sensor Support
   a. The VAV Modular Assembly shall communicate over the Sensor-Actuator Bus (SA Bus) with a Network Sensor.
   b. The VMA shall support an LCD display room sensor.
   c. The VMA shall also support standard room sensors as defined by analog input requirements.
d. The VMA shall support humidity sensors defined by the AI side loop.

D. Network Sensors (NS)

1. The Network Sensors (NS) shall have the ability to monitor the following variables as required by the systems sequence of operations:
   a. Zone temperature
   b. Zone humidity
   c. Zone carbon dioxide
   d. Zone set point


3. The Network Sensors shall include the following items:
   a. A backlit Liquid Crystal Display (LCD) to indicate the Temperature, Humidity and Set point.
   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 initiate a timed override command

4. The NS shall be available with either screw terminals or phone jack.

5. The NS shall be available in either surface mount or wall mount styles.

2.08 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 slide switch 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.

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 sealite 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. Air Flow Monitoring - Fan Inlet Airflow Measuring Station (AFMS)

1. Subject to compliance with all requirements of this section, provide EBTRON, Inc. Model GTx108-F (basis of design) or approved equal.

2. Airflow measurement devices shall use the principle of thermal dispersion and provide one self-heated bead-in-glass thermistor and one zero power bead-in-glass thermistor at each sensing node.

a. Thermal dispersion devices that indirectly heat a thermistor are not acceptable.
3. General
   a. Provide one AMD for each measurement location provided on the plans, schedules and/or control diagrams to determine the average airflow rate and temperature of each fan at each measurement location.
   b. Each AMD shall be provided with a microprocessor-based transmitter and one or more sensor probes.
      1) Devices that have electronic signal processing components on or in the sensor probe are not acceptable.
   c. Airflow measurement shall be field configurable to determine the average actual or standard mass airflow rate.
      1) Actual airflow rate calculations shall have the capability of being field adjusted by the transmitter for altitudes other than sea level.
   d. Temperature output shall be field configurable to provide either the velocity-weighted duct average temperature or simple arithmetic average temperature.

4. Sensor Probes
   a. Each sensor probe shall consist of one sensor node mounted on a 304 stainless steel block with two adjustable zinc plated steel rods connected to 304 stainless steel pivoting mounting feet.
   b. Sensor node internal wiring connections shall be sealed and protected from the elements and suitable for direct exposure to water.
   c. Each sensor probe shall be provided with an integral, FEP jacket, plenum rated CMP/CL2P, UL/cUL Listed cable rated for exposures from -67°F to 392°F and continuous and direct UV exposure.
      1) Plenum rated PVC jacket cables are not acceptable.
   d. Each sensor probe cable shall be provided with a connector plug with gold plated pins for connection to the transmitter.
   e. Sensor node airflow and temperature calibration data shall be stored in a serial memory chip in the cable connecting plug and not require matching or adjustments to the transmitter.
   f. Each sensor node shall be provided with two bead-in-glass, hermetically sealed thermistors potted in a marine grade waterproof epoxy.
      1) Devices that use epoxy or glass encapsulated chip thermistors are not acceptable.
   g. Each thermistor shall be individually calibrated at a minimum of 3 temperatures to NIST-traceable temperature standards.
   h. Each sensor node shall be individually calibrated to NIST-traceable airflow standards at a minimum of 16 calibration points.
   i. The number of independent sensor nodes provided shall be as follows:
5. Transmitter

a. A remotely located microprocessor-based transmitter shall be provided for each measurement location.

b. The transmitter shall be comprised of a main circuit board and interchangeable interface card.

c. All printed circuit board interconnects, edge fingers, and test points shall be gold plated.

d. All printed circuit boards shall be electroless nickel immersion gold (ENIG) plated.

e. All receptacle plug pins shall be gold plated.

f. The transmitter shall be capable of determining the average airflow rate and temperature of each fan.

1) Separate integration buffers shall be provided for display airflow output, airflow signal output (analog and network) and individual sensor output (IR-interface).

g. The transmitter shall have startup firmware to facilitate setup of multiple fans and fan areas.

h. The transmitter shall be capable of providing a high and/or low airflow alarm.

i. The transmitter shall be capable of providing individual fan alarming on fan array configurations.

j. The transmitter shall be capable of identifying an AMD malfunction via the system status alarm and ignore any sensor node that is in a fault condition.

k. The transmitter shall be provided with a 16-character, alpha-numeric, LCD display.

1) The total airflow rate, temperature, airflow alarm, individual fan alarm and system status alarm shall be visible on the display.

l. The transmitter shall be provided with two field selectable (0-5/0-10 VDC or 4-20mA), scalable, isolated and over-current protected analog output signals and either:

1) one isolated RS-485 (field selectable BACnet MS/TP or Modbus RTU) network connection; or

2) one isolated Ethernet (simultaneously supported BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection. Note: LonWorks capable models shall be provided without analog outputs.
m. Analog signal capability shall include two output terminals: the first, shall provide the total airflow rate; while the second output shall be field configurable to provide one of the following:

1) temperature
2) airflow alarm
3) individual fan alarm; or
4) system status alarm

n. Network communications shall provide: the total airflow rate, average temperature, individual fan airflow rates, individual fan temperatures, airflow alarm, individual fan alarm, system status alarm, individual sensor node airflow rates, individual sensor node temperatures and fan inlet area.

o. The transmitter shall be powered by 24 VAC and use a switching power supply that is over-current and over-voltage protected.

p. The transmitter shall use a “watchdog” timer circuit to ensure continuous operation in the event of brown-out and/or power failure.

6. Performance

a. Each sensing node shall have an airflow accuracy of ±2% of reading over an operating range of 0 to 10,000 FPM.

1) Accuracy shall include the combined uncertainty of the sensor nodes and transmitter.

   a) Devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter shall demonstrate compliance with this requirement over the entire operating range.

b. Each sensing node shall have a temperature accuracy of ±0.15° F over an operating range of -20° F to 160° F.

7. Install in accordance with manufacturer’s placement and installation guidelines.

G. Air Flow Monitoring – Duct Mounted

1. Provide airflow temperature measurement devices where indicated on the plans. Airflow devices shown on HVAC equipment schedules shall be provided and factory installed by the equipment manufacturer. Airflow devices will be as specified in the central control and monitoring specification.

2. Each measuring device shall consist of one or more multi-point measuring probes and a single microprocessor-based transmitter. Each transmitter shall operate on 24VAC.

3. Each sensing point shall independently determine the airflow rate and temperature, which shall be equally weighted and averaged by the transmitter prior to output.

4. Each independent airflow sensor shall have a laboratory accuracy of +/-2% of reading over the entire operating airflow range of 0-5000FPM and be wind tunnel calibrated or verified against standards that are traceable to NIST.
a. The number of sensor housings provided for each location shall be:

<table>
<thead>
<tr>
<th>Duct or Plenum Area (ft²)</th>
<th>Total # Nodes / Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>4</td>
</tr>
<tr>
<td>2 to &lt; 4</td>
<td>6</td>
</tr>
<tr>
<td>4 to &lt; 8</td>
<td>8</td>
</tr>
<tr>
<td>8 to &lt; 16</td>
<td>12</td>
</tr>
<tr>
<td>≥ 16</td>
<td>16</td>
</tr>
</tbody>
</table>

5. The transmitter shall be capable of communicating with the host controls using the following interface options:
   a. Linear analog output signal: Field selectable, fuse protected and isolated, 0-10VDC and 4-20mA (4 wire)
   b. RS-485: Field selectable N2 Bus

6. Acceptable Manufacturers: Ebtron

H. 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 ratio 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%).

I. 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 over-current 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.

J. 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 be Veris E50H2A or equivalent.
14. The power meter shall meet both ANSI C12.20 .5% and IEC 62053-22 Class .5S real power and energy accuracy specifications.
15. The power meter shall meet IEC 62053-22 Class 2 reactive power and energy accuracy specifications.
16. The power meter shall be configurable for operation on Single Phase (AN or AB), Split Phase (ABN), Delta (ABC), and Wye (ABCN) systems.
17. The power meter shall have automatic phase reversal compensation such that it is insensitive to the CT’s load orientation.
18. The power meter shall have separate control power inputs such that it may be powered from a different service than it measures.
19. The power meter shall have Phase Loss Alarm contacts with a user configurable phase loss threshold.
20. 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.
21. The power meter shall be configurable for use with Potential Transformers to 5000 volts.
22. 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.
23. The product shall have a 5-year warranty.

2.09 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.

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 control 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.

C. Isolation Room Pressure Monitor
   1. Basis-of-Design Product: Subject to compliance with requirements, provide TSI PresSura RPM10 or comparable product by one of the following:
      a. Dwyer Instruments, Inc
      b. Setra Systems
      c. TSI Incorporated
2. Sensor
   a. Range: -0.20000 to +0.20000 in H2O
   b. Accuracy: ±10% of reading ±0.00001 in H2O
   c. Resolution: 5% of reading
   d. Temperature Compensation Range: 55 to 95 °F

3. Alarms
   a. Low Alarm: -0.19500 to +0.19500 in H2O
   b. High Alarm: -0.19500 to +0.19500 in H2O

4. Touchscreen Display
   a. Size 4.3 in. diagonal
   b. Resolution QVGA

5. Dimensions:
   a. 7 in. x 5.875 in. x 1.75 in.
   b. Protrusion from wall 0.625 in.
   c. Mounts to triple-gang standard depth electrical box

6. Inputs
   a. Exhaust Flow 0-10 VDC
   b. Remote Keyswitch Open/Closed Signal
   c. Pressure Transducer 0-10 VDC
   d. Room Pressure Sensor 0-10 VDC
   e. Door Switch Open/Closed Signal
   f. Room Occupancy Open/Closed Signal

7. Analog Output: (1) Flow or Room Pressure Differential 0-10 VDC or 4-20 mA
8. Contact Outputs: Low Alarm and High Alarm / Room Mode
9. Communications Protocols: compatible with USC Johnson Controls Metasys management system
10. Input Power: 24 VAC, 60 Hz

PART 3 EXECUTION

3.01 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.

3.02 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.

3.03 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 unless otherwise specified.
   b. Conduit is not required for Class 2 wiring in concealed accessible locations. Class 2 wiring not installed in conduit shall be supported every 5’ from the building structure utilizing metal hangers designed for this application. Wiring 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 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 Identification Standards
   1. Node Identification. All nodes shall be identified by a permanent label fastened to the enclosure. Labels shall be suitable for the node location.
2. Cable types specified in Item A shall be color coded for easy identification and troubleshooting.

E. 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.

F. 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.

G. 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.
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:
10. Space Sensors:
   a. Shall be coordinated with Architectural plans and mounted per ADA requirements.
   b. Provide lockable tamper-proof covers in public areas and/or where indicated on the plans.

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.

H. 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 Dampers: Shall be opposed blade for modulating control of airflow. Parallel blade dampers shall be installed for two position applications.
   4. 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.

5. 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.

3.04 TRAINING

A. The manufacturer shall provide factory trained instructor to give 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. The manufacturer shall provide all students with a student binder containing product specific training modules for the system installed. All training shall be held during normal working hours of 8:00 am to 4:30 PM weekdays.

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. Student binder with training modules

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.

3.05 COMMISSIONING, TESTING AND ACCEPTANCE

A. Perform a three-phase commissioning procedure consisting of field I/O calibration and commissioning, system commissioning and integrated system program commissioning. Document all commissioning information on commissioning data sheets which shall be submitted prior to acceptance testing. Commissioning work which requires shutdown of system or deviation from normal function shall be performed when the operation of the system is not required. The commissioning must be coordinated with the owner and
construction manager to ensure systems are available when needed. Notify the operating personal in writing of the testing schedule so that authorized personnel from the owner and construction manager are present throughout the commissioning procedure.

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 on line each control sensor and device. Commissioning 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. After control devices have been commissioned (i.e. calibrated, tested and signed off), each BMS program shall be put on line and commissioned. The contractor shall, in the presence of the owner and construction manager, demonstrate each programmed sequence of operation and compare the results in writing. In addition, each control loop shall be tested to verify proper response and stable control, within specified accuracy's. System program test results shall be recorded on commissioning data sheets and submitted for record. Any discrepancies between the specification and the actual performance will be immediately rectified and retested.

C. After all BMS programs have been commissioned, the contractor shall verify the overall system performance as specified. Tests shall include, but not be limited to:
   1. Data communication, both normal and failure modes.
   2. Fully loaded system response time.
   3. Impact of component failures on system performance and system operation.
   4. Time/Date changes.
   5. End of month/ end of year operation.
   7. Global application programs and point sharing.
   8. System backup and reloading.
   10. Diagnostic functions.
   11. Power failure routines.
   12. Battery backup.
13. Smoke Control, stair pressurization, stair, vents, in concert with Fire Alarm System testing.
14. Testing of all electrical and HVAC systems with other division of work.

D. Submit for approval, a detailed acceptance test procedure designed to demonstrate compliance with contractual requirements. This Acceptance test procedure will take place after the commissioning procedure but before final acceptance, to verify that sensors and control devices maintain specified accuracy's and the system performance does not degrade over time.

E. Using the commissioning test data sheets, the contractor shall demonstrate each point. The contractor shall also demonstrate all system functions. The contractor shall demonstrate all points and system functions until all devices and functions meet specification.

F. The contractor shall supply all instruments for testing and turn over same to the owner after acceptance testing.
   1. All test instruments shall be submitted for approval.
   2. 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: ½% full scale

G. After the above tests are complete and the system is demonstrated to be functioning as specified, a thirty day performance test period shall begin. If the system performs as specified throughout the test period, requiring only routine maintenance, the system shall be accepted. If the system fails during the test, and cannot be fully corrected within eight hours, the owner may request that performance tests be repeated.

3.06 TEMPERATURE CONTROL

A. The sequences on the drawings describe the general intent of the control systems. Provide all devices, equipment, and wiring as required to perform the sequences described.

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

C. See plans for locations of all room thermostats, humidistats, carbon dioxide sensors, ammonia sensors, panels, dampers, valves, and equipment; where such devices are not indicated, however required by the sequences they shall be provided and located in the field by the Architect.

D. Division 26 shall provide all detection devices (heat/smoke) as required by NFPA Standard 90A and the International Building and Mechanical Codes. The installation of detection devices and all control/power wiring for smoke detection devices and smoke dampers shall be
provided under this section. Detection devices shall provide automatic shutdown of the HVAC systems in accordance with NFPA 90A.

E. All fans shall be provided with a current sensors installed around the pump or fan. Sensors shall provide status for pump and fan operation.

F. Adjustable freezestats shall be provided at all preheat and heating coils and shall de-energize their respective air handling system when their setting of thirty-five (35) degrees Fahrenheit is reached. Freezestats for water coils shall be installed in coil leaving air stream.

G. All temperature, humidity, pressure, and time set points shall be fully adjustable from the BAS.

H. 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 5°F 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 deadband.

I. Provide all hardware, software, devices, equipment, and wiring as required to interface with the BAS.

J. All two (2) position dampers shall be proven open by the use of end switches.

K. Refer to input/output summary schedule for additional control items not described in the sequences. Input/output summary are minimum requirements, provide all required points for complete operation of system.

L. All variable frequency drives for fan speed control shall be soft started at minimum speed and increased to operating speed by the BAS.

M. Carbon dioxide (CO2) monitors shall be provided for each air handling system on this project to provide continuous monitoring of CO2 levels. Abnormal levels of CO2 shall be detected by the monitors and alarmed on the BAS.