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Addendum #2
File # 16-0274
Project: Lakewood Water Treatment Plant HVAC System Improvements

This addendum serves to notify all bidders of the following changes to the solicitation documents:

NOTICE
This Addendum is issued to modify, explain or correct the original drawings, specifications and/or previous addendums and is hereby made a part of the Contract Documents.

PROJECT MANUAL

DIVISION 23 - HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

ADD Section 23 90 00 HVAC CONTROLS

REPLACE in its entirety Section 23 92 00 VARIABLE FREQUENCY DRIVES

ADD Section 23 98 00 HVAC INSTRUMENTATION

Please acknowledge receipt of the Addendum by initially and dating Addendum #2 below the bid form on the invitation for bids.

Posted March 17, 2016

SECTION 23 90 00

HVAC CONTROLS

PART 1 GENERAL

1.01 APPLICABILITY

A. This Section covers HVAC control systems and components and applies to and forms a part of Division 23, Section 23 06 00 - SCHEDULES FOR HEATING, VENTILATING AND AIR CONDITIONING.

1.02 SCOPE OF WORK

A. The Building Automation System (BAS) shall be a complete system designed for scalable implementation from small stand-alone use to large, networked systems. This functionality shall extend into the equipment rooms. Devices residing on the enterprise IT network shall be fully IT compatible devices that mount and communicate directly on the IT infrastructure in the facility. 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.

B. All points of user interface shall be accessible on a standard Web Browser

C. The work of the single BAS Contractor shall be as defined individually and collectively in all Sections of this Division specification together with the associated Point Sheets and Drawings and the associated interfacing work as referenced in the related documents.

D. The BAS work shall consist of the provision of all labor, materials, tools, equipment, software, interfaces, wiring, installation, labeling, calibration, documentation, submittals, testing, commissioning, training services, permits and licenses required for a complete, fully functional and commissioned BAS.

E. Provide a complete, neat and workmanlike installation. Use only manufacturer approved employees who are skilled, experienced, trained, and familiar with the specific equipment, software, standards and configurations to be provided for this Project.

F. Manage and coordinate the BAS work in a timely manner in consideration of the Project schedules. Coordinate with the associated work of other trades so as to not impede or delay the work of associated trades.

G. The BAS as provided shall incorporate, as required the following integrated features, functions and services:
   1. Operator information, alarm management and control functions.
   2. Information management including monitoring, transmission, archiving,

retrieval, and reporting functions.
3. Diagnostic monitoring and reporting of BAS functions.
4. Offsite monitoring and management access.
5. Energy management.
6. Standard applications for terminal HVAC systems.

H. Programming and minor items obviously necessary to control, monitor and alarm the functions and systems specified herein and as described in Section 23 98 50 – HVAC Sequences of Operations to be provided.

I. Control work shall be in accordance with the requirements of Section 23 01 20 - HVAC GENERAL PROVISIONS.

J. Manufacturer's and installers that offer products which may comply with the requirements of this contract include the following: Johnson Controls, Inc.; Siemens, other approved by Addenda.

1.03 RELATED SECTIONS

A. Section 23 98 00 INSTRUMENTATION

B. Section 23 98 50 SEQUENCE OF OPERATION

1.04 RELATED WORK DESCRIBED ELSEWHERE

A. After completion of the mechanical installation, the Controls Contractor shall assist the Mechanical Contractor in starting the mechanical equipment and systems and shall test, adjust, and demonstrate the environmental controls as described in the following Sections:
1. Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC

1.05 COORDINATION

A. Coordinate control requirements with the interfacing work provided under other Sections of these Specifications and Division 26.

B. Coordinate locations of all temperature and pressure sensors, thermostats and immersion wells.

1.06 SYSTEM REQUIREMENTS

A. A new work station and color graphic screen shall be provided for new HVAC temperature control system.

B. A new network controller will be connected to owners Ethernet LAN.

1.07 SUBMITTALS

A. Shop Drawings, Product Data, and Samples:

1. The BAS contractor shall submit a list of all shop drawings with submittals dates within 45 days of contract award.
2. Submittals shall be in defined packages. Each package shall be complete and shall only reference itself and previously submitted packages. The packages shall be as approved by the Architect and Engineer for Contract compliance.
3. Allow 15 working days for the review of each package by the Architect and Engineer in the scheduling of the total BAS work.
4. Equipment and systems requiring approval of local authorities must comply with such regulations and be approved. Filing shall be at the expense of the BAS Contractor where filing is necessary. Provide a copy of all related correspondence and permits to the Owner.
5. Prepare an index of all submittals and shop drawings for the installation. Index shall include a shop drawing identification number, Contract Documents reference and item description.
6. The BAS Contractor shall correct any errors or omissions noted in the first review.
7. At a minimum, submit the following:
    a. BAS network architecture diagrams including all nodes and interconnections.
    b. Systems schematics, sequences and flow diagrams.
    c. Points schedule for each point in the BAS, including: Point Type, Object Name, Expanded ID, Display Units, Controller type, and Address.
    d. Detailed Bill of Material list for each system or application, identifying quantities, part numbers, descriptions, and optional features.
    e. Details of all BAS interfaces and connections to the work of other trades.
    f. Product data sheets or marked catalog pages including part number, photo and description for all products including software.

1.08 WARRANTY

A. All control devices and installation shall be warranted to be free from defects in workmanship and material for a period of one year from the date of project acceptance by the Owner. Any equipment, software, or labor found to be defective during this period shall be repaired or replaced without expense to the Owner.

B. Maintain an adequate supply of materials within 50 miles of the Project site such that replacement of key parts and labor support, including programming. Warranty work shall be done during BAS Contractor's normal business hours.

1.09 MAINTENANCE SERVICE

A. Provide service and maintenance of control system for one year from the Date of Final Completion.

B. Provide complete service of controls systems, including call backs. Make a minimum of 3 complete normal inspections of approximately 4 hours duration at the facility in addition to normal service calls to inspect, calibrate and adjust controls and submit written reports.

1.10 BAS SYSTEMS START-UP AND INSTRUCTION

A. The various HVAC BAS systems shall be put into operation under the direct supervision of the temperature control contractor's service engineer. The service engineer shall check the calibration and control settings and shall verify the proper operation of all safety and operating controls both in the spring and in the fall at the beginning of the heating season. He shall instruct the Owner's designated Representative on the operation of the various mechanical systems and the control systems.

B. Furnish, without additional cost to the Owner, the services of competent instructors, who shall fully instruct the Owner's designated representatives in the care, adjustment and operation of the mechanical systems. On-site orientation by a system technician who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the BAS software layout and naming conventions, and a walk through of the facility to identify panel and device locations.

C. The total number of man-hours of instruction furnished shall be eighteen (18). Hours of instruction shall be divided up into a minimum of three (3) instruction periods with 33% of time used for initial instructions and 33% of time used for follow-up instructions, a minimum of four (4) weeks after the initial instructions and 33% of time used at the 11 month time period.

1.09 RECORD DOCUMENTATION

A. Operation and Maintenance Manuals:
   1. Three (3) copies of the Operation and Maintenance Manuals shall be provided to the Owner's Representative upon completion of the project. The entire Operation and Maintenance Manual shall be furnished on Compact Disc media or DVD, and include the following for the BAS provided:
      a. Table of contents.
      b. As-built system record drawings shall represent the as-built condition of the system and incorporate all information supplied with the approved submittal.
      c. Manufacturer's product data sheets or catalog pages for all products including software.
      d. System Operator's manuals.

e. BAS network diagrams.
f. Interfaces to all third-party products and work by other trades.

B. On-Line documentation: After completion of all tests and adjustments the contractor shall provide a copy of all as-built information and product data to be installed on a customer designated computer workstation or server.

1.11 AUTOMATION SYSTEMS SERVICE CONTRACT

A. Prior to final acceptance, submit three (3) copies of an "Agreement for Continued Automation Service" for temperature control systems for possible Owner's acceptance. Offer terms and conditions for furnishing and providing continued testing and servicing, including replacement of materials and equipment, for one-year period with option by Owner for annual renewal of Agreement.

B. Bi-annual Scope of services:
1. System Analysis:
a. Provide review the building automation system to minimize potential software problems that might negatively impact the HVAC control performance. Review the system controllers input and output devices to identify and correct programming errors, failed points, points in alarm and points that have been overridden.
2. Control Loop Tuning:
a. Loop Tuning assures the system is operating at peak performance for the upcoming season. Operators may make manual changes during the heating or cooling season to accommodate current comfort requirements. During Control Loop Tuning, any changes that were made in previous months are reviewed and adjusted to accommodate changing seasonal conditions. The operation of mechanical loop components is verified, as well.
3. Sequence of Operation Verification:
a. Sequence of Operation Verification assures the system is operating as intended. During this assessment, unreleased manual overrides are discovered, scheduling discrepancies are corrected, and appropriate set point values are evaluated.
4. Database Backup:
a. Provide controller(s) database backup. Maintain current and archived backups of all vital databases to expedite system recovery and restoration to the last known set-up following a catastrophic event.
5. Controller Firmware updates:
a. The latest service pack updates will be downloaded and installed to the existing software version when available. This assures the software is always up to date with the current versions that enhance usability and functionality.
6. Operator Coaching:

a. During regularly scheduled visits. Provide on-site operator review and training to ensure end user skills and proficiencies to effectively use the HVAC automation system.

1.12 QUALITY ASSURANCE

A. General:

1. The Building Automation System Contractor shall be a dealer that is regularly engaged in the engineering, programming, installation and service of total integrated building management systems.
2. The BAS Contractor shall have a fully staffed branch facility within a 50-mile radius of the job site supplying complete maintenance and support services on a 24-hour, 7-day-a-week basis.
3. As evidence and assurance of the contractor's ability to support the Owner's system with service and parts, the contractor must have been in the BAS business for at least the last five (5) years.
4. The Building Automation System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Automation Systems, and shall be the manufacturer's latest standard of design at the time of bid.

B. Quality Management Program:

1. Designate a competent and experienced employee to provide BAS Project Management. The designated Project Manger shall be empowered to make technical, scheduling and related decisions on behalf of the BAS Contractor. At minimum, the Project Manager shall:
   a. Manage the scheduling of the work to ensure that adequate materials, labor and other resources are available as needed.
   b. Manage the financial aspects of the BAS contract.
   c. Coordinate as necessary with other trades.
   d. Be responsible for the work and actions of the BAS workforce on site.

PART 2 PRODUCTS Not used

PART 3 EXECUTION Not used

END OF SECTION

SECTION 23 92 00

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.01 APPLICABILITY

A. This Section covers Variable Frequency Drives (VFD's) / Adjustable Frequency Drives (AFD's) and applies to and forms a part of Division 23, Section 23 90 00 - HVAC CONTROLS.

B. Variable Frequency Drives / Adjustable Frequency Drives shall be in accordance with this section of these specifications and the requirements of Section 23 01 20 - HVAC GENERAL PROVISIONS.

1.02 GENERAL

A. Furnish and install Variable Frequency Drives / Adjustable Frequency Drives of type and characteristics specified in this Section and as required for sequences of control specified in Section 23 98 50 - SEQUENCE OF OPERATION.

B. Furnish and install VFD's/AVF's in compliance with Section 26 23 29.16 – Adjustable Frequency Drives.

1.03 RELATED SECTIONS

A. Division 23 – All Sections

B. Division 26 – All Sections

C. Section 23 98 50 – Sequence of Operation

D. Section 26 23 29.16 – Adjustable Frequency Drive

1.04 SUBMITALS

A. Refer to Section 26 23 29.16 – Adjustable Frequency Drive.

1.05 OPERATION/MAINTENANCE MANUALS AND INSTRUCTIONS

A. Refer to Section 26 23 29.16 – Adjustable Frequency Drive

1.06 QUALIFICATIONS

A. Refer to Section 26 23 29.16 – Adjustable Frequency Drive

1.07 QUALITY ASSURANCE

A. Refer to Section 26 23 29.16 – Adjustable Frequency Drive

PART 2 PRODUCTS

2.01 GENERAL

A. Manufacturers: Subject to compliance with requirements, provide motor starters and control stations of one of the following (for each type and rating of motor starter):
   1. Eaton / Cutler Hammer, H-Max Series.
   2. Allen Bradley “Powerflex” or equivalent series.
   3. Naming Specific Venders does not imply acceptance of their standard product nor relieve them from meeting these specifications in their entirety.

B. VFD’s/AFD’s shall be furnished in accordance with 26 23 29.16 Adjustable Frequency Drives – HVAC

C. It is the intent of this project to furnish a single manufacture for all motor controllers.

2.02 MOTOR STARTERS

A. Provide a separate variable frequency controller for each motor to be controlled unless specifically noted otherwise on drawings.

B. Each Motor shall be automatically controlled as described in the temperature control specifications. The variable frequency control shall provide stepless continuously variable speed of the connected motor.

C. Provide as components of the VFD the necessary contractors, protection devices, and control to achieve the operation described. Each drive unit shall conform to the following specifications.

D. Each converter unit shall convert input voltage to a sinusoidal adjustable frequency output voltage. Output shall be three phase sine coded adjustable voltage/frequency to provide stepless speed control of the installed squirrel cage induction AC motor throughout a continuous speed range 0 to 100% rated speed under variable load not exceeding the motor's full load rating. The converter shall have a diode bridge rectifier section, with constant voltage output, filtered dc link and inverter section. The inverter output waveform shall be an average value, including harmonics, not exceeding 1.05 fundamental at all normal operating speeds. Unit shall be fully rated across the rated switching frequency. Maximum input current distortion shall not exceed values in Table 10.3 of IEEE 519 for $20 < I_{sc}I_L < 50$. Equipment which causes current distortions with DC offset is not acceptable.

E. The following protection features and control functions shall be provided:
   1. Current limit protection of converter and connected motor to provide soft starting, acceleration and running current never exceeding 150% of motor rated amperes; and dynamic current limiting to the same value under any fault condition of inverter and/or motor. Limitation shall be of the type which reduces output voltage and frequency while limiting current with directly causing a shutdown.

2. Instantaneous over current trip for short circuit or overload condition.
3. Under-voltage and over-voltage for both line and output trip.
4. Over temperature trip.
5. Components shall be designed to withstand or control logic and auxiliaries shall be provided, to protect the converter unit from internal or external short circuits, internal or external open circuits, internal or external transients under any condition of load. Alphanumeric message shall be provided to indicate shutdown due to any of the preceding listed trip indicators. Control shall be provided for remote alarm.

   All shutdowns shall be orderly and protection shall be provided without component failure. Status indication lights shall be provided by the four segment digital display which indicates shutdown due to any of the preceding listed trip indicators. Control shall be provided for remote alarm.

   Except for overload, load short circuits, load open circuits and ground faults, drives shall automatically restart when conditions causing trips cease to be, overload, load short circuit, load open circuit, and ground faults shall require manual reset for restart.

F. The controller shall always automatically restart motor at low speed after return of power after any loss or upon being called upon to starter after any shutdown.

G. The drive shall be equipped with a line side voltage transient suppression network to protect drive components from voltage transients.

H. Signal and power circuits shall be isolated.

I. Drive logic shall be microprocessor based.

J. The capability of the control to withstand open and short circuits on its output terminals shall be documented by factory test. Variable speed control shall be tested at 1/4, 1/2, 3/4 and full load, with the motor connected. At full load with motor load connected, control shall be tested for load short circuit by operating a contractor or switch wired for test purposes to place a short across the output. At full load with motor load connected, control shall be tested or load open circuit by operating a contractor or switch first to open all 3 phases to the load and secondly by opening only one phase to the load. Upon removal of short or open and after manual reset the control shall return to normal operation without component replacement.

K. The input power factor of the system including control and motor shall be not less than 0.95 lagging at full load, at speeds from 70 to 100% rated speed.

L. VFD shall contain the following controls and features:

1. Lighted power on indication
2. Reset for overload, short circuits, and open circuits

3. Manual speed adjust control
4. Maximum and minimum speed adjustment capability
5. Controlled speed range of 20.1, or greater
6. Overload capability of 120% for 60 seconds.
7. Process follower 4-20MA, 0-5VDC, or 0-10VDC input. Total speed signal shall follow an adjustable linear time ramp to provide accelerating and deceleration control
8. Minimum of three selectable output frequency ranges
9. Sixteen selectable volt/hertz patterns
10. Front-door mounted micro-processor-based unit with digital programming panel (HIM). Panel shall have programming keys and alpha-numeric display to allow operator to view and modify drive parameters, alarms, and operating conditions. Include a separate speed-potentiometer if speed adjustment capability is not built into programming unit. Unit shall be able to display output frequency, status, percent current, percent voltage, and percent response signal.
11. Input circuit breaker with through-door handle
12. Current limiting circuit
13. Coast and ramp to stop
14. Electronic reversing
15. Fault indicators
16. Fault contacts (1NO. INC)
17 A terminal strip for up to six customer safety interlocks and remote start-stop.
18. On loss of speed reference signal, the drive shall operate at a preset minimum speed.
19. The drive shall have an open-collector output signal to indicate when the drive's output is at maximum and minimum speed.
20. 3% line-side reactor, in addition to 3% VFD internal impedance.
21. Line-side main disconnecting means with external operating handle and padlock-off provisions.

M. The variable frequency drive shall have, as a minimum, the following protective features:
1. Ground fault protection.
2. An adjustable thermal motor overload relay, sized specifically for the motor(s) it is protecting.
3. Current limited stall prevention during acceleration, deceleration, and run conditions.
4. Automatic restart after momentary power loss or momentary over-voltage.
5. Start into a rotating motor.
6. Anti-windmill protection.
7. Fault indicators shall indicate the following fault conditions.
   a. Over-current while running.
   b. Over-current on output.
   c. Internal short circuit.
   d. Overload.
   e. Over-voltage during deceleration.

f. Over-voltage due to power surge.
g. Over temperature.
h. Control function error.
i. Ground fault.

N. The VFD shall have the following adjustments:
1. Acceleration - 0.1 to 200 seconds.
2. Deceleration - 0.1 to 200 seconds.
3. Volts/hertz adjustments.
4. Maximum frequency range.
5. Minimum frequency.
6. Maximum frequency.
7. Carrier frequency
8. Bias and gain adjustment for 4-20mA, O-5VDC, 0-10VDC follower (Can be direct or indirect acting).
9. Calibration adjustment for remote speed indicator (provided by others).

O. The variable frequency drive shall be designed to operate within the following environmental and service conditions.
1. Ambient service temperature: -10^{o}C to 40^{o}C.
2. Ambient storage temperature: -20^{o}C to 60^{o}C.
3. Humidity: non-condensing to 90%.
4. Altitude to 3300 feet.
5. Service factor: 1.1.
6. Input voltage: Three phase, 208/230 VAC $\pm$ 10% for 230 VAC series and 380/400/460 VAC $\pm$ 10% for 460 VAC series.
7. Input frequency: 60 Hertz + or - 3%.

P. Output from control shall be provided to alert supervisory controls to following conditions:
1. Control Off
2. Control Manual
3. Control or Motor Failure

Q. The VFD shall be designed to control connected motor.

2.03 ENCLOSURE:

A. The variable speed system which includes the speed control, circuit breaker, motor starters, etc., shall be all supplied by the manufacturer of the variable speed control package.

B. Drive components shall all be factory preassembled and prewired in a NEMA 12 wall mounted steel cabinet with hinged lockable door. Indicators and controls shall be mounted on the front of the unit.

C. The variable speed drive enclosures for motors shall be capable of being installed on

wall as indicated in Mechanical Room.

D. The VFD enclosure shall come with a front mounted HIM (Human Machine Interface) VFD display.

PART 3 EXECUTION

3.01 INSTALLATION OF VARIABLE FREQUENCY CONTROL:

A. Install control where indicated, in accordance with equipment manufacturer's written instructions, and with recognized industry practices; complying with applicable requirements of NEC, UL and NEMA standards, to insure that products fulfill requirements. Control shall not be installed without factory test.

B. The Contractor shall select overload protection in accordance with code for actual nameplate current of motor installed. Horsepower sizes noted on drawings are nominal. Contractor is responsible for ensuring VFD is rated for connected motor.

C. Coordinate with other work including motor and electrical wiring/cabling work, as necessary to interface installation of control with other work.

D. Tighten connectors and terminals including screws and bolts, in accordance with equipment manufacturer's recommendation.

3.02 ADJUSTING AND CLEANING

A. Inspect control's operating mechanisms for malfunctioning and, where necessary, adjust units for free mechanical movement.

B. Touch up scratched or marred surfaces to match original finish.

3.03 FIELD QUALITY CONTROL

A. Energize control and demonstrate functioning of equipment in accordance with requirements; where necessary correct malfunctioning units, and then retest to demonstrate compliance. Ensure that direction of rotation of motor fulfills requirements.

B. Contract sum shall include a minimum of two, 4-hour periods of start-up services at the installation site for inspection and adjustment of the drive equipment. Services shall be performed by an employee engineer of the manufacturer fully trained in the operation and maintenance of the specified equipment.

END OF SECTION

SECTION 23 98 00

HVAC INSTRUMENTATION

PART 1 GENERAL

1.01 APPLICABILITY

A. This Section covers instrumentation and applies to and forms a part of Division 23, Section 23 90 00 - HVAC CONTROLS.

B. Instrumentation shall be in accordance with this section of these specifications and the requirements of Section 23 01 20 - HVAC GENERAL PROVISIONS.

1.02 GENERAL

A. Furnish and install instrumentation of type and characteristics specified in this Section and as required for sequences of control specified in Section 23 98 50 - SEQUENCE OF OPERATION.

PART 2 PRODUCTS

2.01 GENERAL DESCRIPTION

A. The Building Automation System (BAS) shall use an open architecture and where applicable support a multi-vendor environment. To accomplish this effectively, the BAS shall not be limited to a single open communication protocol standard, but to also integrate third-party devices and applications via additional protocol and through the latest software standards. The system configuration shall be available for use on the Internet, or intranets using off the shelf, industry standard technology compatible with other owner provided networks.

B. The Building Automation System shall consist of the following:
   1. Supervisory Controllers.
   2. Programmable Controllers (HVAC equipment, etc.)
   3. Input, Output Modules.
   4. Local Display Devices.
   5. Portable Operator's Terminals – Portable PC’s.
   6. Distributed User Interfaces.
   7. Network processing, data storage and communications equipment.
   8. 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. The system architectural design shall eliminate dependence upon any single device for alarm generation and control execution. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

E. Acceptable Systems:
   1. Facility Explorer by Johnson Controls.
   2. Others per addendum.

2.02 BAS ARCHITECTURE

A. Automation Network:

   1. The automation network shall be configured as a Client/Server network with a web server operating on the Client's LAN/WAN. The web browser interface is extended over the LAN/WAN. Monitoring and control of the BAS is available using the web browser interface.
   2. The automation network shall include the option of a PC industry standard of Ethernet TCP/IP. Where used, LAN controller cards shall be standard "off the shelf" products available through normal PC vendor channels.
   3. The BAS shall network multiple user interface clients, system controllers and systems supervisors as required for systems operation.
   4. The automation network option shall be capable of operating at a communication speed of 100 Mbps.
   5. Supervisory Controllers shall reside on the Automation Network.
   6. The automation network option will be compatible with other enterprise-wide networks. Where indicated, the automation network shall be connected to the enterprise network and share resources with it by way of standard networking devices and practices.

B. Control Network
   1. Supervisory Controllers shall provide management over the control network(s) and shall support the following communications protocols:
      a. BACnet® Standard (ANSI/ASHRAE Standard 135-) MS/TP and Ethernet/IP
      b. LONWORKS® enabled devices using the free topology transceiver (FTT-1x).
      c. Johnson Controls® N2 Open.
      d. Modbus RTU and Modbus TCP.

2. The Supervisory Controller shall be BTL (BACnet Testing Laboratories) listed as B-BC (BACnet Building Controller) and support the following data link options:
    a. BACnet Internet Protocol (IP) (Annex J).
    b. BACnet IP (Annex J) Foreign.
    c. ISO 8802-3, Ehternet (Clause 7).
3. 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.
4. Programmable Controllers shall reside on the control network.

C. Integration:
1. Hardwired:
    a. Analog and digital signal values shall be passed from one system to another via hardwired connections.
    b. There will be one separate physical point on each system for each point to be integrated between the systems.
2. Direct Protocol (Integrator Panel):
    a. The BAS shall include appropriate hardware equipment and software to allow bi-directional data communications between the BAS system and 3rd party manufacturers' control panels. The BAS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, boilers, variable frequency drives, power monitoring system, lighting and medical gas.
    b. All data required by the application shall be mapped into the BAS, and shall be transparent to the operator.
    c. Point inputs and outputs from the third party controllers shall have real time interoperability with BAS software features such as: Schedules, Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Local Area Network Communications.
3. BACnet Protocol Integration:
    a. The BACnet over Ethernet and BACnet MS/TP shall comply with the ASHRAE BACnet standard 135-2004.
    b. A complete Protocol Implementation Conformance Statement (PICS) shall be provided for all BACnet system devices.
    c. The ability to command, share point object data, change of state (COS) data and schedules between the host and BACnet systems shall be provided.
4. Modbus Protocol Integration:
    a. The BAS shall provide direct connection to Modbus devices without the use of protocol converters.
    b. All data required by the application shall be mapped into the BAS and shall be transparent to the operator.
    c. Point inputs and outputs from the Modbus devices shall have real-time interoperability with BAS software features such as: Schedules,

Control Software, Energy Management, Custom Process programming, Alarm Management, Historical Data and Trend Analysis, Totalization and local area network communications.

2.03 USER INTERFACE

A. Browser Based Operator Interface

1. The system shall be capable of supporting an unlimited number of clients using standard Web browser such as Internet ExplorerTM or Mozilla FirefoxTM. Systems requiring additional software (to enable a standard Web browser) to be resident on the client machine, or manufacture-specific browsers shall not be acceptable.
2. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function with the Building Automation System (BAS), shall not be acceptable.
3. The Web browser client shall support at a minimum, the following functions:
    a. User log-on identification and password shall be required. If an unauthorized user attempts access, notice of access failure shall be displayed. Security using authentication and encryption techniques to prevent unauthorized access shall be implemented.
    b. HTML programming shall not be required to display system graphics or data on a Web page. Editing of the Web page shall be allowed if the user desires a specific look or format.
    c. Storage of the graphical screens shall be in the Supervisory Controller or the server, without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.
    d. Real-time values displayed on a web page shall update automatically without requiring a manual “refresh” of the web page.
    e. Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
        1. Modify common application objects, such as schedules and setpoints in a graphical manner.
        2. Commands binary objects to start and stop.
        3. View logs and charts.
        4. View alarms.
    f. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.
4. Alarms
    a. Alarm feature shall allow user configuration of criteria to create, route, and manage alarms and events. It shall be possible for specific alarms

from specific points to be routed to specific alarm recipients. The alarm management portion of the user interface shall, at the minimum, provide the following functions:

1. Allow configuration to generate alarms on any numeric, binary, or data point in the system.
2. Generate alarm records that contain a minimum of a timestamp, original state, acknowledged state, alarm class and priority.
3. Allow the establishment of alarm classes that provide the routing of alarms with similar characteristics to common recipients.
4. Allow a user, with the appropriate security level, to manage alarms - including sorting, acknowledging, and tagging alarms.

5. Reports and Summaries
   a. Reports and Summaries shall be generated and directed to the user interface displays. 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 BAS schedules
      7. All user defined and adjustable variables, schedules, interlocks and the like
   b. The system shall allow for the creation of custom reports and queries.
6. 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. Regular schedules
      2. Repeating schedules
      3. Exception Schedules
   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.
   d. Monthly calendars shall be provided that allow for simplified scheduling of holidays and special days. Holidays and special days shall be user-selected with the pointing device or keyboard.
7. Password
   a. Multiple-level password access protection shall be provided to allow the system manager to assign user interface control, display, and database manipulation capabilities deemed appropriate for each user based on an assigned password.

b. Each user shall have the following: a user name, a password, and access levels.
c. The system shall provide the capability to require a password of minimum length and require a combination of characters and numerical or special characters.
d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
e. The system shall provide unlimited flexibility with access rights. A minimum of four levels of access shall be provided along with the ability to customize the system to provide additional levels.
f. A minimum of 100 unique passwords shall be supported.
g. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
h. The system shall automatically generate a report of log-on/log-off and system activity for each user.
i. All log data shall be available in .pdf, .txt, and .csv formats.

8. Dynamic Color Graphics
   a. The graphics application program shall be supplied as an integral part of the User Interface.
   b. The graphics applications shall include a create/edit function and a runtime function.
   c. The graphics shall be able to display real-time data that is acquired, derived, or entered.
   d. Graphics runtime functions –Each graphic application shall be capable of the following functions:
      1. All graphics shall be fully scalable
      2. The graphics shall support a maintained aspect ratio.
      3. Multiple fonts shall be supported.
      4. Unique background shall be assignable on a per graphic basis.
   e. Operation from graphics – It shall be possible to change values (setpoints) and states in systems controlled equipment within the Web browser interface.
   f. Graphic editing tool – A graphic editing tool shall be provided that allows for the creation and editing of graphic files. The graphic editor shall be capable of performing/defining all runtime binding.
9. Historical Data Collection
   a. All numeric, binary or data points in the system database shall allow their values to be logged over time (trend log). Each historical record shall include the point's name, a time stamp including time zone, and the point's value.
   b. The configuration of the historical data collection shall allow for recording data based on change of value or on a user-defined time interval.

c. The configuration of the historical data collection shall allow for the collection process to stop or rollover when capacity has been reached.
d. A historical data viewing utility shall be provided with access to all history records. This utility shall allow historical data to be viewed in a table or chart format.
e. The historical data chart view shall allow different point histories to be displayed simultaneously, and also provide panning and zooming capabilities.

10. Audit Log
    a. For each log entry, provide the following data;
        1. Time and date
        2. User ID
        3. Change or activity: i.e., Change setpoint, add or delete objects, commands, etc.
11. Database Backup and Storage
    a. The user shall have the ability to backup the Supervisory Controller databases.

2.04 AUTOMATION NETWORK

A. Supervisory Controller
1. The Supervisory Controller must provide the following hardware features as a minimum:
    a. Communications
        1. One 10/100 Mb Ethernet Port – RJ-45 connection
        2. One RS-232 port
        3. One RS-485 port (up to 57,600 baud)
        4. Expandable communications ports including LON, RS485, Modem, Wireless Terminal Equipment Control
        5. All required protocol drivers are included.
    b. Optional Inputs/Outputs
        1. Four form A SPST relay outputs rated for 24 VAC/VDC @ 500 mA resistive each with individual LED indicators
        2. Eight Universal Inputs for 10K NTC, 4-20 mA, 0-10 V, Dry contact
        3. Four 0-10v analog outputs.
    c. Optional Inputs/Outputs
        1. Ten form A SPST relay outputs rated for 24 VAC/VDC @ 500 mA resistive each with individual LED indicators
        2. Sixteen Universal Inputs for 10K NTC, 4-20 mA, 0-10 V, Dry contact
        3. Eight 0-10 V analog outputs.
    d. Optional Remote Inputs/Outputs
        1. Four form A SPST relay outputs rated for 24 VAC/VDC @ 500 mA resistive each with individual LED indicators

2. Eight Universal Inputs for 10K NTC, 4-20 mA, 0-10 V, Dry contact
3. Four 0-10v analog outputs.
4. Communicates to Supervisory Controller via standard RS-485 connection.

e. Battery Backup
1. Battery backup provided for all on board functions including I/O
2. Battery is monitored and trickle charged
3. Battery maintains processor operation through power failures for a pre-determined interval, and then writes all data to flash memory, shuts the processor down, and maintains the clock for three months.

2. The Supervisory Controller shall be a fully user-programmable device capable of providing all of the capability described in Section 1.4 Part A.
3. Automation network – The Supervisory Controller shall reside on the automation network. Each Supervisory Controller shall support one or more sub-networks of controllers.
4. The Supervisory Controller shall have the capability to communicate directly with Modbus without the use of an additional gateway.
5. The Supervisory Controller shall have the capability to provide secure communications via SSL (Secure Socket Layer).
6. User Interface – Each Supervisory Controller shall have the ability to deliver a web based user interface as previously described. All computers connected physically or virtually to the automation network shall have access to the web based UI.
7. Power Failure – In the event of the loss of normal power, The Supervisory Controller shall continue to operate for a defined period after which there shall be an orderly shutdown of all programs to prevent the loss of database or operating system software. Flash memory shall be incorporated for all critical controller configuration data.
   a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
   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.
8. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.05 DDC SYSTEM CONTROLLERS

A. General Purpose Programmable Controllers (PCG)
1. The General Purpose Programmable Controller (PCG) shall be a fully user-programmable, digital controller that communicates via BACnet MS/TP protocol.

a. The PCG shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9 on the controller network.
    1. A BACnet Protocol Implementation Conformance Statement shall be provided for the PCG.
    2. The Conformance Statement shall be submitted 10 days prior to bidding.

2. The PCG shall employ a finite state control engine to eliminate unnecessary conflicts between control functions at crossover points in their operational sequences. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.
3. The PCG shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.
4. The PCG shall include troubleshooting LED indicators to identify the following conditions:
    a. Power On
    b. Power Off
    c. Download or Startup in progress, not ready for normal operation
    d. No Faults
    e. Device Fault
    f. Field Controller Bus - Normal Data Transmission
    g. Field Controller Bus - No Data Transmission
    h. Field Controller Bus - No Communication
    i. Sensor-Actuator Bus - Normal Data Transmission
    j. Sensor-Actuator Bus - No Data Transmission
    k. Sensor-Actuator Bus - No Communication
5. The PCG shall accommodate the direct wiring of analog and binary I/O field points.
6. The PCG 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
    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, Current Mode
        2. Binary Output Mode
7. The PCG 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 Standard protocol SSPC-135, Clause 9.
b. The FC Bus shall support communications between the PCGs and the Supervisory Controller.
c. The FC Bus shall also support Expansion I/O (PCX) communications with the PCG and with the Supervisory Controller.
d. The FC Bus shall operate at a maximum distance of 15,000 Ft. between the PCG and the furthest connected device.

8. The PCG 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 Standard Protocol SSPC-135, Clause 9.
   b. The SA Bus shall support up to 10 devices per trunk.
   c. The SA Bus shall operate at a maximum distance of 1,200 Ft. between the PCG and the furthest connected device.
9. The PCG shall have the capability to execute complex control sequences involving direct wired I/O points as well as input and output devices communicating over the FC Bus or the SA Bus.
10. The PCG shall support, but not be limited to, functional programming to perform all defined sequence of operations for equipment, as defined in Section 23 98 50 – HVAC SEQUENCES OF OPERATIONS

B. Programmable Controller Expansion I/O Modules (PCX)
1. The Programmable Controller Expansion I/O Module (PCX) provides additional inputs and outputs for use in the PCG.
2. The PCX shall communicate with the PCG over the FC Bus or the SA Bus.
3. The PCX shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9 on the controller network.
   a. A BACnet Protocol Implementation Conformance Statement shall be provided for the PCG.
   b. The Conformance Statement shall be submitted 10 days prior to bidding.
4. The PCX shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.
5. The PCX shall have a minimum of 4 points to a maximum of 17 points.
6. The PCX 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
   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 PCX shall include troubleshooting LED indicators to identify the following conditions:
   a. Power On
   b. Power Off
   c. Download or Startup in progress, not ready for normal operation
   d. No Faults
   e. Device Fault
   f. Normal Data Transmission
   g. No Data Transmission
   h. No Communication

C. Programmable VAV Box Controller (PCV)

1. The Programmable VAV Box Controller (PCV) shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units. It shall control both single and dual duct applications.
2. The PCV shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9 on the controller network.
3. The PCV 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 PCV 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 PCV 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 VAV controller 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 table of controller parameters.
12. Control setpoint changes initiated over the network shall be written to PCV non-volatile memory to prevent loss of setpoint 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 setpoints.
16. 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.
17. 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.
18. 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. 1000 ohm 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.
19. 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.
20. Application Configuration

a. The PCV shall be configured with a software tool that provides a simple Question/Answer format for developing applications and downloading.

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

2.06 INPUT DEVICE CHARACTERISTICS

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.
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. Setpoint adjustment providing a +3 degree (adjustable) range
        2. Dial adjustment for setpoint value or warmer or cooler requests. The dial shall also initiate temporary occupancy during unoccupied times.
        3. A momentary override request push button for activation of after-hours operation
        4. Backlit LCD temperature display shall display temperature and setpoint with units.
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 ½-inch 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.
7. Acceptable Manufacturers: Johnson Controls, Setra, and ACI.

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 degree F unless specified elsewhere.
4. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA 3R enclosure with sealtite fittings and stainless steel bushings.
5. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
6. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.
7. Acceptable Manufacturers: Johnson Controls, Veris Industries, and ACI.

D. 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.
      e. Acceptable Manufacturers: Setra and Mamac.
   2. 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 or 0-10V 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 or 0-10V output
         3. Maintain accuracy up to 20 to 1 ratio turndown.
         4. Reference Accuracy: +0.2% of full span.
      c. Acceptable Manufacturers: Johnson Controls and Setra.

E. 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.
d. Acceptable manufacturers: Veris Industries, RIB, and ACI

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 120 VAC.
   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.
   d. Acceptable manufacturers: Johnson Controls, Cleveland Controls
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.
   b. Acceptable manufacturers: Johnson Controls, Cleveland Controls
5. Air Pressure Safety Switches
   a. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120 VAC.
   b. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.
   c. Acceptable manufacturers: Johnson Controls, Cleveland Controls
6. Water Flow Switches
   a. Water flow switches shall be equal to the Johnson Controls P74.
7. 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 120 VAC.
   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.
   d. The low temperature limit switch shall be equal to Johnson Controls A70.

2.07 OUTPUT DEVICE CHARACTERISTICS

A. Actuators
   1. General Requirements

a. Damper and valve actuators shall be electronic and/or pneumatic, as specified in the System Description section.

2. Electronic Damper Actuators
   a. Electronic damper actuators shall be direct shaft mount.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer's recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in either direction and a gear release to allow manual positioning.
   c. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for troubleshooting 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.
   e. Acceptable manufacturers: Johnson Controls, Schneider Electric, Belimo, and Mamac.

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 troubleshooting 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.

f. Acceptable manufacturers: Johnson Controls, Schneider Electric, and Belimo

B. External Manual Override Stations

1. External manual override stations shall provide the following:

a. An integral HAND/OFF/AUTO switch shall override the controlled device pilot relay.

b. A status input to the Building Automation System shall indicate whenever the switch is not in the automatic position.

c. A Status LED shall illuminate whenever the output is ON.

d. An Override LED shall illuminate whenever the HOA switch is in either the HAND or OFF position.

e. Contacts shall be rated for a minimum of 1 ampere at 24 VAC.

C. Electronic/Pneumatic Transducers

1. Electronic to Pneumatic transducers shall provide:

a. Output: 3-15 psig.

b. Input: 4-20 mA or 0-10 VDC.

c. Manual output adjustment.

d. Pressure gauge.

e. External replaceable supply air filter.

f. Acceptable manufacturers: Johnson Controls, Mamac.

2.08 CONTROL VALVES

A. Manufacturers:

1. Danfoss Inc.; Air Conditioning & Refrigeration Div.
2. Erie Controls.
3. Hayward Industrial Products, Inc.

4. Magnatrol Valve Corporation.
5. Neles-Jamesbury.
6. Parker Hannifin Corporation; Skinner Valve Division.
7. Pneuline Controls.
8. Sauter Controls Corporation.
9. Belimo

B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

C. Hydronic system globe valves shall have the following characteristics:
1. NPS 2 and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. NPS 2-1/2 and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. Internal Construction: Replaceable plugs and stainless-steel or brass seats.
   a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
   b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.
4. Sizing: 5-psig maximum pressure drop at design flow rate or the following:
   a. Two Position: Line size.
   b. Two-Way Modulating: Either the value specified above or twice the load pressure drop, whichever is more.
   c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.
5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

D. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
2. Sizing: 3-psig maximum pressure drop at design flow rate, to close against pump shutoff head.
3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.

E. Self-Contained Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.

2. Thermostatic Operator: Liquid-filled integral sensor with integral adjustable dial.

2.09 DAMPERS

A. Manufacturers:
1. Air Balance Inc.
2. Don Park Inc.; Autodamp Div.
3. TAMCO (T. A. Morrison & Co. Inc.).
4. United Enertech Corp.
5. Vent Products Company, Inc.
6. Ruskin
7. Arrow
8. Greenheck

B. Dampers: AMCA-rated, opposed-blade design; 0.108-inch- minimum thick, galvanized-steel or 0.125-inch- minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch- thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.
1. Secure blades to 1/2-inch- diameter, zinc-plated axles using zinc-plated hardware, with oil-impregnated sintered bronze blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Operating Temperature Range: From minus 40 to plus 200 deg F.
3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4-inch wg when damper is held by torque of 50 in. x lbf; when tested according to AMCA 500D.

2.10 ELECTRIC WIRING AND CONTROL CABLE

A. All wiring and control cabling in conjunction with the temperature control system shall be done by T.C. Contractor unless specifically stated otherwise.

B. Refer to Division 26 for materials and methods.

C. Provide conduit and electrical wiring in accordance with Division 26 and in accordance with conduit types and electrical classifications as shown on Electrical Drawings. HVAC control circuitry shall be installed within its own conduit systems provided under this Section. Do not install HVAC control circuitry within conduit systems that are shown on the Electrical Drawings.

1. All BAS wiring materials and installation methods shall comply with BAS manufacturer recommendations.

2. 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.
3. Class 2 Wiring
    a. All Class 2 (24 VAC 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.
4. Class 2 signal wiring and 24 VAC power can be run in the same conduit. Power wiring 120 VAC and greater cannot share the same conduit with Class 2 signal wiring.
5. 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.

D. BAS Line Voltage Power Source:
1. 120-volt AC circuits used for the Building Automation System shall be taken from panel boards and circuit breakers provided by Division 26.
2. Circuits used for the BAS shall be dedicated to the BAS and shall not be used for any other purposes.
3. DDC terminal unit controllers may use AC power from motor power circuits.

PART 3 EXECUTION

3.01 INSTALLATION

A. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above the floor.
1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

B. Install guards on thermostats in the following locations:
1. Where indicated.

C. Install automatic dampers according to Section 23 33 00 "Air Duct Accessories."

D. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

E. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC Piping and Equipment."

F. Install hydronic instrument wells, valves, and other accessories according to Division 23 Section "Hydronic Piping."

G. Install refrigerant instrument wells, valves, and other accessories according to Division 23 Section "Refrigerant Piping."

H. Install duct volume-control dampers according to Division 23 Sections specifying air ducts.

I. Install electronic and fiber-optic cables according to Division 26 Section "Communications Horizontal Cabling."

J. 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.

K. Input Devices:
   1. All Input devices shall be installed per the manufacturer recommendations.
   2. Locate components of the BAS in accessible local control panels wherever possible.

L. HVAC Input Devices – General:
   1. All Input devices shall be installed per the manufacturer recommendations.
   2. Locate components of the BAS in accessible local control panels wherever possible.
   3. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, airflow stations, etc.
   4. Input Flow Measuring Devices shall be installed in strict compliance with ASME guidelines affecting non-standard approach conditions.
   5. Outside Air Sensors:
      a. Sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air conditions accurately.
      b. Sensors shall be installed with a rain proof, perforated cover.
   6. Water Differential Pressure Sensors:
      a. Differential pressure transmitters used for flow measurement shall be sized to the flow-sensing device.
      b. Differential pressure transmitters shall be supplied with tee fittings and shut-off valves in the high and low sensing pick-up lines.

c. The transmitters shall be installed in an accessible location wherever possible.

7. Medium to High Differential Water Pressure Applications (Over 21" w.c.):
   a. Air bleed units, bypass valves and compression fittings shall be provided.
8. Building Differential Air Pressure Applications (-1" to +1" w.c.):
   a. Transmitter's exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind.
   b. The interior tip shall be inconspicuous and located as shown on the drawings.
9. Duct Temperature Sensors:
   a. Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement.
   b. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate.
   c. For ductwork greater in any dimension than 48 inches or where air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor.
   d. The sensor shall be mounted to suitable supports using factory approved element holders.
10. Space Sensors:
   a. Shall be 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. Install with static pressure tips, tubing, fittings, and air filter.
13. Water Differential Pressure Status Switches:
   a. Install with shut off valves for isolation.

M. 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.

3.02 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems."

B. Install building wire and cable according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

C. Install signal and communication cable according to Division 26 Section "Communications Horizontal Cabling."
   1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
   2. Install exposed cable in raceway.
   3. Install concealed cable in raceway.
   4. Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.
   5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
   6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
   7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

F. 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.

3.03 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Approved installation and quality control by T.C. Contractor. Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:
   1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
   2. Test and adjust controls and safeties.
   3. Test calibration of controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
   4. Test each point through its full operating range to verify that safety and operating control set points are as required.
   5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
   6. Test each system for compliance with sequence of operation.
   7. Test software and hardware interlocks.

C. DDC Verification:
   1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
   2. Check instruments for proper location and accessibility.
   3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
   4. Check instrument tubing for proper fittings, slope, material, and support.
   5. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
   6. Check temperature instruments and material and length of sensing elements.
   7. Check control valves. Verify that they are in correct direction.
   8. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
   9. Check DDC system as follows:
      a. Verify that DDC controller power supply is from emergency power supply, if applicable.
      b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
      c. Verify that spare I/O capacity has been provided.
      d. Verify that DDC controllers are protected from power supply surges.

END OF SECTION