BACNET BUILDING AUTOMATION SYSTEM
DIRECT DIGITAL CONTROLS GUIDE SPECIFICATION

CONTENTS

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PART 1 – GENERAL

1.1 DIRECT-DIGITAL CONTROL (DDC) SYSTEM DESCRIPTION

A. The Controls Contractor shall supply and install a complete Direct Digital Control (DDC) Building Automation System (BAS) as required to accomplish the Sequences of Control for heating, ventilating, air-conditioning and other building-level equipment and systems as described herein.

1.2 WORK INCLUDED

A. Furnish all labor, materials, equipment and service necessary for a complete and operational DDC BAS pursuant with this specification and as shown on the associated contract drawings.

B. Coordinate the existing conditions and requirements of all mechanical and electrical equipment that will be controlled by the DDC BAS.

C. Coordinate interface requirements for integration into BAS of following building-level equipment and systems:

1. Computer/Server Room Air Conditioning Units
2. Utility Metering (public utility-provided and smart meters)
3. Occupancy, Lighting controls
4. Variable Speed Drives

D. All labor, material, equipment and service not specifically referred to in this specification or on associated drawings that are required to fulfill the functional intent of this specification shall be provided at no additional cost to the Owner.

1.3 DDC SYSTEM REQUIREMENTS

DDC Systems installed under this specification shall strictly adhere to the following characteristics:

A. Building Automation System (BAS) Direct Digital Controls (DDC) shall consist of **native BACnet**, microprocessor-based, peer-to-peer, networked, distributed devices utilizing the BACnet communication protocol in an open, interoperable system. The BAS also includes operator interface devices, programming and configuration software applications, DDC input/output devices, non-DDC automatic temperature controls, enclosures and interconnecting conduit and wire.

  1. The BACnet operating stack must be embedded directly in every Device at the board level, and in all operator interface software packages.

  2. No Gateways, Communication Bridges, Protocol Translators or any other device that translates any proprietary or other communication protocol to the BACnet communication protocol shall be permitted as a part of the BAS installation pursuant with this specification section. Gateways may only be used as required for communication to existing systems or systems installed pursuant with other specification sections.

  3. DDC controllers that are not BACnet compliant shall not be acceptable under this specification and are strictly prohibited.

B. The BAS shall be modular in nature and comprised of a network of stand-alone DDC devices. The System shall be designed and implemented in such a way that it may be expanded in both capacity and functionality through the addition of DDC Devices, sensors, actuators, etc,

C. All BAS controllers shall be tested, certified, clearly stamped and listed by the BACnet Testing Laboratories (BTL).

D. Program database, data acquisition, and all control sequence logic shall reside in each DDC Device. The Building Level Communication Network (BLCN) shall not be dependent upon connection to a Server or Master Controller for performance of the Sequence of Control as outlined in this specification. Each individual Device shall, to the greatest possible extent, perform its programmed sequence without reliance on the BLCN.

E. BAS shall be provided with a complete Web enabled operator interface. The Web enabled application shall operate on industry standard PC hardware. Proprietary server hardware or "Black Boxes" will not be acceptable. Third party Web enabled applications are acceptable if they are configured to be indistinguishable from the OWS applications.

F. The Owner at the Owner's expense shall provide connection to the Internet for the BAS. The LAN connection type and configuration (TCP/IP addressing scheme, etc.) will be information provided to the System Contractor from the Owner, or Owner's representative.

G. All BAS DDC Devices at all levels shall be fully custom-programmable in the field using the standard Operators Workstation Software. No configurable, canned program application specific controllers will be permitted.

H. All BAS DDC Devices shall be capable of updating firmware using software via internet without replacing any hardware, microprocessors or chips.

I. The BAS shall be capable of sending system alarms and Event Notifications to pagers, and email services.

J. Actuation of control devices shall be electronic. Spring return fail-safe actuation shall be provided when loss of property and/or property damage is possible and where specified.

K. DDC Automatic Temperature Control (ATC) System shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started; along with the time delay between starts shall be user-selectable.

L. All binary output points shall be protected from short cycling via output configuration and/or programming. This feature shall allow minimum on time and off-time to be configurable.

1.4 BASIC SYSTEM ARCHITECTURE

A. The DDC BAS as provided and installed under this specification shall be a complete system from a single manufacturer designed for use on intranets and the internet.

B. The primary BAS components shall include but not be limited to:

   1. Web Server with operating software

   2. Operator Workstation Software (B-OWS)

   3. Remote Operator Workstation Software (Remote B-OWS)

   4. Portable Operator Workstation Software (Portable B-OWS)

   5. Building Controllers (B-BC)

   6. Advanced Application Controllers (B-AAC)

   7. Application Specific Controllers (B-ASC)

C. Enterprise Level Communication Network (ELCN) shall consist of high-speed BACnet/IP Local Area Network (LAN) and/or Wide Area Network (WAN) to host Operators Workstations (B-OWS), Building Controllers (B-BC), Building Level Communication Networks (BLCN) and Web-Enabled remote connectivity

D. Building Level Communication Network (BLCN) shall consist of a BACnet internetwork to host field level DDC Controllers

E. B-BC's shall automatically route BACnet communications to all configured available BACnet networks.

F. B-OWS shall be fully IT-compatible devices that communicate directly on a TCP/IP Local Area Network (LAN).

   1. LAN shall be 10/100Mbps TCP/IP with the following minimum requirements:

      a. Cable: 10 base-T, UTP-8 wire, category 5e or greater

      b. Minimum throughput: 10Mbps with the ability to increase to 100Mbps

   2. Enterprise Level Communication Network (ELCN) shall provide communication between B-BC's, B-OWS, remote B-OWS and Web Server using a B/IP LAN backbone.

3. B-BC's shall connect directly to the LAN and communicate using B/IP without a TCP/IP Gateway or network server

4. Owner shall be responsible for providing TCP/IP networking scheme, addressing, &c. It shall be the responsibility of the BAS Contractor to coordinate implementation of the BAS on the Owner's LAN without disruption.

G. BAS Manufacturer must natively support the following BACnet data links as defined in the ANSI/ASHRAE Standard 135-2008, BACnet:

1. Point-to-Point (PTP)

2. Master Slave/Token Passing (MS/TP)

3. Ethernet (ISO 8802-3)

4. BACnet IP (B/IP)

H. Field sensors and control devices shall connect to peer-to-peer, fully programmable B-BC, B-AAC & B-ASC as required to achieve the point monitoring and Sequence of Control as specified herein. All devices are to be monitored by a B-OWS. Final control devices are to be electronic.

I. Each Mechanical System and/or major piece of Mechanical Equipment shall have one (1) dedicated DDC controller with sufficient I/O capacity such that it shall be connected to ALL field devices and sensors associated with that system and/or piece of equipment. Distributed control of one (1) single piece of major mechanical equipment shall not be performed by multiple controllers.

J. All BAS controllers, sensors and devices shall be UL listed.

1. All BAS controllers and interface devices must be UL 916 Listed

2. Where required by the local Authority Having Jurisdiction (AHJ), all BAS controllers and interface devices must be UUKL-UL 864 Listed

1.5 MATERIAL FURNISHED UNDER THIS SECTION BUT INSTALLED UNDER OTHER SECTIONS

A. Provide, supervise and coordinate the installation of components supplied under this Section but installed under other Divisions of the specification

B. Automatic control valves, thermo-wells, liquid flow switches, and liquid flow sensors are to be installed by Mechanical Contractor.

C. Automatic control dampers, airflow measuring stations, and duct-mounted airstream sensors and devices to be installed by Mechanical Contractor

D. Air Terminal Unit (ATU) B-ASC with integral damper operators are to be installed at factory by ATU manufacturer.

1.6 RELATED SECTIONS

Work related to this Section but covered by other Sections include but are not limited to:

A. "Integrated Automation System Specification"

B. "Heating, Ventilating and Air-Conditioning Specification"

C. "Electrical System Specification"

D. "Lighting Control Systems"

1.7 QUALITY ASSURANCE

A. The BAS Contractor shall be responsible for inspection and Quality Assurance (QA) for all materials and workmanship provided under this Specification Section.

B. BAS components shall be manufactured by firms regularly engaged in the manufacture of equipment of the types, sizes and service required.

C. The BAS Contractor shall be a factory certified contractor specializing and experienced in BAS installations and with experience in networked microprocessor based commercial HVAC, building and enterprise level control systems.

    1. BAS Contractor shall maintain a comprehensive service office location within 100 miles of project location prior to bid date and at a minimum until the completion of the warranty period.

D. The BAS Contractor shall use technicians and application engineers certified by the manufacturer in the installation, configuration, programming and service of the BAS products

E. The BACnet internetwork shall be based upon the Manufacturer's standard integrated hardware and software product design intent and in accordance with Manufacturer's installation and application documentation.

F. To the highest extent practical, all BAS equipment of the same type serving the same function shall be identical and from the same manufacturer. All new B-ASC, B-AAC, B-BC, B-OWS software and web-server software shall be the products of a single manufacturer.

G. The completed and operational BAS shall be in compliance with and meet the requirements of all governing bodies, Authorities Having Jurisdiction (AHJ), applicable local or national standards and codes, except where more stringent or detailed requirements are indicated by the Contract Documents, including the requirements set forth in this Specification and the following:

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

        a. ASHRAE 135-2008: BACnet – Building Automation and Control Networking Protocol

    2. National Institute of Standards and Technology (NIST)

        a. NIST IR 6392 Annex B: Profiles of Standard BACnet Devices

    3. Underwriters Laboratories (UL)

        a. UL 916: Energy Management Systems (EMS)

        b. UUKL-UL 864: Control Units and Accessories for Fire Alarm Systems

    4. Institute of Electrical and Electronic Engineers (IEEE)

a. IEEE 142: Recommended Practice for Grounding of Industrial and Commercial Power Systems

5. Electronics Industries Association (EIA)

   a. EIA-232: Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange

   b. EIA-485: Standard for Electrical Characteristics of Generator and Receivers for Use in Balanced Digital Mutli-Point System

6. Federal Communications Commission (FCC)

   a. Part J: Class "A" Applications

1.8 SYSTEM PERFORMANCE

A. The system shall conform at a minimum to the following performance standards:

   1. Graphics shall display with a minimum of 50 dynamic real-time data points and within 10 seconds of the request

   2. The maximum time between the command of a binary object by the operator and the reaction by the device shall be 10 seconds. Analog objects shall start to adjust within 10 seconds of being commanded to change.

   3. All changes of state or change of analog values shall be transmitted such that no reporting of a value is more than 15 seconds old.

   4. The maximum time from when an object goes into alarm to when it is annunciated at the B-OWS shall not exceed 20 seconds. Those points denoted as critical shall be annunciated within 5 seconds.

   5. B-BC, B-AAC, & B-ASC shall be able to execute control loops at a selectable frequency at least 1 time every second. The controller shall scan and update the process value and output generated by this calculation at this same frequency at a minimum.

   6. All B-OWS on the network shall receive alarms within 5 seconds of each other.

   7. No devices utilizing mercury shall be acceptable for any application

   8. Unless noted otherwise in these Specifications, the end-to-end accuracy from sensor to operator interface shall be as noted in Table 1.

Table 1 – System Accuracy	
Measured Variable	Reported Accuracy
Space temperature	+/-0.5 deg C (+/-1 deg F)
Ducted air	+/-1.0 deg C (+/-2 deg F)
Outside air	+/-1.0 deg C (+/-2 deg F)
Water temperature	+/-0.5 deg C (+/-1 deg F)
Delta-T	+/-0.15 deg C (+/-0.25 deg F)

Relative humidity	+/-2% RH 10-90% RH
Water flow	+/-2% of actual value
Air flow (terminal)	+/-10% of actual value (Note 1)
Air flow (measuring stations)	+/-2% for calibrated range.
Air pressure (ducts)	+/-25 Pa (+/-0.1 "WG)
Air pressure (space)	+/-3 Pa (+/-0.01 "WG)
Water pressure	+/-1PSI (Note 2)
Electrical Power	$\pm$2% of Range (Note 3)
Carbon Monoxide (CO) Carbon Dioxide (CO_2)	+/-5% of Reading +/- 50 PPM
Note 1: (10% to100% of scale) (cannot read accurately below 10%)	
Note 2: for both absolute and differential pressure	
Note 3: * not including utility supplied meters	

a. Overall combined system repeatability of sensors, controllers and readout devices for a particular application shall be plus or minus 2% of full scale of the operating range. Repeatability of overall combined system of sensor, controller and readout device in a control loop application will be plus or minus 5% of full scale of the operating range.

b. Long-term electronic drift shall not exceed 0.4% per year.

9. The system provided shall be expandable to at least 500,000 hard points without additional database licensing fees, or replacing any devices, software or wiring provided herein.

10. All components provided as part of this system shall operate under ambient environmental conditions of -7°C (20°F) to 40°C (104°F) dry bulb and 10% to 90% relative humidity, non-condensing as a minimum. Sensors and control elements shall operate under the ambient environmental temperature, pressure, humidity, and vibration conditions encountered for the installed location. B-OWS equipment (hardware only), such as CRTs and printers, shall, unless designated otherwise, operate properly under ambient environmental conditions of 7°C (45°F) to 32°C (90°F) and a relative humidity of 10% to 90%.

11. Networked components of the system shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%.

1.9 SUBMITTALS

A. Submit under provisions of and pursuant with the [Division 15900] [Section 23 09] Specifications.

B. All submittals and documentation including complete BAS System Engineering Design Submittal & Drawings, Project Record Documents, Application Engineering Documents and Owner's & Maintenance Manuals shall be submitted electronically in the form of an Adobe Portable Document Format (.pdf). All Control Schematics, Wiring Diagrams, Riser Diagrams, &c. shall be formatted for A3 11" x 17". All other documentation may be formatted for 8.5" x 11".

C. Submit in writing and so delineated at the beginning of each submittal, known substitutions and deviations from requirements of Contract Documents. Deviation from Contract Documents must be approved by the University of Houston Energy Management Environmental Controls Systems (EMECS) office prior to submittal.

D. Complete BAS Engineering Design Submittal & Drawings shall be prepared pursuant with the following guidelines:

1. Submittal documentation and drawings shall consistently use the same abbreviations, symbols, nomenclature and identifiers. Each control system element shall be assigned a unique identifier pursuant with the Contract Documents

2. Submittal documentation and drawings shall have at the beginning an Index and Design Drawing Legend.

   a. Index shall list all design drawings and elements including the drawing number, sheet number, drawing title, etc.

   b. Legend shall show and describe all symbols, abbreviations and acronyms used on the Design Drawings

E. Submit the following:

1. A complete bill of materials of all equipment, controllers, devices and sensors to be provided and/or used indicating unique equipment identifier/tag, unique device/controller identifier/tag, manufacturer and model number.

2. Riser diagram of Building Level Communication Network (BLCN) and Enterprise Level Communication Network (ELCN) shall outline execution and details of all network cabling, BAS & Network Hardware including the following:

   a. All BAS/DDC Hardware with controller number, unique identifier/tag, location, equipment and service

   b. All Network Hardware with unique identifier, location and service

   c. Network cabling configuration and execution specification

   d. Location of all cabling termination points and End of Line (EOL) terminators

   e. Location of all network interface jacks

   f. A separate riser diagram shall be provided for each network segment

3. A schedule of all control valves including the unique equipment identifier/tag, valve size, dimensions and installation/maintenance clearance, model number (including pattern and connections), close-off rating, flow, CV, pressure drop, pressure rating and location. The valve schedule shall also contain actuator selection data supported by calculations of the force required to move, close and seal the valve at design conditions.

4. A schedule of all control dampers. This shall include the unique equipment identifier, unique damper identifier/tag, damper size, pressure drop, blade configuration, orientation and axis of frame, blade rotation, location and selection criteria of actuators, nominal and actual sizes, and manufacturer and model number. The Damper Schedule shall include the AMCA 500-D maximum leakage rate at the operating static-pressure differential.

5. Provide manufacturers cut sheets for major system components. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Include for every BAS component including but not limited to the following:

a. Operator Workstation (B-OWS)

b. Building Controllers (B-BC)

c. Advanced Application Controllers (B-AAC)

d. Application Specific Controllers (B-ASC)

e. Provide a BACnet Protocol Implementation Conformance Statement (PICS) or BIBB table for each BACnet device type in the submittal.

6. Provide shop drawings and/or manufacturer's standard specification submittal data sheets for all associated BAS equipment, sensors and control devices including unique identifier/tag, manufacturer model number and specific accessories, mounting, &c.

7. Sequence of Operation shall be submitted for every piece of equipment being controlled by and/or associated with the BAS. No operational deviation from specified Sequences of Operation as outlined in Contract Documents shall be permitted without prior written approval. Sequences of Operation shall include and conform to the following:

a. Refer to equipment and control devices by their specific unique identifiers/tags pursuant with the Contract Documents and BAS Submittal package.

b. Clearly represent actual Application Programming methodology and functional control operation. Do not merely provide a copy of Contract Document specified Sequence of Control.

c. Include description of functional system operation under normal and failure conditions.

8. BAS Control Schematics and Wiring Diagrams shall be submitted for every piece of equipment being controlled by and/or associated with the BAS. BAS Control Schematics and Wiring Diagrams shall include and conform to the following:

a. Control Schematic flow diagram of each system (air, water, gas, & etc.) being controlled showing actual physical configuration and control device/sensor location of all fans, coils, dampers, valves, pumps, heat exchangers, control devices, &c. including each hardware point type, controller and mnemonic.

b. Controller termination details showing every controller point termination, type and mnemonic.

c. Wiring Diagrams of all packaged equipment, motor starters, relay wiring, equipment interlock, safety circuits, & etc. clearly indicating all interconnecting wiring and termination of all conductors and cables including labels of all cables and point mnemonics.

d. Control Enclosure details for every enclosure including panel identifier, location, physical lay-out, dimensions, instrumentation, labels, & etc. Also include detail wiring (I/O, network and power) and power source for each panel, transformer and controller.

F. Project Record Documents. Upon completion of installation and systems commissioning submit record documents for review. "As-Built" Project Record Documents should include:

1. Project Record Application Engineering Drawings shall include all BAS System Engineering Design Submittal with Drawings updated to reflect actual field conditions, architecture and execution

2. Operating & Maintenance (O&M) Manual including:

   a. Operator's Manual with Manufacturers' complete operating instructions.

   b. Programming Manual including:

      1) Documentation of all project specific Application and DDC programs

      2) All necessary system Administrator-Level passwords and/or required access credentials

      3) Information required for programming BAS

      4) Complete Final Point Schedule including all hardware and software data points and documentation of calibration and configuration values for all Inputs, Outputs, Variables and PID Loops at the conclusion of systems commissioning and functional testing.

      5) Routine preventative maintenance procedures, corrective diagnostic troubleshooting procedures and calibration processes

      6) Final Bill of Material with all installed parts, manufacturers, manufacturers' part numbers and ordering information

      7) A schedule of recommended spare parts with part numbers and supplier

   c. Complete system database as functional at the conclusion of systems commissioning and functional testing including all graphics and images used by and/or created for BAS on electronic format as accepted by Owner.

1.10 CALIBRATION, COMMISSIONING, DEMONSTRATION AND ACCEPTANCE

A. Calibration and Commissioning

1. As a part of this contract, the BAS Contractor shall fully commission the entire BAS. All commissioning shall be fully documented and all documentation shall be submitted prior to Demonstration and Acceptance testing. Commissioning shall include a "point-to-point" check-out of the following at a minimum:

   a. Verify that all Temperature Control Panels (TCP), BAS equipment, controllers, devices and sensors are installed and operational according to the specifications, submittals and manufacturer's installation and application instructions

   b. Test, calibrate and bring on-line every control device

   c. Calibrate all inputs by comparing the actual site condition with the B-OWS point display.

   d. Verify all outputs from B-OWS command to observed response of controlled device.

e. Verify failure response and fail-safe conditions of all devices and safeties

f. Each control program shall be fully commissioned and tested for complete design intent compliance and functionality

g. Verify overall network performance of BAS for complete design intent compliance and functionality with all devices on-line, communicating and fully-operational

h. Subsystems not directly controlled by the BAS but associated with the ATC shall also be fully tested and commissioned as to design intent compliance and functionality

B. Demonstration and Acceptance

1. As a part of this contract, the BAS Contractor shall demonstrate compliance of the BAS with the contract documents and operational functionality pursuant with the design Sequences of Operation. Using the documented calibration and commissioning test data the Owner and/or his representative shall select, at random, results to be demonstrated. At least 95% of the results demonstrated must perform as specified and documented on commissioning data sheets or the system must be re-calibrated and re-commissioned before being re-tested.

2. When the Calibration, Commissioning, Demonstration and Acceptance process has been completed and approved by Owner, Contractor shall be provided with signed letter from Owner indicating Acceptance within ten (10) days of approval.

1.11 TRAINING

A. As a part of this contract, the BAS Contractor shall provide instruction on the adjustment, operation and maintenance of the BAS as installed including all hardware and software provided by a manufacturer-trained, competent application engineer and/or technician with sufficient experience in the installation, programming and operation of the BAS. All training equipment and material shall be provided by this Contractor.

B. Training shall be scheduled within thirty (30) days of BAS Acceptance and shall consist of a 1-day operational training program for up to 4 operators at the discretion of the owner. A training day shall be defined as an 8-hour day of instruction Monday through Friday during regular working hours, including two (2) 15-minute breaks and excluding lunchtime and travel.

C. 1 day of on-site training shall cover the entire execution of the complete BAS and components. Training shall be performed on the Owner's ATC/BAS and shall include:

1. Location of all TCP's, Control Enclosures, controllers, devices, sensors, &c.

2. Equipment Layout

3. Sequences of Operation

4. Maintenance and Repair

5. Troubleshooting

6. Preventative Maintenance

7. Sensor Calibration

8. Proper Use of Service Tools and Materials

D. At the discretion of the Owner, on-site training and installed system demonstration sessions may be video-taped

E. Instructor shall provide one (1) copy of training materials for each attendee at the time of the training. Two additional copies of training materials shall be provided to Owner at time of training at the request of the Owner for archival. Training materials shall include:

1. Agenda

2. Defined objectives for each lesson

3. Copies of audio-visuals and/or Power Point Presentations

1.12 WARRANTY, MAINTENANCE, NORMAL AND EMERGENCY SERVICE

A. BAS manufacturer shall warranty all DDC controllers to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of five (3) years at a minimum.

1. BAS manufacturer shall warranty all DDC controller on-board integral carbon dioxide (CO2) sensing elements to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of two (2) years at a minimum

2. BAS manufacturer shall warranty all DDC controller on-board integral relative humidity (RH) sensing elements to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of one (1) year at a minimum

B. As a part of this contract, the BAS Contractor shall warranty all other components of the BAS and installation to be free of defects in workmanship and material under normal expected service and use for a period of one (1) year from the date of final acceptance of the BAS by the Owner.

C. During the installation warranty period the Contractor shall provide all labor and materials required to repair or to replace all items or components that fail due to defects in workmanship or manufacture at no charge or reduction in service to the Owner.

D. Except in the event of property loss or damage, warranty service shall be provided during regular working hours Monday through Friday at no charge unless otherwise explicitly outlined in the Contract Documents.

1. Emergency service performed outside of these parameters shall be performed for charge by BAS Contractor according to the provisions set forth in the Contract Documents.

END OF PART 1

PART 2 – PRODUCTS

2.1 ACCEPTIBLE MANUFACTURERS

A. Controls-Unlimited (Reliable Controls Corporation),
    Craig Campbell, 713-554-0560, ccampbell@controls-unlimited.com

B. Kratos (Andover Controls),
    Mike McGraw 713-482-0856, Mike.McGraw@Kratosdefense.com

C. UES Controls, United Environmental Services (Automated Logic Controls),
    Jim Barber, 281-837-0777, jimb@uescontrols.com

2.2 BACNet WEB SERVER

A. The WEB Server Hardware shall comply with the following:

    1. Operating System: Microsoft Windows Server 2003 Standard Edition or Microsoft Windows Server 2008 Standard Edition

        a. Where multiple simultaneous user access is not required, hardware platform may alternately be at a minimum Microsoft Windows 6 Professional.

    2. Processor: Pentium Quad Core 2 GHz

    3. Memory: 4 GB minimum

B. The WEB Server Database shall comply with the following:

    1. Complete controller database of each B-BC, B-AAC, and B-ASC shall reside (at a minimum) within the respective device. The Web Server Hardware may retain and utilize a backup of the database within each device; however, the complete and original database must reside in the B-BC, B-AAC, and B-ASC.

C. The WEB Server Software shall comply with the following:

    1. Provide licensed copy of the Control System WEB Enabled Application Software described in Section 2.4. This license shall allow unlimited isolated systems to be served, and access by an unlimited number of users.

    2. The Owner shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

        a. Manufacturer's Standard Software and Firmware licensing agreement shall be executed by Owner in writing prior to software acquisition and/or installation

2.3 WEB ENABLED APPLICATION SOFTWARE

A. The WEB Enabled Application software and Graphical User Interface (GUI) is to be stored on the WEB hard disk drive server. WEB Enabled Applications that require system graphics to be stored on the client machines will not be acceptable. The application shall support unlimited access by 20 simultaneous clients using standard Web browser such as Internet Explorer.

B. The WEB enabled application shall perform native BACnet communications directly to all BACnet devices on the BACnet internetwork. Applications that require translation of data, gateways, or mapping of any kind shall not be acceptable.

C. The WEB Enabled Application shall provide the same methodology as the B-OWS application when viewing the BACnet Internetwork in terms of network architecture, system graphics, calendars, logs, etc. Systems utilizing Web Enabled Applications and Control Operator Workstation Applications of different manufacturer shall implement both applications so that the methodology is the same. Control Systems that utilize different methodology between the WEB Enabled Application and the Control System Operator Workstation Application for network architecture views, system graphic presentation or request, object, schedule or alarm interaction will not be 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 utilize those features described herein at different levels of interface varying between View only and Modify.

F. HTML programming shall not be required to create or display system graphics or data on a Web page.

G. A new point displayed on a B-OWS graphic screen shall appear automatically on the identical graphic screen served by the web-server with no further programming or file transfer required.

H. The WEB Enabled Application shall support via the Web Browser client the following as it is described in the Control System Operator Workstation Application as a minimum:

   1. Password Protection

   2. Alarming and Event Notification

   3. Weekly, Annual and Special Event Exception Scheduling

   4. Trend Log Graphing, and the capability to export in ASCII and Microsoft Excel format

   5. Runtime Log Information

   6. Ability to Manually Override any Database point

   7. Ability to Adjust any Setpoint

I. The WEB Enabled Application shall support via the Web Browser client the following in addition to what is described above:

   1. Color Graphical User Interface (GUI)

      a. All color graphic displays shall be dynamic with current point data automatically

updated from the BACnet internetwork to the browser without operator intervention. Manual operator intervention shall use the same methodology as on the B-OWS application.

b. Depending upon configured access level; the operator shall be able to manually adjust digital, analog or calculated values in the system, adjust values of control loops, override points or release points to automatic mode.

2. System Graphic screens developed for the B-OWS shall be the same image file used for the Web Browser Client. Systems, which require special translation or re-export of graphics to accommodate the web domain, will not be accepted. The Web Browser client shall support any System Graphic animation supported by the B-OWS. System Graphic screens on the Web Browser client shall support hypertext links to other location on the Internet or on Intranet sites by specifying the Uniform Resource Locator (URL) for the desired link.

J. The WEB Enabled Application shall provide the capability to create a user's (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to a defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.

K. The WEB Enabled Application shall include an Audit Trail feature that automatically records the time, date, and user, and action associated with all user changes made via Web Browser clients.

L. The WEB Enabled Application shall store complete help files describing system configuration, and use of the Browser Client interface, The help files shall be served on-line as part of the Browser Client interface. Creation, storage and serving of custom-made help files by the owner shall be possible, in lieu of the manufacturer's help files.

2.4 OPERATORS WORKSTATION PLATFORM (B-OWS)

A. Provide as specified herein complete all associated Operating System, Operators Workstation Application Software and Third-Party Software Applications preloaded and configured

B. Local Operators Workstation (B-OWS) shall be PC-based desktop workstation. Common BAS database and graphic files shall be stored on workstation designated and acting as the system server. Workstation Hardware minimum requirements are as follows:

1. Intel QuadCore 2.5 GHz Processor

2. 4 GB RAM minimum

3. 1 TB (terabyte) or larger hard disc drive with 12 millisecond access time

4. 16x DVD+/-RW

5. 22" Flat Panel LCD Monitor and 1 GB high performance graphics adapter with a minimum resolution performance of at least 1680 x 1050.

6. Tower case with at least two spare drive slots and 3 spare board slots.

7. At least one (1) Ethernet 10/100 Network Interface Card (NIC)

8. At least four (4) USB 2.0 ports

9. Enhanced style keyboard with 101 key layout, 10 function keys, numeric keypad and separate cursor control pads.

10. Two button mouse with adjustable sensitivity and desk pad.

11. All necessary cables

12. A combination surge suppressor/UPS dedicated to this server and printer.

13. Provide an integral audio tone generator to activate on detection of an alarm. Audio tone shall be capable of being enabled or disabled on operator command.

C. Remote Operators Workstation (Remote B-OWS) shall be PC-based desktop workstation. Workstation Hardware minimum requirements are as follows:

1. Remote B-OWS shall have the same hardware and software configuration and requirements of the B-OWS

D. Portable Operators Workstation (Portable B-OWS) shall be notebook computer workstation. Portable Workstation Hardware minimum requirements are as follows:

1. Intel Quad Core 2.5 GHz Processor

2. 4 GB RAM

3. 500 GB to 1 TB or larger hard disc drive with 12 millisecond access time

4. 8x DVD+/-RW

5. 14.1" Flat Panel LCD Monitor and 2 GB high performance graphics adapter with a minimum resolution performance of at least 1280 X 800

6. At least one (1) Ethernet 10/100 Network Interface Card (NIC)

7. At least four (4) USB 2.0 ports

8. 87 key keyboard with touchpad and track stick pointing devices

9. All necessary cables

10. Provide an integral audio tone generator to activate on detection of an alarm. Audio tone shall be capable of being enabled or disabled on operator command.

E. Communications and Protocols

1. B-OWS information access for the control system shall utilize the BACnet protocol only for communication to B-BC's, B-AAC's, B-ASC's and all other BAS DDC controllers

2. B-OWS shall reside on the same LAN as B-BC's. B-OWS shall as a minimum support point-to-point (PTP) and BACnet/IP physical/data link layer protocols.

3. The B-OWS specified here may, at the Owner's option, be located remote from the BACnet internetwork. Other than the difference in B-OWS communication speed, the system shall be capable of remote operation via BACnet LAN types with no degradation in application performance.

F. B-OWS Operating System (OS) Software shall be consistent on all B-OWS hardware platforms provided.

   1. The B-OWS hardware platform OS shall Microsoft Windows 7 Business, or newer.

G. B-OWS Application Software shall be provided and licensed to Owner. Provide latest versions of software available as follows at a minimum:

   1. One (1) Copy of Microsoft Office 2010 Professional

   2. Adobe Acrobat 9.0 Standard

2.5 CONTROL SYSTEM OPERATORS WORKSTATION APPLICATION SOFTWARE

A. The B-OWS Software shall be provided, licensed and installed on at least one B-OWS Platform. If more than one Platform is provided a licensed copy of the B-OWS Software shall be provided for every Platform.

B. The Owner shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

   1. Manufacturer's Standard Software and Firmware licensing agreement shall be executed by Owner in writing prior to software acquisition and/or installation

C. The B-OWS Software shall be BTL listed as either a B-OWS or B-AWS.

D. Password Protection

   1. Multiple-level password access protection shall be provided.

   2. Passwords shall be exactly the same for all software applications provided to communicate with the internetwork.

   3. A minimum of 10 levels of access shall be supported with a configurable matrix of operator actions allowed for each access level, broken down into at least 200 possible operator actions

   4. A minimum of 50 passwords shall be supported at each B-OWS.

   5. Operators will be able to perform only those commands available for their respective passwords.

   6. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving B-OWS in an unsupervised logged-in state.

E. Alarming and Event Notification

   1. B-OWS shall utilize BACnet Alarm Events and PICS shall support at a minimum the following BIBBs:

      a. Alarm and Event – Acknowledge-A (AE-ACK-A)

        b.   Alarm and Event – Notification-A (AE-N-A)

        c.   Alarm and Event – Alarm Summary View-A (AE-AS-A)

        d.   Alarm and Event – View and Modify-A (AE-VM-A)

        e.   Alarm and Event – View Notifications-A (AE-VN-A)

2. B-OWS terminal shall provide audible, visual, and printed means of alarm and event notification

3. System shall provide log of notification messages. Complete Alarm log of all system and operator transactions shall be archived to the hard disk of the system B-OWS.

4. Alarm messages shall be in user-definable text (English or other specified language) and shall be entered either at the B-OWS terminal or via remote communication.

5. An alarm summary shall be available to show all alarms whether including but not limited to whether or not they have been acknowledged.

6. System shall provide ability to prioritize and differentiate communications for at least 20 different levels of alarms

7. Alarm messages shall be fully customizable in size, content, behavior and sound.

F. Weekly Annual and Special Event Scheduling

1. B-OWS Software shall utilize BACnet Schedules and PICS shall support at a minimum the following BIBBs:

        a.   Scheduling – Advanced View and Modify-A (SCH-AVM-A)

2. Provide ability to view and modify the schedule for the calendar week and up to 255 special events in a graphical format. Each calendar day and special event shall provide at least six time/value entries per day.

3. Provide the ability for the operator to select scheduling for either binary, analog, or multi-state object values.

4. Provide the ability for the operator to designate days, date ranges, or repeating date patterns as exception schedules.

5. Provide the capability for the operator to define special or holiday schedules and to link the BACnet schedule to a BACnet calendar, thereby over-riding weekly schedule programming on holidays defined in the BACnet calendar.

6. There shall be a provision with proper password access to manually override each schedule.

7. Provide the capability to designate any exception schedule to be "Executed Once" then automatically cleared.

8. Provide the ability to name each exception schedule with a user defined term to describe each special event.

G. Trend Log Graphing

1. B-OWS Software shall allow viewing of BACnet Trend Logs and PICS shall support at a minimum the following BIBBs:

   a. Trending – View-A (T-V-A)

2. All data points (both hardware and software) system-wide shall be assignable to a historical trending program by gathering configurable historical samples of object data stored in the local controller (B-BC, B-AAC, B-ASC).

3. All trend log information shall be displayable in text or graphic format. All information shall be able to be printed in black & white or color and exported directly to a Microsoft Excel Spreadsheet.

4. Long-term archives shall be automatically stored on the B-OWS platform or automatically stored onto a dedicated server using an SQL database data acquisition service. The B-OWS and/or SQL Database Application shall perform the following at a minimum:

   a. Be capable of automatically retrieving any trend-log from any device on the network without user-intervention

   b. Manage connection to internetwork automatically based upon configurable data acquisition thresholds; retrieving data only when necessary rather than streaming data

   c. Generate standard, secure SQL database accessible by third-party applications

   d. Shall operate as a Microsoft Windows service

   e. Archived data shall be limited only by SQL license and hard disk space available

   f. Be capable of exporting data directly to Microsoft Excel

   g. Not require a separate "viewer" but shall seamlessly present all archived data together with real-time data stored in device using the standard B-OWS Trend Log Viewer.

H. Runtime Log Information

   1. B-OWS Software shall be capable of displaying Runtime and On/Off Cycle data of all Binary data points (both hardware and software) system-wide. Runtime logs shall provide the following at a minimum:

      a. Total Accumulated Runtime

      b. Accumulated Starts Today

      c. Total Accumulated Starts

      d. Timestamp each Start/Stop and duration of each on/off cycle

      e. Monitor equipment status and generate maintenance messages based upon user designated run time

I. System Configuration, Set-Up and Definition.

1. Device and network status shall be displayed for any device on the BACnet internetwork. At a minimum the following Device Management BIBBs shall be supported:

   a. Device Management – Automatic Device Mapping-A (DM-ADM-A)

   b. Device Management – Automatic Network Mapping-A (DM-ANM-A)

   c. Device Management – Reinitialize Device-A (DM-RD-A)

2. All control strategies and energy management routines shall be stored in the controller and shall allow modification and additions by the operator using the B-OWS software. No strategies or routines shall be stored on the B-OWS platform.

3. B-OWS Software shall have the capability to back-up and restore the programming and database of any BACnet device on the BACnet internetwork. The B-OWS BTL listing shall support the Device Management – Backup and Restore-A (DM-BR-A) BIBB.

4. Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system.

J. Graphical User Interface (GUI)

1. B-OWS Software shall support at a minimum BMP, GIF, TIF, JPG, EMF, PNG, SWF and DIB graphic file formats and allow for the use of custom Flash animation objects and URL hyperlinks in every GUI

2. B-OWS Software shall provide a color graphics package to allow the user to generate custom dynamic graphics for graphical representation of system design and system parameters. Graphic images may reside on the B-OWS or server; however, all dynamic data and attributes must reside in the controller.

   a. A listed set of symbols and graphic slides shall be available to allow operators to select from the graphics table to assist in graphic generation.

   b. All color graphic displays shall be dynamic with current point data automatically updated from the BACnet internetwork to the B-OWS workstation without operator intervention.

   c. The operator shall be able to manually adjust all data point values (hardware or software) in the system, adjust values of control loops, and command points to local mode or release points to automatic mode.

   d. The windowing environment of the B-OWS shall allow the user to simultaneously view several graphics at the same time to analyze total building operation, and/or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

   f. Pre-packaged animations for display of fans, pumps, dampers, etc., and shall allow custom user-created .swf and .gif animations to be used to display objects on graphic displays.

   g. The contractor shall submit all new graphics to University of Houston for approval.

J. The BAS shall be provided with fully automatic diagnostic procedures for verification of internetwork communication. In the event of communications failure, the system shall automatically Alarm the

condition. B-OWS Software shall be capable of remote annunciation to printer, pager and e-mail

K. Control Summaries, Reports and Logging:

1. The system shall provide self-documentation reporting to summarize control strategies for any point or any user selected group of points within the Control System.

2. The B-OWS reporting package shall allow the user to configure the point information display in custom format.

3. The B-OWS shall enable operator to perform Wild Card data point sorting and searches

4. The B-OWS shall perform automated network back-up of runtime databases in all devices on the BACnet network according to operator configurable schedule and storage directory structure

2.7 BUILDING CONTROLLERS (B-BC)

A. B-BC shall comply with all aforementioned BAS System Requirements and shall comply with the BACnet profile for Building Controllers (B-BC)

B. Furnish B-BC(s) as necessary to control large point count major mechanical equipment, and execution of BAS global strategies, and as noted in the execution portion of this specification.

1. Each Mechanical System and/or major piece of Mechanical Equipment (e.g., Chilled Water, Heating Water, Large AHU, etc.) shall have one (1) dedicated DDC controller with sufficient I/O capacity such that it shall be connected to ALL field devices and sensors associated with that system and/or piece of equipment. Distributed control of one (1) single piece of major mechanical equipment shall not be performed by multiple controllers.

2. Each B-BC shall support local hardware Inputs and Outputs (I/O) by the use of on-board I/O and/or I/O expansion modules.

C. B-BC shall be capable of locally executing global strategies for the BAS based on information from any object in the internetwork. Control Systems that require a higher-level host processor for update, time stamps, global point data, COS transfer, on-line control instruction, or communications control between B-BC panels shall not be acceptable.

D. BAS shall communicate with all B-OWS, B-BC, B-AAC & B-ASC on a peer-to-peer basis, and shall provide real-time clock functions for scheduling and network-wide time synchronization

E. B-BC shall have sufficient memory to support its operating system, database, and programming requirements. Battery/capacitor shall retain static RAM memory and clock functions for a minimum of 72 hours.

1. B-BC operating system, field database, and application programs shall reside in EEPROM.

2. B-BC run-time field database and application programs shall reside in battery backed-up on-board memory or EEPROM.

F. B-BC shall comply with the following Hardware Configuration:

1. B-BC shall have integral power switch. If the device manufacturer provides no on-board switch then the System Contractor shall provide a separate dedicated transformer and switch within each enclosure for each controller present

2. B-BC shall provide diagnostic LEDs for power, communications and processor status. The B-BC shall continually check the status of its processor and memory circuits

3. Controller wiring terminals shall be removable terminal strips for ease of installation and service replacement

4. All hardware inputs shall be Universal (i.e., binary or analog) configured on hardware and/or in software.

    a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-5VDC

    b. Pulse accumulation shall accommodate a maximum frequency of 40Hz

    c. Inputs shall have a minimum 10 Bit A/D conversion resolution

    d. 24VAC over-voltage protection

    e. Status LED indicators for each input

5. All hardware outputs shall be Universal and configured on hardware and/or in software.

    a. Outputs shall provide configurable modulating voltage signal to industry standard 0-5VDC and 0-10VDC analog control devices and relays

    b. Outputs shall be capable of sourcing 75mA at 12VDC

    c. Outputs shall have a minimum 8 Bit D/A conversion resolution

    d. 24VAC over-voltage and short protection
    [E & F deleted]

G. B-BC shall interact with the Control System Application Software in compliance with the following:

B. Database programming, configuration and modification shall be accomplished through the B-OWS online with the B-BC. The complete database and application program shall reside in the B-BC. The System Contractor shall configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents. Provide a copy of all programming on disc to the UH Project Manager.

C. The B-BC shall function in a real-time, multi-tasking networked operating environment; able to display database values, programs, and control loops in real-time while functional and online using the B-OWS. The user shall be able to add, delete, or modify objects on-line as required without taking the B-BC offline. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary to execute the specified sequence of control.

D. All required application programming shall be resident in the B-BC, B-AAC & B-ASC, and third party BACnet devices, and not in the B-OWS.

E. B-BC shall manage system-wide alarms by performing distributed, independent alarm analysis and filtering. At no time shall the B-BC panel's ability to report alarms be affected by

either operator activity at a B-OWS or local I/O device, or communications with other B-BC on the network.

    a. B-BCs shall have capability to broadcast alarm conditions automatically across the BLCN. Alarm Event notifications shall be sent to off-site computer or serial printer. A minimum of one B-BC per site shall be capable of sending SMTP email messages to an email server for configured alarm conditions.

    b. Active Alarm Events log shall be stored on the B-BC and may be viewed locally or remotely.

    c. All alarm or point change reports shall include the point's English language description, and the time and date of occurrence.

    d. The user shall be able to define the specific system reaction for each point alarm and shall be able to customize reaction and filtering to minimize nuisance reporting. Each B-BC panel shall automatically inhibit the reporting of selected alarms during the standby power modes of operation, loss of power, fire alarm mode, and normal system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

    e. Alarm reports, messages, and files can be directed to a user-defined list of operator devices, or PCs used for archiving alarm information.

F. B-BC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.

    1. B-BC panels shall store point history files for all analog and binary inputs and outputs.

    2. Measured and calculated analog and binary data shall also be assignable to user-definable trends.

    3. Up to six points of any type can be assigned to a single trend log

    4. Trend data shall be stored at the stand-alone B-BC panels, and uploaded to hard disk storage automatically at preconfigured intervals when archival is desired. Separate archival application software will be accepted.

G. Stand-alone B-BC panels shall automatically accumulate and store runtime hours for binary input and output points.

H. B-BC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

I. B-BC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

H. Communication and Protocols

    1. The B-BC shall continuously scan the BACnet network and maintain a current database of field data in on board battery/capacitor backed RAM or EEPROM, including alarms, passwords, binding tables, device status, etc. The B-BC shall communicate with BACnet devices on the BLCN using the BACnet physical data link MS/TP at a baud rate of 76.8 Kbps

where not limited by third party BACnet devices such as drives, utility meters, ect.

2. The B-BC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the network using BACnet/IP.

3. B-BC shall support and be capable of monitoring and controlling a network of communicating remote space sensors. These networked sensors shall occupy input/output hardware points in the B-BC. All Software points must be preapproved by Utility Service BMS manager.

4. Provide all functions that will allow remote communications via modem to off-site locations. Include modem along with all cabling necessary for installation.

5. B-BC shall support at a minimum of two (2) distinct dedicated BACnet/IP (B/IP) data link networks using TCP/IP and one (1) BACnet/Ethernet data link network simultaneously

6. B-BC shall support integral communication using Modbus RTU and TCP protocols as both a Slave and Master for building systems third-party integration.

7. B-BC shall support SMTP and provide stand-alone remote annunciation of alarms via e-mail without additional hardware, B-OWS, or web-server.

8. B-BC shall support, transmit, and receive of segmented messages.

2.8 ADVANCED APPLICATION CONTROLLERS (B-AAC)

A. B-AAC shall comply with all aforementioned BAS System Requirements and shall comply with or exceed the BACnet profile for Advanced Application Controllers (B-AAC).

B. Furnish one dedicated B-AAC(s) for each small or medium sized mechanical system, as noted in the execution portion of this specification. Each B-AAC shall acquire, process, and store point input data on a real time basis for internal use and for sharing with other controllers. Each B-AAC shall also maintain and supervise digital and analog output signals to the control devices and have a real time operating system capable of time of day scheduling and other time based functions.

1. If the hardware point requirements of any medium-sized system should exceed the I/O configuration of available B-AAC offerings then a B-BC must be used. Control of one piece of mechanical equipment may not performed by more than one controller.

C. B-AAC shall provide microprocessor based self-contained stand-alone fully programmable operation of local process control loops. All local level application programs shall be installed on individual controllers in non-volatile memory.

D. Each B-AAC shall be capable of sharing point information with other B-BC, B-AAC, or B-ASC on a peer-to-peer basis via the BACnet BLCN.

E. Control systems that utilize 'canned' programs or programmable read only memory (PROM) level application programming are not acceptable.

F. Once downloaded, a B-AAC shall not require further communication with the B-OWS except for data base changes, operator commands, and requests from the B-OWS for B-AAC data. Programming of B-AACs shall be completely modifiable in the field, over the installed BACnet network or remotely via the internet.

G. Each B-AAC shall be provided with the ability to prevent unauthorized access to its software program.

H. B-AAC shall have sufficient memory to support its operating system, database, and programming requirements. .

   1. B-AAC operating system, field database, and application programs shall reside in EEPROM.

I. B-AAC run-time field database and application programs shall reside in on-board memory or EEPROM.

J. B-AAC shall feature real-time 24-hour clock and 365-day calendar. Battery or capacitor back-up of these functions is required where the B-AAC is installed as a standalone controller.

K. B-AAC shall be designed for wall-mounting to a single or double-device box in the space

   [L. section: on-board integral LCD requirements eliminated]

L. B-AAC shall feature a software configurable audible enunciator which shall be configured to trigger on the occurrence of selected alarms, and shall be audible and acknowledgeable either to all users, or only to those users with sufficient password authority.

M. B-AAC shall comply with the following Hardware Configuration:

   1. B-AAC shall provide diagnostic LEDs for power, communications and processor status. The B-AAC shall continually check the status of its processor and memory circuits

   2. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:

      a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-5VDC

      b. Pulse accumulation shall accommodate a maximum frequency of 100Hz

      c. Inputs shall have a minimum 10 Bit A/D conversion resolution

      d. 24VAC over-voltage protection

   3. In addition to field device Hardware inputs, the B-AAC shall feature the following on-board integral hardware inputs at a minimum:

      a. Temperature sensor (local or remote)

         1) 10k or 20k Thermistor

         2) -7°C to 40°C (20°F to 104°F) range

         3) +/- 0.1°C (+/- 0.2°F) resolution

         4) User calibrated +/- 0.1°C (+/- 0.2°F)

      b. Setpoint Adjustment Slider

         1) 20k potentiometer

         2) Range defined, limited and configured via Application Software

  c. Relative Humidity (RH)

    1) 10% – 90% range

    2) 0.1% resolution

    3) +/- 2% accuracy

    4) Replaceable sensing element

    5) User calibrated as necessary

  d. Occupancy

    1) Passive Infrared Radiation (PIR)

    2) 5m/16.4' detection distance

    3) 100° horizontal / 82° vertical detection

    4) 64 detection zones

  e. Carbon Dioxide (CO2)

    1) 0 – 2000ppm

    2) +/- 30ppm Accuracy

    3) Auto-Drift Calibration

4. Hardware Outputs shall be configured as to be modular in nature and support the following characteristics:

  a. Universal Output

    1) 0 – 24 VDC @ 75 mA

    2) Digital or Analog functional operation

  b. Single Stage Relay

    1) SPDT Form C Dry Contact

    2) Minimum 0.5 A @ 24 VAC/VDC Contact Rating

    3) NO/NC Selectable

  c. Single Stage TRIAC

    1) Single NO Contact for Switching AC Loads

    2) Minimum 0.5 A @ 24 VAC/VDC Contact Rating

    3) Minimum Switching Current of 20 mA

     5. Universal hardware outputs shall be provided and configured on hardware or in software and comply with the following:

        a. Universal Outputs shall provide configurable modulating voltage signal to industry standard 0-5VDC and 0-10VDC analog control devices and relays

        b. Outputs shall be capable of sourcing 75mA at 12VDC and 24VDC

        c. Outputs shall have a minimum 8 Bit D/A conversion resolution

        d. 24VAC over-voltage and short protection

N. Control System Application Software:

    1. The B-AAC application software shall be the same as and indistinguishable from the B-BC specified interaction with the Control System Application Software.

    2. The controller software shall reside in a real time, multi-tasking, networking operating environment. Database definition shall be accomplished through the B-OWS online with the B-AAC. The complete database and application program shall reside in the B-AAC. The System Contractor shall configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents.

    3. The user shall be able to add, delete, or modify objects on-line as required. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary for proper sequence of control.

O. Communications and Protocols

    1. The B-AAC shall communicate with field devices and controllers on the BLCN using the BACnet physical data link MS/TP at 76.8 Kbps where not limited by third party devices such as variable speed drives, utility meters, etc.

    2. The B-AAC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the network.

    3. B-AAC shall support and be capable of monitoring and controlling a network of a minimum of four (4) communicating remote space sensors. These networked sensors shall not consume input/output hardware points in the B-AAC.

P. B-AAC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.

    1. B-AAC panels shall store point history files for all analog and binary inputs and outputs.

    2. Measured and calculated analog and binary data shall also be assignable to user-definable trends.

    3. Up to six points of any type can be assigned to a single trend log.

    4. Trend data shall be stored at the stand-alone B-AAC panels, and uploaded to hard disk storage automatically at preconfigured intervals when archival is desired. Separate archival application software will be accepted.

Q. Stand-alone B-ASC panels shall automatically accumulate and store runtime hours for binary input and output points.

R. B-ASC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

S. B-ASC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

T. B-AAC shall support, transmit, and receive of segmented messages.

2.8 APPLICATION SPECIFIC CONTROLLERS (B-ASC)

A. B-ASC shall comply with all aforementioned BAS System Requirements and shall comply with the BACnet profile for Application Specific Controllers (B-ASC).

B. Provide one dedicated B-ASC for each Terminal Unit Mechanical Device on the project. Those include Variable Air Volume (VAV) Air Terminal Units (ATU), Serial and Parallel Fan-Powered (FP) VAV ATU's, Unit Heaters (UH), Unit Ventilators (UV), Fan Coil Units (FCU), Roof-Top Units (RTU) and Individual Fans. Terminal Units specifically called out in the sequence of operation, as "Non-DDC" shall be excluded from this requirement.

C. B-ASC shall provide microprocessor based self-contained stand-alone fully programmable operation of local process control loops. All local level application programs shall be installed on individual controllers in non-volatile memory.

D. Each B-ASC shall be capable of sharing point information with other B-BC, B-AAC, or B-ASC on a peer-to-peer basis via the BACnet BLCN.

E. Control systems that utilize 'canned' programs or programmable read only memory (PROM) level application programming are not acceptable.

F. Once downloaded, a B-ASC shall not require further communication with the B-OWS except for data base changes, operator commands, and requests from the B-OWS for B-ASC data. Programming of B-ASCs shall be completely modifiable in the field, over installed BACnet Internetwork or remotely via modem.

   1. Each B-ASC shall be provided with the ability to prevent unauthorized access to its software program.

   2. B-ASC shall have sufficient memory to support its operating system, database, and programming requirements.

   3. B-ASC operating system, field database, and application programs shall reside in EEPROM.

   4. B-ASC run-time field database and application programs shall reside in on-board non-volatile memory or EEPROM.

G. ASC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.

   5. B-ASC panels shall store point history files for all analog and binary inputs and outputs.

   6. Measured and calculated analog and binary data shall also be assignable to user-definable

trends.

7. Up to six points of any type can be assigned to a single trend log.

8. Trend data shall be stored at the stand-alone B-ASC panels, and uploaded to hard disk storage automatically at preconfigured intervals when archival is desired. Separate archival application software will be accepted.

H. Stand-alone B-ASC panels shall automatically accumulate and store runtime hours for binary input and output points.

I. B-ASC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

J. B-ASC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

K. B-ASC for VAV ATU's application shall comply with the following:

1. B-ASC shall be provided with integral damper actuator. Actuator shall feature the following at a minimum:

   a. 35 in-lbs of torque

   b. Brushless DC Operator

   c. Actual damper position feedback. Drive time or other software calculated damper position shall not be accepted

   d. Damper End Switch using motor current sense or equivalent for positive feedback of both end stop positions

   e. Software selectable rotation

2. B-ASC shall be provided with integral differential pressure transducer, with range of 0–1 inwc, +/-5% FS.

3. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:

   a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-5VDC

   b. Pulse accumulation shall accommodate a minimum frequency of 40Hz

   c. Inputs shall have a minimum 10 Bit A/D conversion resolution

   d. 24VAC over-voltage protection

4. Hardware outputs for field devices shall be provided as follows:

   a. Three (3) Universal Outputs or One (1) Universal Output, one (1) single stage TRIAC Output, and one (1) Dual Stage TRIAC Output

5. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:

   a. Universal Outputs shall provide configurable modulating voltage signal to industry 0-5VDC and 0-10VDC analog control devices and relays

   b. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA

   c. Universal Output shall be capable of sourcing 75mA at 12VDC

   d. Outputs shall have a minimum 8 Bit D/A conversion resolution

   e. 24VAC over-voltage and short protection

6. Airflow Calibration, Test and Air Balance, etc. shall be performed via dedicated handheld configuration tool connected directly to communication port located at ATU B-ASC sensor] and/or [via the integral SS Flow Calibration interface of each space mounted SS. Special proprietary software and/or applications loaded on a computer or PDA shall not be acceptable to perform this function.

7. B-ASC shall provide diagnostic LEDs for power, communications and processor status. The B-ASC shall continually check the status of its processor and memory circuits

8. Controller wiring terminals shall be 5mm space between poles with removable terminal strips for ease of installation and service replacement

9. B-ASC Enclosure shall be rated as follows:

   a. NEMA 1

   b. UL 94-5V

L. B-ASC for unitary applications shall comply with the following:

1. B-ASC shall provide diagnostic LEDs for power, communications and processor status. The B-ASC shall continually check the status of its processor and memory circuits

2. Controller wiring terminals shall be removable terminal strips for ease of installation and service replacement

3. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:

   a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-5VDC

   b. Pulse accumulation shall accommodate a minimum frequency of 40Hz

   c. Inputs shall have a minimum 10 Bit A/D conversion resolution

   d. 24VAC over-voltage protection

4. Hardware outputs for field devices shall be provided as follows:

   a. Four (4) Universal Outputs, or Four (4) TRIAC Outputs or One (1) Universal Output, one (1) single stage TRIAC Output, and two (2) Dual Stage TRIAC Output

5. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:

   a. Universal Outputs shall provide configurable modulating voltage signal to industry standard 0-5VDC and 0-10VDC analog control devices and relays

   b. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA

   c. Universal Output shall be capable of sourcing 75mA at 12VDC

   d. Outputs shall have a minimum 8 Bit D/A conversion resolution

   e. 24VAC over-voltage and short protection

M. Control System Application Software:

1. The B-ASC application software shall be the same as and indistinguishable from the B-BC specified interaction with the Control System Application Software.

2. The controller software shall reside in a real time, multi-tasking, networking operating environment. Database definition shall be accomplished through the B-OWS online with the B-ASC. The complete database and application program shall reside in the B-ASC. The System Contractor shall configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents.

3. The user shall be able to add, delete, or modify objects on-line as required. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary for proper sequence of control.

N. Communications and Protocols

1. The B-ASC shall communicate with field devices and controllers on the BLCN using the BACnet physical data link MS/TP at 76.8 Kbps where not limited by third party devices such as variable speed drives, utility meters, ect.

2. The B-ASC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the inter-network.

3. B-ASC shall support and be capable of monitoring and controlling a network of a minimum of four (4) communicating remote space sensors, each with capability of a local LCD Display, adjustable set-point and outputs for zone controls. These networked sensors shall not consume input/output hardware points in the B-ASC.

4. B-ASC shall support, transmit, and receive of segmented messages.

2.9 NETWORKED COMMUNICATING SPACE SENSORS

A. Wall-Mounted Networked Communicating Space Sensors (SS) on a daisy-chained network are not allowed, each SS must occupy a hardware point.

B. Each SS shall provide a Liquid Crystal Display (LCD), where indicated on the drawings, with the following minimum features:

1. 36mm x 36mm (1.4" x 1.4") display area

2. Display four (4) 0.6" digits and six (6) 0.3" characters simultaneously

3. Capable of displaying icons, time, analog, and digital engineering units

4. Programmable to display up to ten (10) data points in any combination of local and/or networked values from any device on the internetwork

C. Each SS shall provide a local keypad for local user interface to perform navigation and adjustment of points configured as adjustable.

D. Each SS shall provide a point of access for a B-OWS, Service Tool, etc. to the BACnet internetwork via the SS communication network.

E. Where indicated on the drawings each SS shall provide at a minimum the following on-board integral I/O without the consumption of any inputs and/or outputs at the host DDC controller:

1. Temperature sensor (local or remote)

   a. 10k or 20k Thermistor

   b. 12 Bit A/D Conversion

   c. -7°C to 40°C (20°F to 104°F) range

   d. +/- 0.1°C (+/- 0.2°F) resolution

   e. User calibrated +/- 0.1°C (+/- 0.2°F)

2. Relative Humidity (RH)

   a. 10% – 90% range

   b. 0.1% resolution

   c. +/- 2% accuracy

   d. Replaceable sensing element

   e. User calibrated

4. Occupancy

   a. Passive Infrared Radiation (PIR)

   b. 5m/16.4' detection distance

   c. 100° horizontal / 82° vertical detection

   d. 64 detection zones

5. Additional Space/Zone I/O

   a. Two (2) thermistor or dry-contact inputs

b. Two (2) TRIAC Outputs (24VAC @ 0.5A)

2.10 TEMPERATURE CONTROL PANELS (TCP), ENCLOSURES & SUB-PANELS

A. Provide pedestal base or wall mounted local control enclosure to house all control components associated with each area, system or mechanical equipment room

1. The enclosures shall be minimum 16 gauge steel or aluminum, totally enclosed on all sides and painted with a baked enamel finish. All enclosures must maintain a minimum separation of 1" from the back wall.

2. Enclosures located in wet indoor conditions or located outdoors shall meet NEMA 4X.

3. Penetrations are permitted on bottom of enclosure only. Do not make conduit penetrations in top or side of enclosure. Each enclosure shall be equipped with a wire gutter below with a minimum of six ¾" minimum conduit penetrations into the bottom of the enclosure to accommodate system wiring.

4. Where required by AHJ, enclosures located in mechanical or electrical rooms shall meet NEMA 2 requirements

5. Enclosures located in all other locations including but not limited to mechanical or electrical rooms not requiring NEMA 2, occupied spaces, above ceilings and plenums shall be the same NEMA classification as all other enclosures located in the same environment, except if location requires additional protection due to potential vandalism or environmental conditions and shall at a minimum meet NEMA 1 requirements

6. Enclosures provided as an integral (pre-packaged) part of another product and/or piece of equipment are acceptable

7. Provide a continuous piano hinged door, keyed locking latch and removable sub-panel. A single key shall be common to all control enclosures.

B. Provide each DDC panel with a line filter, surge suppressor, electrical disconnect, control fuse, and control transformer. All sized and provided by the control system contractor.

C. Provide power supplies located inside control enclosures shall be fully enclosed with external 24 Vac terminals, on/off control, equipment overcurrent protection, power indication, high/low voltage separation, and convenience 120VAC outlets.

D. Provide insulated, modular, feed-through, clamp-style terminal blocks suitable for rail-mounting with end plates and partitions for the termination of all field wiring in control enclosures. Field wiring to equipment with integral terminals and/or unitary equipment (i.e., VAV ATU's, EF's, &c.) shall not be required to have terminal blocks.

E. Rail mounted terminal blocks shall be color coded to match the associated conductor colors adhering to the University of Houston standard wire recognition coloring scheme as scheduled in section 2.11.

2.11 INTERCONNECTING WIRE & CABLE

A. All wiring regardless of service and/or voltage shall comply with the Contract Document [Division 16] [Section 26] Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ).

B. Where required all wiring regardless of service and/or voltage shall be in conduit in accordance with [Division 16] [Section 26] "Raceways and Boxes for Electrical Systems" and "Cable Trays for Electrical Systems" and shall be routed parallel to or at right angles with the structure, properly supported every six (6) feet at a minimum and installed in a workmanlike manner.

C. Where permitted by all applicable specifications, local codes, NEC and AHJ; plenum-rated control cabling may be used where final application will be concealed but accessible. Where plenum-rated cable is allowed, it shall be routed parallel to or at right angles with the structure, properly supported every six (6) feet at a minimum and installed in a workmanlike manner.

D. The University of Houston Energy Management Environmental Controls System wiring color shall be as below:

Low Voltage Wiring	
BACnet Communications	Green with White Strip
24 VAC Power	Red and black jacketed conductors with black jacketed sheath over the pair
Input/Output	White and black jacketed conductors and white jacketed sheath over the pair.
Communicating Sensor	Green jacketed sheath

2.12 GENERAL FIELD DEVICES

A. All control relays shall be UL listed with contacts and coils rated for the application

  1. Relays used for in-line control start/stop of line voltage motors and shall have a current rating at least 150% full load amps.

B. Control transformers shall be CSA and UL listed. Primary and secondary sides shall be fused in accordance with the NEC or shall be class 2 current limiting type. Transformers shall be sized such that the connected load is not greater than 80% of the transformer rated capacity.

C. Voltage/Current to Pneumatic Transducer shall be non-bleed type 0-5V or 0-10V input and output pressure to match spring range of controlled device.

D. Emergency shut-off switches shall be heavy duty, two-position push-pull, maintained contact, and illuminated 1-3/8 inch in diameter mushroom style push button switch. Provide hinged easy open protective clear cover to prevent accidental operation of switch.

2.13 ANALOG SENSORS

A. Temperature Sensors: Temperature sensors are required leaving each element designed to change or vary a given supply temperature.

1. Temperature sensors shall be linear precision element Thermistor type.

2. Single point duct temperature sensor shall consist of 316 stainless steel or platinum sensing element, junction box for wiring connections and gasket to prevent air leakage and vibration noise.

3. Averaging duct temperature sensor shall consist of a copper or stainless steel averaging element, junction box for wiring connections and gasket to prevent air leakage or vibration noise.

4. Liquid immersion temperature sensor shall include thermowell, sensor and connection head for wiring connections.

5. Outside air temperature sensor shall consist of a single device sensor, ventilated non-metallic sun shield, utility box for terminations, and watertight gasket to prevent water seepage.

6. Space temperature sensor shall consist of an element within a ventilated cover. Sensors located in mechanical areas, plenums, lobbies, or other public spaces shall be simple sensor with no setpoint adjustment.

   a. Terminal Unit space temperature sensors shall be provided in accordance with the drawings at the locations indicated with the following options as indicated on drawings:

      1) Standard Wall-Mount Space Sensor

      2) Setpoint Adjustment Buttons ("+" & "-")

      3) Override/Bypass

      4) Occupancy

      5) CO2

      6) RH

      7) Network Jack

   b. All sensors not located in public spaces and associated with B-ASC or B-AAC that is located in normally inaccessible locations shall be the same.

   c. Sensors shall be manually calibrated on site so that the wiring length does not detract from the sensor accuracy specified.

7. Where necessary due to structural cavities, masonry walls, proximity to exterior openings, and unconditioned spaces an insulated mounting base shall prevent temperature of mounting location from affecting sensor temperature reading.

8. Sensor guards shall protect sensor from damage in all public areas such as gymnasiums, classrooms, vestibules, restrooms, and corridors or as indicated at locations on the drawings.

9. Provide brass or stainless steel thermowells for each immersion type temperature sensor and

switch.

B.   Wet Bulb temperature and humidity station shall be suitable for duct or outside mounting and consist of sensors, ventilated non-metallic sun shield, utility box for terminations, and watertight gasket to prevent water seepage.

C.   Pressure

1.   Static Air Pressure Sensor shall have linear output voltage signal. Zero and span shall be field-adjustable. Tubing shall be connected to a Pitot tube or other pressure/airflow sensing device. Under no circumstances shall tubing pass through equipment housing or ductwork.

2.   Pitot tube probe shall be at least 4 inches allowing for internal duct insulation.

3.   Steam and water gauge pressure sensor shall include connections secured to a stainless steel diaphragm sensor with a gasketed, dust and watertight housing for remote mounting.

a.   All steam devices and sensors shall incorporate a "pig-tail" in installation

4.   The differential pressure sensor for air applications shall provide a linear output voltage signal. The device shall be capable of over-pressurization to 10 PSI without a zero-shift and shall have a field adjustable zero and span. The assembly shall consist of pressure connections that secure pressure sensor to a housing for duct or remote mounting.

5.   Differential Pressure Sensor for water shall consist of a differential pressure tap secured to a stainless steel diaphragm and an electronic sensor enclosed in a gasketed, dust and watertight case.

6.   Five-valve manifold assembly shall be required to allow isolation and bypass of operating pressures from differential pressure sensor.

7.   Snubbers shall be required to prevent system pressure hammers and surges from being fully transmitted to the pressure sensor.

D.   Position

1.   Damper Position indication consists of a potentiometer mounted in housing.

a.   Damper Position End Switches shall employ mechanical position proving. Mercury style end switches shall not be accepted.

2.   Control valve Position indicator consists of a potentiometer mounted on the valve actuator.

3.   Float type level switch with SPDT snap acting contacts. Electronics shall be housed in a watertight enclosure.

4.   Proximity Limit Switch shall be oil-tight, roller type, SPDT snap-acting switch with adjustable trim arm.

E.   Flow

1.   Electronic Air Flow Monitoring System (Type II): Other installations: Airflow monitoring systems shall be a solid state electronic device comprised of a thermistor based sensing grid and microprocessor based electronics panel for flow averaging, temperature compensation and signal transmission. [Ebtron,] [Paragon,] [Tek-Air] or [Air Monitor].

2. Water Flow In-Line Type: (For Pipe Sizes up to 1 ½ inches): In-line type flow sensor shall have a nonmagnetic spinning impeller. Sensor shall be Data Industrial Model 250B or equal. [See also 33 10 00, Water Distribution]

3. Water Flow Insertion Type: (For Pipe Sizes 1 ½ inch to 10 inches): Provide a probe-mounted insertion type turbine sensor. [See also 33 10 00, Water Distribution]

F. Gas

    1. Refrigerant Vapor Detection System

        a. Provide a refrigerant vapor detection system to meet ASHRAE 15-1994 and the applicable local codes. The system shall sample and monitor a minimum of two (2) remote sampling points per Chiller.

        b. Provide the following accessories:

            1) One alarm relay for each level of alarm and one relay for flow failure or horn silence. Failure relay output that shall energize upon failure of monitor system operation. Failures include but are not limited to the following: low airflow through monitor, power circuit failure, and a saturated or absent sensor signal.

            2) Analog Output 4-20 mA or 0-5 VDC.

            3) Sample Pump shall be capable of drawing 0.25-1 liter/minute through 3/16 inch ID tubing for distances up to 100 ft.

            4) Enclosure type: NEMA 4X.

        c. Sampling Tubing shall be Type L or hard drawn copper tubing.

        d. The read out/control unit shall be wall mounted pursuant with contract drawings. Remote sampling points shall be located within the central plant area according to the drawings.

        e. If the equipment and installation procedures are in accordance with these Specifications, products and services from Mine Safety Appliances Instruments Company (MSA) or approved equal will be acceptable.

        f. The water chilling unit manufacturer shall provide refrigerant data.

    2. Indoor Air Quality Sensors shall measure both VOCs and CO_2 in PPM. Sensors shall be mounted as indicated on the drawings.

    3. Carbon Monoxide detection, where required on the contract drawings shall be a single or multi-channel, dual-level detectors, using solid-state sensors with 3-year minimum life, maximum 15-minute sensor replacement, suitable over a temperature range of 23°F to 130°F, calibrated for 50 and 100 ppm, with maximum 120-second response time to 100-ppm carbon monoxide.

    4. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of 23°F to 130°F (-5°C to 55° C) and calibrated for 0% to 2% of full range, with continuous or averaged reading, 4- to 20-mA output for wall mounting.

5. Occupancy Sensor: Passive infrared, with time delay, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment; for flush mounting.

6. Oxygen Sensor and Transmitter: Single detectors using solid-state zircon cell sensing; suitable over a temperature range of -32°F to 1100°F (0°C to 593°C) and calibrated for 0% to 5%, with continuous or averaged reading, 4- to 20-mA output; for wall mounting.

2.14 SWITCHING SENSORS/THERMOSTATS

A. Temperature Thermostats

1. Provide one (1) Low Limit thermostat for each 20 sq/ft of coil face. Low limit thermostat shall be of the vapor pressure remote element, manual reset type with adjustable set point. The device shall respond to the lowest temperature to which any 1 foot of the element is exposed. Capillary sensing tubing serpentine vertically across the discharge face of the coil, and be supported firmly by mechanical clips.

   a. Low Limit thermostats shall be DPDT with a minimum of one (1) NO contact and one (1) NC contact

2. High limit thermostat shall be manual reset type. Sensing element shall be bimetal.

3. Capillary Type Thermostats shall have liquid or vapor-filled thermal system consisting of stainless steel or copper sensing element, connected to a fully compensating capillary tube, and operating bellows or spiral.

4. Surface Mounted Thermostats shall be line voltage on-off type suitable for strapped mounting to pipe.

5. Wall Mounted Thermostats shall be line voltage on-off type suitable for wall mounting.

2.15 AUTOMATIC CONTROL VALVES

A. General Requirements: Honeywell is a preferred product.

1. Valves shall be provided with metallic linkage.

2. Unless otherwise indicated, all valves shall have a minimum range-ability of 50:1. All valves shall be guaranteed to have not more than 1% leakage of design flow rate at the pump shut-off pressure

3. Globe valves shall have replaceable seats.

4. Valves shall be quiet in operation.

5. Unless otherwise indicated, minimum body rating for any valve is 125 psi and maximum fluid temperature of 177°C (350°F).

6. Valves shall have stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation.

7. Valve bodies shall meet or exceed pressure and temperature class rating based upon design operating temperature and 150% design operating pressure.

8. Unless otherwise indicated two and three-way Automatic Control Valves shall be globe-style bodies and comply with the following selection criteria:

   a. Globe-style valve minimum body rating for any valve is 125 psi and maximum fluid temperature of 120°C (250°F).

   b. Bodies for valves 2" and smaller shall be brass or bronze with NPT threaded connections, and shall be rated for ANSI Class 250 working pressure. Spring-loaded packing shall be required to protect against leakage at the stem.

   c. Bodies for valves 2½" to 3" shall be brass, bronze or iron with flanged connections and shall be rated for ANSI Class 125 working pressure. Packing shall protect against leakage at the stem.

   d. Bodies for valves 3" to 6" shall be iron, cast iron or cast steel with flanged connections and shall be rated for ANSI Class 125 working pressure. Packing shall protect against leakage at the stem.

   e. For modulating applications, valve Cv (Kv) shall be within 100% to 125% of the design Cv (Kv)

   f. For two-position applications, valve Cv (Kv) shall be the largest available for the valve size

   g. Valve and actuator combination shall be Normally-Open (NO) or Normally-Closed (NC) as shown

9. Where specified ball-style body Automatic Control Valves shall adhere to the following:

   a. Ball-style valve minimum body rating for any valve is 125 psi and maximum fluid temperature of 100°C (212°F).

   b. Bodies for valves 2" and smaller shall be forged brass body with nickel plating, NPT threaded connections

   c. All control ball valves shall be furnished with chrome plated bronze ball and stainless steel stem and fiberglass reinforced Teflon® seats and seals. The valves shall have a blow out proof stem design.

   d. The stem packing shall be 2 O-rings designed for modulating service and requiring no maintenance.

   e. All control ball valves shall feature characterized flow guides when used for modulating applications

10. Where specified butterfly-style body Automatic Control Valves shall adhere to the following:

   a. Unless otherwise indicated, butterfly valves shall have a minimum range ability of 10:1. All valves shall be guaranteed to have not more than 1% leakage of design flow rate at the pump shut-off pressure

   b. Butterfly-style valve minimum body rating for any valve is 125 psi and maximum fluid

temperature of 120°C (250°F).

    c. Bodies for valves 3" to 12" shall be fully-lugged cast iron body

    d. Flanges shall meet all ANSI 125 and ANSI 150 standards.

    e. The stem shall be one piece stainless.

    f. The 416 stainless shaft shall be supported at three locations with PTFE bushings for positive shaft alignment.

    g. The seat shall be EPDM; Phenolic backed, non-collapsible, and easy to replace.

    h. The disc shall be aluminum bronze to provide bubble-tight close off in either direction.

    i. Valve shall have a long stem design to accommodate 2 inches insulation.

11. Valves for Chilled Water (CHW) and Glycol (GCHW) service shall adhere to the following:

    a. All internal trim regardless of body type shall be Type 316 Stainless Steel. Valves 3" and larger shall be butterfly valves.

12. Valves for Heating Hot Water (HHW) service shall adhere to the following:

    a. Valves for HHW service between 210°F (99°C) and 250°F (120°C) shall have all internal trim (including seats, rings, modulating plugs and springs) of Type 316 Stainless Steel

    b. Valves for HHW service below 210°F (99°C) shall have all internal trim (including seats, rings, modulating plugs and springs) of Brass, Bronze or Type 316 Stainless Steel

    c. Nonmetallic valve components shall be suitable for a minimum continuous operating temperature of 250°F (120°C) and/or 50°F (10°C) above the system design temperature, whichever is higher

2.16 VALVE ACTUATORS: Honeywell and Belimo are preferred products.

A. Actuators used in wet conditions and/or in or near outdoor air streams shall have NEMA 2 housings.

B. Valve Actuators shall be modulating, with feedback signal, two-position and spring return fail safe as called out in the control sequence of operation or indicated on the drawings. All modulating valves shall be positive positioning, and respond to a 0-10VDC or 2-10 VDC with the exception that terminal unit zone valves may use an actuator that responds to a floating or tri-state with feedback signal.

C. All control valves shall have a visual position indicator.

D. All non-spring return actuators shall have an external clutch/manual gear release to allow manual positioning of the valve when the actuator is not powered. Spring return actuators with more than 60-in-LB torque capacity shall have a manual crank for this purpose. In lieu of a manual positioning device, it will be acceptable for the contractor to provide a full line size bypass around the control valve. Three bypass shut off valves shall be provided to allow the control valve to be isolated while the open stop valve in the bypass allows flow around the control valve.

E. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.

F. Any mechanical equipment with direct introduction of outside air shall require fail-safe spring return valve actuators. Terminal equipment (VAV ATU, &c.) without direct introduction of outside air are permitted to have actuators that maintain their last commanded position when power is lost to the actuator. Equipment isolation and differential or temperature pressure bypass valves shall not be required to be provided with a spring return actuator provided that a failure of the valve to return to its "fail-safe" position will not incur damage to property or the system it serves.

2.17 AUTOMATIC CONTROL DAMPERS

A. All Automatic Control Dampers provided as a part of this Specification shall bear the AMCA Seal as an indication that they comply with all requirements of the AMCA Certified Ratings Programs.

B. A single damper section shall have blades that do not exceed 48" in length and shall be no higher than 72". Damper blades shall not exceed 8" in width. Applications requiring larger dampers shall be achieved by combining single damper sections.

C. Frame construction shall be a minimum of #14 gauge galvanized steel formed into channels and welded, 14 gauge galvanized roll-formed steel or extruded aluminum at a minimum 4½" by 1' by 0.125" thick.

D. Blades and baffles shall be fabricated of minimum 16 gauge steel with corrosion resistant galvanized finish or extruded aluminum 6" by 0.08".

E. All dampers shall be provided with nylon, cycoloy or oilite bearings, stainless steel or elastomeric side seals, and zinc plated hardware as standard.

F. Axles shall be a minimum of ½" diameter and be locked to blade with rivets or welded.

G. Dampers shall be made up of 6" or 8" blades or combination of the two. Dampers shall have a minimum of four brakes running the entire length. Silicone or polyurethane blade edging shall be furnished on all dampers.

H. Maximum leakage rate through any 48 inches by 48 inches closed damper in any application shall not exceed 10.0 cfm per sq. ft. of damper face area at 4 inches of water pressure differential and a maximum closing torque of 4 inch-lbs/sq. ft. of damper face area. Damper leakage ratings shall be certified in accordance with AMCA Standard 500-D.

I. Blades mounted vertically shall be supported by thrust bearings

J. All Automatic Control Dampers in modulating applications shall be sized so as to achieve linear airflow characteristics

K. Flow Control Application Dampers (Opposed Blade Operational Style)

   1. Opposed Blade Automatic Flow Control Dampers shall be required as indicated on the drawings for:

      a. All mixing, volume throttling, airflow control, &c. applications installed in Outdoor, Relief, Exhaust, and/or Supply airstreams.

   b. Any application upstream of critical components

   c. Ducted Outlets

   d. Automatic Flow Control Dampers specifically indicated to be provided by Mechanical Equipment manufacturer and/or as a component of packaged equipment shall not be provided by the Contractor.

  2. To minimize leakage, blade edges shall be interlocked and blade seals shall be compressible at all contact points. Channel frames shall also be provided with jamb seals.

  3. All Outdoor Air Damper components shall be suitable for applications operating in the temperature range of -40°F (-4°C) to 167°F (75°C)

  4. Damper shall be rated for a minimum velocity of 2000 ft/min

 L. Mechanical Ventilation, Miscellaneous Utility Dampers (Parallel Blade Operational Style)

  1. Parallel Blade Automatic Flow Control Dampers shall be permitted as indicated on the drawings for applications not requiring Opposed Blade operation pursuant with that specification section and for:

   a. Two-position (fully-open or fully-closed) applications

   b. Applications where the damper constitutes the primary source of total system pressure loss

   c. Applications where greater control is required at the upper end of airstream volume operating range

   d. Mechanical Space ventilation and exhaust, combustion intake & exhaust, &c.

  2. Shall comply with AMCA 500-D Class 4 and shall not leak in excess of 80cfm per sq/ft at 4inwc static pressure when closed.

  3. Damper shall be rated for a minimum velocity of 1500 ft/min

 M. Operating Linkages and Damper Accessories

  1. All operating linkages and/or damper accessories required for installation and application in accordance with specification design intent and manufacturer's installation procedures shall be provided

  2. Operating linkages provided external to dampers (crank arms, connecting rods, shaft extensions, &c.) for transmitting motion from the actuator/operator to dampers shall be designed as to functionally operate a load equal to or in excess of 300% of the maximum required operating force for the damper.

  3. Crank arms and connecting rods shall be adjustable. Linkages shall be brass, bronze, zinc-coated steel, or stainless steel.

  4. Adjustments of Crank Arms shall control the position of the damper

  5. Use of Operating Linkages external to damper drive shaft shall neither delay nor impede operation of the damper in a manner of performance less than a direct-coupled damper

actuator. Operating linkages shall not under any circumstances be permitted to flex, warp, shift &c. under normal operation of connected damper sections.

2.18 AUTOMATIC CONTROL DAMPER ACTUATORS: (Belimo and Honeywell are preferred products)

A. Control damper actuators shall be electronic direct-coupled type. Actuators shall have a means for reversing drive direction and a manual override accessible at the front cover.

[Fastener language deleted]

B. The actuator shall have electronic overload or digital rotation sensing circuitry. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.

C. For spring return fail-safe applications, an internal mechanical spring return mechanism shall be built into the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable.

D. All non-spring return actuators shall have an external manual clutch/gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-LB torque capacity shall have a manual crank for this purpose.

END OF PART 2

PART 3 – EXECUTION

3.1 GENERAL

A. BAS component locations are the responsibility of the System Contractor. All control system components shall be installed in locations as required to properly sense the controlled medium.

B. BAS Installation shall be performed by professionals in a workmanlike manner and in compliance with the Contract Documents, [Division 16] [Section 26] Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ) and the following:

   1. Complete BAS installation including all DDC Devices, Enclosures, wiring, equipment, control devices and sensors shall be installed in accordance with the manufacturers' recommended installation procedures and as specified.

   2. All control devices are to be provided and installed with all required gaskets, seals, flanges, connection enclosures, thermal compounds, insulation, piping, fittings and valves as required for design operation, isolation, equalization, purging and calibration.

   3. Strap-on control devices shall not be permitted except as explicitly called out

   4. All control devices mounted outdoors shall be protected by a weather-shield, integral outdoor enclosure, &c. from ambient elements in such a manner as to not impede design functionality and/or sensing

   5. BAS installation shall be such that it provides sufficient clearance for system maintenance by maintaining sufficient access for equipment, device and/or component service, calibration, removal, repair or replacement.

   6. BAS installation shall not interfere with required clearance for mechanical and/or electrical equipment maintenance.

   7. Penetrations through and mounting holes in the building exterior associated with the BAS installation shall be sealed and made water-tight

   8. Dielectric isolation shall be provided where dissimilar metals are used in installation for connection and support

   9. Installation, wiring and material shall be protected from damage by and during BAS installation by BAS Contractor,

C. The Contractor shall be responsible for his/her work and equipment until finally inspected, tested and accepted. The Contractor shall protect his/her work against theft or damage, and shall carefully store material and equipment received on site that is not immediately installed.

D. After completion of installation, calibrate and commission all components provided as part of the Control System and demonstrate proper sequence of operation in compliance with the specifications. BAS components not operating correctly shall be field corrected or replaced.

2.1 DIRECT AND WEB-ENABLED BAS APPLICATION SOFTWARE

A. At time of acceptance all operating system, Third party and Control System Application software shall be at least the latest official release version available.

B. Software programs are described to their general intent. It is recognized that Networked System manufacturer's software differ; however, the Application software provided shall incorporate the features described fully implemented and optimized to provide the sequences described, minimize energy consumption and prolong equipment life.

C. The following standard naming convention shall be utilized for the naming of BACnet Devices on the BACnet internetwork.

    1. The convention for object names must adhere to the standards set by University of Houston Energy Management Environmental Controls System (EMECS) office.

D. When programming the system BACnet addressing rules will be strictly adhered to. All addressing strategies will have to be approved by University of Houston EMECS office prior to configuring any LAN types.

E. All analog and binary values shall be programmed with appropriate alarms.

F. Except as specified otherwise, throttling ranges, proportional bands, and switching differentials shall be centered on the associated set point.

G. All set points unless otherwise indicated are adjustable and shall be programmable for all control loops.

H. Each control loop and/or interlock(s) for all mechanical system including terminal unit systems shall be programmed with a control loop specific graphical trend to trend all values associated with each specific control loop or system interlock.

I. Where any sequence or occupancy schedule calls for more than one motorized unit to start simultaneously, the system start commands shall be staggered by 60-second (adj.) intervals to minimize inrush current.

J. Scheduling shall be developed for each mechanical system. Final schedules shall be coordinated with University of Houston EMECS office prior to system commissioning. Until indicated otherwise the following schedule shall be used:

    1. Occupied: Monday – Friday/07:00 – 20:00

    2. Unoccupied: All other times and all statutory holidays.

K. Optimal start/stop programs shall be applied to all regularly scheduled mechanical and electrical systems.

L. At a minimum, trend log/historical data shall be implemented for every hardware point on the system. Additionally all software (virtual) points used as setpoints shall be trended. Point trends shall be grouped into logically interrelated points for individual mechanical and building systems. Initial set-up shall be to log values once every 5 minutes. Refer to points list on electrical and mechanical drawings for components requirements.

M. B-OWS Graphical User Interface (GUI) must be approved by University of Houston EMECS office and shall incorporate at a minimum the following:

1. At a minimum, all physical hardware, sensors, control devices and set points shall be visible on a B-OWS in graphical form.

2. All mechanical systems shall have a programmed real time color graphic for primary graphical user interface

3. Individual floor plan graphics will be programmed for each floor or area of the building. All space sensors will be visible on floor plan graphics and system graphic.

O. The system shall observe the following command priorities (from highest to lowest):

1. Smoke Control and Life Safety (BACnet Object Priority Array Level 1 & 2)

2. Manual Operator Command (BACnet Object Priority Array Level 8)

3. Energy Management (BACnet Object Priority Array Level 9)

4. Normal Automatic Control (BACnet Object Priority Array Level 10)

2.2 DIRECT AND WEB-ENABLED SERVER, (B-OWS) HARDWARE

A. Provide as specified for each PC-Based B-OWS

B. Assemble server components in a configuration that allows easy operator access to all necessary components from one position. Locate components as required by the University of Houston EMECS office.

C. Connect to LAN as required. If LAN/WAN is not dedicated to the BACnet network then Contractor shall develop a LAN/WAN System Architecture diagram denoting server B-OWS relative to other nodes on its segment of the LAN/WAN. This diagram shall be submitted at a minimum as a part of the As-Built and O&M Documentation.

D. Provide sufficient permanent and removable storage drives for 25% free memory after provision for all operating system, Third party and Control System Application software, all fully configured point databases, storage/back-up of all B-BC, B-AAC and B-ASC application programming, all graphic files, all user-defined reports and a three year archive of all trend and historical data described in this specification.

E. Provide sufficient RAM to meet system performance requirements.

2.3 LOCAL AREA NETWORKS (LAN)

A. The control system shall be configured so that any individual network shall not exceed 80% of its total design network capacity. The system shall have a reserve of 20% network capacity.

B. Where possible all Hubs, Switches, Half and Full Routers will be from the same manufacturer. Switches will be all "Store and Forward" type and will be installed in accordance with manufacturer specifications.

C. Inverted Networks will not be allowed. Networks with minimum packet sizes smaller than those it

connects to will not interconnect networks with larger minimum packet sizes. If three or more networks are interconnected the network with the highest speed and minimum packet size will be utilized to interconnect the slower networks.

D. Where BACnet/IP LAN type is used, non-TCP/IP devices shall not be used. Where BACnet/IP is provided it shall comply with all Addendum to ANSI/ASHRAE 135-1995 BACnet/IP.

2.4 BACnet PROTOCOL VERIFICATION SOFTWARE

A. Demonstrate exclusive communication utilizing the BACnet Protocol on all segments of the BACnet network.

2.5 BUILDING CONTROLLER (B-BC)

A. Provide as required to meet performance requirements of the system with a 20% increase in connected B-AAC and B-ASC on any individual network. Provide a dedicated B-BC for all project specific equipment requiring this controller type.

B. Locate strategically such that B-BC locations are as equally distributed throughout the project as possible.

2.6 ADVANCED APPLICATION CONTROLLERS (B-AAC)

A. Provide a dedicated B-AAC for each medium-sized mechanical system.

B. All points used for a single mechanical system shall be connected to the same B-AAC. Points used for control loop reset based on outside air, or space/zone temperature, or extremely remote differential pressure sensors on slow acting control loops are exempt from this requirement.

C. Provide spare additional I/O such that future use of spare capacity shall require providing only the field device, field wiring, point database definition and operational sequence programming changes as required. Additional point modules may be required to implement use of these spare points.

    1. Provide at least one (1) spare universal input and one (1) spare universal output or 15% spare I/O of the total capacity of each B-AAC whichever is greater.

    2. If B-AAC I/O is not universal then provide at least one (1) spare analog input, one (1) spare digital input, one (1) spare analog output and one (1) spare digital output or 15% spare I/O of the total capacity for each point type of each B-AAC whichever is greater.

2.7 APPLICATION SPECIFIC CONTROLLERS (B-ASC)

A. Provide a dedicated B-ASC for each Terminal Unit Mechanical Device on the project, including VAV and Fan Powered Terminal Units, Unit Heaters, and Individual Fans. Terminal Units specifically called out in the sequence of operation, as "Non-DDC" shall be excluded from this requirement.

B. All points used for a single Terminal Unit Mechanical Device shall be connected to a dedicated B-ASC. Points used for control loop reset based on outside air, or space/zone temperature, or extremely remote differential pressure sensors on slow acting control loops are exempt from this

requirement.

C. VAV ATU and FP-VAV ATU Controllers

1. Provide networked B-ASC for each VAV ATU and FP-VAV ATU consisting of a controller, damper actuator, and velocity transducer.

2. The ATU manufacturer shall provide a transformer, and factory wire the B-ASC and other unit mounted control devices such as actuators.

3. The ATU shall be provided with multi-point averaging type flow sensor factory piped to the velocity transducer.

4. Provide a networked communicating room sensor for each terminal unit that shall be field mounted and wired. Networked communicating room sensors shall be capable of performing airflow calibration and TAB functions without additional hardware or software.

5. Where indicated on the drawings and/or in one (1) location per floor, wing, building or section (whichever is more frequent), install networked communicating room sensor enabled to provide BACnet network connection to Service Tool and/or Portable B-OWS.

2.8 LOCAL SYSTEM NETWORK INTERFACE

A. At a minimum the Portable B-OWS shall be able to connect to the BACnet Internetwork within each mechanical equipment space within the project. For manufacturers systems that do not allow direct portable B-OWS connections to B-AAC and B-ASC this may require that a higher level LAN be routed to each mechanical equipment space with a jack.

2.9 TEMPERATURE CONTROL PANELS (TCP), ENCLOSURES & SUB-PANELS

A. All system components not designed for or required to be field installed shall be mounted in a control enclosure. Those components shall be sub panel mounted except components that are mounted on the panel face. Provide on/off power switch with over-current protection for control power sources in each local enclosure.

B. All control enclosures shall be located as shown on the drawings and wherever possible (or where not indicated on the drawings) so that visual observation and adjustment can be accomplished while standing flatfooted on the floor in a convenient location adjacent to the equipment served. Install all equipment in readily accessible location as defined by Chapter1 Article 100 Part A of the NEC.

C. Label all control system components.

D. A copy of the "As-built" application engineering for the system served shall be laminated in clear plastic, shall be legible and suspended within enclosure.

E. All B-BC shall be mounted in an enclosure.

2.10 INTERCONNECTING WIRING AND CABLING

A. General

1. It shall be the System Contractor's responsibility to provide all wiring required for a complete Control System.

2. Control system wiring and cabling installed for this project shall be performed by professionals in a workmanlike manner and in accordance with the Contract Documents, [Division 16] [Section 26] Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ) and shall include but may not be limited to the following:

    a. All power wiring required not indicated on the electrical plans and specifications.

    b. Power to all actuators and sensors.

    c. Provide all wiring and cabling for network communications except for owner provided LAN's/WAN's.

    d. All sensor and control device input and output wiring.

    e. All interconnecting cabling between and amongst network devices, PCs printers, modems, etc.

    f. Interlock wiring between devices, and between motor starters.

    g. All other necessary wiring for fully complete and functional system as specified.

    h. Install piping, wiring/cabling routed parallel to or at right angles with the structure, properly supported every six (6) feet at a minimum and installed in a workmanlike manner.

3. Maximum allowable voltage for control wiring shall be 120-volts.

4. All wiring shall be installed as continuous links. Any required splices shall be made only within an approved junction box or other approved protective device with a maximum fill of 50%.

    a. BACnet network cabling shall not be field spliced

5. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

6. This Contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

B. Power Wiring and Cabling

1. Where required, power wiring for the control system shall be from circuits on emergency power panels. At a minimum; B-BC's, the B-OWS and any other DDC devices and control devices connected to and/or responsible for system critical equipment shall be powered from circuits on emergency power panels.

2. Power wiring for all enclosures and equipment, including branch circuit wiring from circuit breaker panels shall be the responsibility of the System Contractor unless specifically shown on the Plans or Specifications to be provided under [Division 16] [Section 26]. Dedicated branch circuits shall be provided under [Division 16] [Section 26].

3. All B-OWS equipment shall be served from isolated ground receptacles via UPS by dedicated

branch circuits.

4. All other enclosures, sensor and control devices shall be fed from separate circuits in the electrical distribution panels and shall not be served from the typical floor receptacle or lighting circuits.

C. Network Wiring and Cabling

1. Network installation shall strictly adhere to the manufacturer's networking installation instructions and procedures

2. All communications wire shall be externally identified as "Building Energy Management System Network" at least once every five feet.

3. Network installation shall conform to standards for the LAN types and cabling types selected. Specific network rules inherent to the ANSI/AHRAE Standard 135-1995, BACnet will be followed. Those include but are not limited to:

    a. Only one path can exist from any BACnet device to another

    b. Each BACnet device connected to an internetwork LAN must have a unique device instance (0 - 4,194,303).

    c. Each internetwork LAN must have a unique Network Number (1 - 65,545).

    d. Wire type used for MSTP, RS-485 twisted pair communications must be balanced twisted pair with 100 to 120 Ohms Characteristic Impedance. The wire shall be less than 30 pF per foot, and preferred 22AWG or lower. A shield wire shall be included for ground connection.

4. Primary LAN Network wire and cable shall be run separately from all other wiring.

5. Other LAN Network wire and cabling shall be installed separate from any wiring over thirty (30) volts.

6. All communications shielding shall be grounded as per Networked System manufacturer's recommendations.

D. Installation

1. Except in mechanical and electrical spaces where other conduits or piping is exposed, conceal wiring and cabling as much as possible and install and comply with the requirements of the Contract Documents, [Division 16] [Section 26] Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ)

2. All wiring and cabling installed in and/or routed through TCP, Enclosures and Sub-Panels shall regardless of voltage and/or service be fastened securely using cable ties, non-metallic wiring duct and/or other standard industry wiring management means and methods in a workmanlike manner parallel and/or perpendicular with enclosure.

3. All TCP, Enclosures, Sub-Panels, Junction Boxes, Pull Boxes, Troughs, Trays, Raceways, Conduits, &c. shall not exceed 70% maximum conductor fill.

4. Each Input/Output device shall be controlled from a dedicated 2-pair conductor

5. Each Input/Output device requiring power shall have a dedicated power wire run to the control enclosure and shall be terminated to a dedicated terminal strip

6. All wire with controls enclosure shall be neat and suitably bundled and contained in Panduit wire duct or equivalent

7. All wiring will be suitably identified by thermal print heat shrink tubing at controller and Input/Output device.

2.11 ANALOG SENSORS

A. Temperature

1. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor readings.

2. Install and properly support all enclosures and sensing elements as much as possible in the center of duct cross section and in straight duct runs. In condensing environments use stainless steel flanges to support sensing elements.

3. Sensors mounted on air ducts having exterior insulation shall be provided with handy-box mounting with insulating material firmly fitted around handy-box.

4. Sensors for mixed air and outdoor air streams greater than 6 square feet or 24" in either direction shall be averaging type. Provide a minimum of 1 linear foot of sensor per 4 square feet of duct area or equal to duct width where installed, whichever is longer. Averaging sensing tubing shall serpentine vertically across airstream and be supported firmly by mechanical clips.

5. Temperature sensors installed in piping or tanks shall be in separable thermowells. Sensors shall be inserted into thermowells with conductive paste. Assembly shall allow removal of sensor without loss of fluid.

6. At a minimum one outside air temperature sensor shall be installed. It shall be mounted outside on a northern exposure as high as serviceable on the building. The sensor shall be mounted within a ventilated enclosure to shield the sensor from the effects of the sun. The sensor location shall be selected such that it may not be affected by artificial and/or mechanical airstreams (i.e., building exhaust, building relief, &c.).

7. Terminal Unit Sensors shall be provided one per terminal unit device with the exception of large non-partitioned areas served by multiple terminal units.

    a. They shall be wall mounted in the space served 60" above finished floor and located as shown on drawings.

    b. Provide a minimum of 16' of coiled temperature sensor control wiring for equipment with space sensor not located on the Drawings.

    c. In all areas where terminal unit sensor locations are not known at the time of building startup, sensors shall be hung approximately 24 inches from the ceiling in the area of the controlled zone and connected. Control wiring shall be neatly coiled and attached to ceiling grid. Sensors located in service corridors where subject to regular damage shall be mounted 84" above finished floor.

8. Zone temperature sensors shall not be located on perimeter walls. Where explicitly indicated on drawings to do so and/or in locations near exterior walls and/or subject to drafts sensors shall have insulated mounting bases to prevent false room temperature readings.

9. Where wall sensors are mounted in an area subject to damage provide suitable protective guard.

10. Where wall sensors are mounted in public spaces with adjustable set points provide suitable security guard.

11. Provide matched temperature sensors for differential temperature measurement. Differential accuracy shall be within 0.1°C (0.2°F).

B. Wet Bulb

1. For outside air mount same as outside air temperature sensor.

2. For duct mounting execute same as duct mounted temperature sensor.

C. Pressure

1. Orient static pressure sensing taps faced directly down-stream in the airflow so as to eliminate velocity pressure effects. Locate pressure transducers within 50' of sensing point and use tubing sized such as to prevent signal phase lag.

    a. Final location of static/differential pressure sensing taps shall be pursuant with Contract Documents and as indicated on drawings. Where not explicitly indicated on drawings, pressure sensing taps shall be located as follows:

        1) Duct static pressure control sensor tap shall be located 2/3 distance from the Air Handling Unit of the total duct length in a straight section of ductwork with a minimum or four (4) duct diameters in both directions

        2) Positive static high-pressure safety cut-outs shall be located at Air Handling Unit immediately downstream of fan section

        3) Mixed-Air static and/or differential sensor tap shall be located in mixing box section

        4) Negative static pressure safety cut-outs shall be located immediately upstream of fan section

        5) Filter differential pressure taps shall be installed on both filter inlet and outlet

    b. Mount air differential pressure taps so that true differential is sensed

2. Water gauge taps shall include snubbers and isolation valves

3. Water differential pressure sensors shall be piped through a five-valve bypass assembly with snubbers

D. Position

1. Mount damper position indicator onto damper blade and out of air stream as much as possible.

E. Flow

1. Mount airflow measuring station differential pressure sensor outside of fan casing.

2.12 SWITCHING SENSORS

A. Temperature

1. Wherever mixed or entering air temperatures are below 35°F (1.4°C), the sensing tube shall be installed across the leaving face of the first coil in the airstream. The low-temperature thermostat shall be arranged to stop the units supply fan and its associated return air fan should the temperature at any point along the sensing element fall below 35°F (1.4°C). Provide a minimum of one foot of sensing element for each square foot of coil face area. In condensing environments use stainless steel sensing element and capillary mounting clips.

B. Differential Pressure

1. Differential pressure type switches shall be installed as per differential pressure sensors and shall provide a maximum switching differential of 10% of the sensed operating range for the application at minimum and maximum designed flow rates. Set point shall be selected to operate at midpoint of span.

2. Paddle type water flow switch shall be used to verify flow through chillers, other applications for operational, safety or other critical control interlock, on-off flow status monitoring, and at locations as indicated on the Drawings. Provide with NEMA 4 enclosure when installed in a condensing environment.

3. Differential pressure type water flow switch shall be used for on-off flow status monitoring of equipment and to position secondary chilled water loop return control valves. The sensing tubes shall be installed between the equipment and the nearest service valves.

C. Position

1. Mount damper blade end switch in such a manner that it is located out of the airstream as much as possible. End switch as installed shall be repeatable to within a range of 5 degrees. Under no circumstances shall mercury-style end switches be permitted.

D. Direct drive motors are permitted to utilize a current switch without an adjustable set point.

2.13 AUTOMATIC CONTROL VALVES

A. Flow characteristics shall be as follows:

a. Flow type for 2-way valves shall be equal percentage, except for terminal unit zone valves, and differential pressure control applications.

b. Flow type for 3-way valves shall be linear, except for terminal unit zone and ball valves.

c. Terminal unit zone, differential pressure applications shall be linear flow characteristic.

B. Two-way, control valves shall be provided for all convectors, fin radiation, horizontal unit heaters, unit ventilators, and all steam applications.

C. Two-way control valves shall be provided for all cabinet unit heaters, duct coils, and any other locations noted on drawings.

D. Two-way valves shall not be placed on branch or main hydronic circuits where these valves will cause a "dead-head" pumping condition. Three-way valves shall be used to avoid this condition.

E. Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:

1. Two-Way liquid valves shall be 150% of total system (pump) head.

2. Three-Way liquid valves shall be 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head, whichever is greater.

F. Water Sizing Criteria at full flow:

1. Two-position service shall be line size.

2. Two-way or three-way modulating service shall have a maximum pressure drop not to exceed 4 PSI.

3. Differential pressure modulating service shall have a maximum pressure drop not to exceed 12 PSI.

2.14 VALVE ACTUATORS

A. When an air handling unit or major piece of mechanical equipment is not in operation, control devices shall remain in their "off" positions. Fail-safe positions shall be the same and defined as follows:

DEVICES	OFF/FAIL-SAFE POSITION
1. HHW Coil Valves:	As-is position to Coil/Equipment
2. CHW Coil Valves:	As-is position to Coil/Equipment

2.15 DAMPER ACTUATORS

A. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

B. Spring return actuators shall be provided except as follows.

1. Terminal or unitary equipment without direct introduction of outside air are permitted to have actuators that maintain their last commanded position when power is lost.

2. Damper actuator shall not be required to be provided with spring return provided that it is not directly connected to Outdoor Air and a failure of the damper to return to its "normal" position will not incur damage to the system/space it serves.

C. Modulating actuators shall be provided for terminal unit mechanical devices may use an actuator that responds to a floating or tri-state signal.

D. Minimum torque and power output requirements of actuators shall not be less than 1.2 times required design load.

E. When an air handling unit or major piece of mechanical equipment is not in operation, control damper shall remain in their "off" positions. Fail-safe positions shall be the same and defined as follows

DEVICES	OFF/FAIL-SAFE POSITION
1. Outdoor Air Dampers:	Closed
2. Return Air Dampers:	Open
3. Exhaust/Relief Air Dampers:	Closed

END OF SECTION