25 50 00 INTEGRATED AUTOMATION FACILITY CONTROLS (BACNET)

(Formerly SECTION 23 06 06 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.

B. Scope: Furnish all labor, materials and equipment necessary for a complete and operating Building Management System (BMS), utilizing Direct Digital Controls as shown on the drawings and as described herein. Drawings are diagrammatic only. All controllers furnished in this section shall communicate on a peer-to-peer bus over an open protocol bus (Examples: LonTalk, BACnet, MODBUS).

C. The intent of this specification is to provide a system that is consistent with BMS systems throughout the owner's facilities running the Niagara 4 Framework.

D. System architecture shall fully support a multi-vendor environment and be able to integrate third party systems via existing vendor protocols including, as a minimum, LonTalk, BACnet and MODBUS.
E. System architecture shall provide secure Web access using any of the current versions of Microsoft Internet Explorer, Mozilla Firefox, or Google Chrome browsers from any computer on the owner's LAN.
F. All control devices furnished with this Section shall be programmable directly from the Niagara 4 Workbench embedded toolset upon completion of this project. The use of configurable or programmable controllers that require additional software tools for post-installation maintenance shall not be acceptable.
G. Any control vendor that shall provide additional BMS server software shall be unacceptable. Only systems that utilize the Niagara 4 Framework shall satisfy the requirements of this section.
H. The BMS server shall host all graphic files for the control system. All graphics and navigation schemes for this project shall match those that are on the existing campus NiagaraAX or Niagara 4 Framework server.
I. A laptop computer including engineering/programming software to modify Operating System Server BMS programs and graphics shall be included.
J. Owner shall receive all Administrator level login and passwords for engineering toolset at first training session. The Owner shall have full licensing and full access rights for all network management, operating system server, engineering and programming software required for the ongoing maintenance and operation of the BMS.
K. OPEN NIC STATEMENTS - All Niagara 4 software licenses shall have the following NiCS: "accept.station.in=*"; "accept.station.out=*"and "accept.wb.in=*"and "accept.wb.out=*". All open NIC statements shall follow Niagara Open NIC specifications.
L. All JACE hardware licenses and certificates shall be stored on local MicroSD memory card employing encrypted “safe boot” technology.
M. To ensure quality, any JACE 3E, 6E, or 7 hardware products used on this project shall come through the Tridium Richmond, VA shipping facility. JACE hardware products not meeting this requirement will not be allowed.

N. All products of the BMS shall be provided with the following agency approvals. Verification that the approvals exist for all submitted products shall be provided on request, with the submittal package. Systems or products not currently offering the following approvals are not acceptable.
    1. Federal Communications Commission (FCC), Rules and Regulations, Volume II -July 1986 Part 15 Class A Radio Frequency Devices.
    2. FCC, Part 15, Subpart B, Class B
    3. FCC, Part 15, Subpart C
    4. FCC, Part 15, Subpart J, Class A Computing Devices.
    5. UL 504 - Industrial Control Equipment.
    6. UL 506 - Specialty Transformers.
    7. UL 910 - Test Method for Fire and Smoke Characteristics of Electrical and Optical-Fiber Cables Used in Air-Handling Spaces.
    8. UL 916 - Energy Management Systems All.
    9. UL 1449 - Transient Voltage Suppression.
    10. Standard Test for Flame Propagation Height of Electrical and Optical - Fiber Cables Installed Vertically in Shafts.
    11. EIA/ANSI 232-E - Interface Between Data Technical Equipment and Data Circuit Terminal Equipment Employing Serial Binary Data Interchange.

12. EIA 455 - Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices.
13. IEEE C62.41- Surge Voltages in Low-Voltage AC Power Circuits.
14. IEEE 142 - Recommended Practice for Grounding of Industrial and Commercial Power Systems.
    a. NEMA 250 - Enclosures for Electrical Equipment.
15. NEMA ICS 1 - Industrial Controls and Systems.
16. NEMA ST 1 - Specialty Transformers.
17. NCSBC Compliance, Energy: Performance of control system shall meet or surpass the requirements of ASHRAE/IESNA 90.1-1999.
18. CE 61326.
19. C-Tick.
20. cUL.

1.2 WORK INCLUDED

A. Scope: Furnish all labor, materials and equipment necessary for a complete and operating Building Management System (BMS), utilizing Direct Digital Controls as shown on the drawings and as described herein. Drawings are diagrammatic only. All controllers furnished in this section shall communicate on a peer-to-peer bus over an open protocol bus (Examples: LonTalk, BACnet, MODBUS).

B. Conduct a BAS Mockup session to prove sequence of operations, graphics and overall acceptance prior to construction. The owner, MEP consultant and General Contractor shall be present and the mockup session shall be conducted at the BAS contractor's facility. The Mockup session shall take no longer than one week. At completion, all parties present shall sign off that the mockup was completed and proven to meet the design intent.

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

D. 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

E. 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. NACNetwork Area Controllers (NAC)
6. Expandable Application Controllers (EAC)
7. Unitary Controllers (UC)

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), NACNetwork Area Controllers (NAC), 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. NACNAC'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: 100Mbps with the ability to increase to 1 gig

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

3. NACNAC'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 NAC, EAC & UC 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) UC with integral damper operators are to be installed at factory by ATU manufacturer. At the contractor's option, damper actuators not integral to the UC are acceptable and preferred.

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 Control System Contractor shall have a full service DDC office within 50 miles of the job site. This office shall be staffed with applications engineers, software engineers and field technicians. This office shall maintain parts inventory and shall have all testing and diagnostic equipment necessary to support this work, as well as staff trained in the use of this equipment.

B. Single Source Responsibility of Supplier: The Control System Contractor shall be responsible for the complete installation and proper operation of the control system. The Control System Contractor shall exclusively be in the regular and customary business of design, installation and service of computerized building management systems similar in size and complexity to the system specified. The Control System Contractor shall be the manufacturer of the primary DDC system components or shall have been the authorized representative for the primary DDC components manufacturer for at least 5 years. All control panels shall be assembled by the Control System Contractor in a UL-Certified 508A panel shop.

C. Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in the production and installation of HVAC control systems. Products shall be manufacturer's latest standard design and have been tested and proven in actual use.

D. 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. NAC, EAC, & UC 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	±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 Section 01 30 00.

B. Product Data: Manufacturer's data sheets on each product to be used, including:
   1. Preparation instructions and recommendations.
   2. Storage and handling requirements and recommendations.
   3. Installation methods.

C. Submit documentation of contractor qualifications, including those indicated in "Quality Assurance" if requested by the A-E.

D. copies of shop drawings of the entire control system shall be submitted and shall consist of a complete list of equipment and materials, including manufacturers' catalog data sheets and installation instructions. Submit in printed electronic format. Samples of written Controller Checkout Sheets and Performance Verification Procedures for applications similar in scope shall be included for approval.

E. Shop drawings shall also contain complete wiring and schematic diagrams, sequences of operation, control system bus layout and any other details required to demonstrate that the system has been coordinated and will properly function as a system. Terminal identification for all control wiring shall be shown on the shop drawings.

F. Upon completion of the work, provide 5 complete sets of ' as-built' drawings and other project-specific documentation in 3-ring hard-backed binders and on Flash media.

G. Any deviations from these specifications or the work indicated on the drawings shall be clearly identified in the Submittals. 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, , 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..

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. Network Area Controllers (NAC)

c. Expandable Application Controllers (EAC)

d. Unitary Controllers (UC)

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

    c. The sequence of operations shall be proven during the Mock Up phase. Refer to Mock Up specification section for any sequence of operation changes.

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.

B. 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) Information required for programming BAS

3) 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.

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

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

6) 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 BAS MOCK – UP REQUIREMENTS

A. Provide a mockup of select components and features of the BAS during the early stages of construction. The BAS mockup shall be constructed at the BAS subcontractors' s facilities and remain intact as long as necessary to obtain the Consultant and Owner approvals.

B. The BAS mockup shall include the following hardware components as applicable to the project and required to meet the mockup intent:

1. Network Data Server
2. Operators Workstation
3. Remote Operators Workstation
4. Hand Held Device
5. Partial Management LAN
6. NAC - Network Area Controller(s) in the final panel enclosure
7. Appropriate Field LAN to support the Expandable Application Controllers (EAC) and Unitary Controllers (UC) listed below.
8. Expandable Application Controllers (EAC), mounted in the final panel enclosures, serving the following systems as applicable to the project:
    a. Central CHW Plant
    b. Condenser Water System
9. Unitary Controllers (UC) Serving the following systems:
    a. Typical single zone AHU
    b. Typical VAV AHU
    c. Typical Multi-Zone

d. Typical OAHU
e. Typical terminal units – one of each type

10. Interface to Lighting Control Relay Panel – Electrical Subcontractor to provide
11. One Terminal Unit of each type shall be provided by the mechanical subcontractor for the BAS Mockup.
12. One VFD shall be provided by the Mechanical subcontractor
13. Any temporary power required for the BAS mockup including components provided by the Mechanical or Electrical subcontractor shall be provided by the BAS subcontractor.
14. Acutators and sensors associated with the above systems are not required as part of the mockup.

C. Provide a software based I/O point operational simulator to confirm proper operation of each type of I/O configuration.

D. The BAS mockup shall include, at minimum, the following software components:
1. All necessary software
2. All monitoring and control software including system graphics for the entire BAS. The graphics required for each system shall be created. Repetitive graphics for identical units are not required. Contractor shall also show the graphics and navigation of the entire system, not just equipment graphics.
3. All operating sequences of operation software and programming required for the systems listed above.
4. Software interface to the VFD
5. Software interface to the Lighting Relay Panel

E. Provide demonstration of the above components, software and operating features to the owner, Consultant and General Contractor in a BAS review session. It is anticipated that each feature and function of the hardware and software will be reviewed over a one (1) week period. The Consultant will create a deficiency list from the BAS Mockup Review Session. The BAS subcontractor shall correct all deficiencies noted and a follow up BAS Mocup review session will be scheduled to prove operation. The Consultant, Owner and General Contractor sign off that the BAS Mockup was completed and successful to meet the intent of the project.

1.11 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. During system commissioning and at such time acceptable performance of the Control System hardware and software has been established, the Control System Contractor shall provide on-site operator instruction to the owner's operating personnel. Operator instruction shall be done during normal working hours and shall be performed by a competent representative familiar with the system hardware, software and accessories.

B. The Control System Contractor shall provide 48 total hours of comprehensive training in multiple sessions for system orientation, product maintenance and troubleshooting, programming and engineering. These classes are to be spread out during the 1st year warranty period. The first class starting after final commissioning and the last class is to be in the last month of 1-year warranty period.

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

D. Controls Contractor is required to send a UofH Building Automation representative to Factory training for programming and Integration support.

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 two (2) years 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 BACNet WEB SERVER

A. **Minimum Computer Configuration (Hardware Independent).**
   1. **Central Server. Owner shall provide a dedicated BAS server with configuration that includes the following components as a minimum:**
   2. **Processor: Intel Xeon CPU E5-2640 x64 (or better), compatible with dual- and quad-core processors.**
   3. **Memory: 2 GB or more recommended for large systems, 8 GB or more recommended for the Windows 64-bit version.**
   4. **Hard Drive: 256 GB minimum, more recommended depending on archiving requirements.**
   5. **Display: Video card and monitor capable of displaying 1024 x 768 pixel resolution or greater.**
   6. **Network Support: Ethernet adapter (10/100 Mb with RJ-45 connector).**
   7. **Connectivity: Full-time high-speed ISP connection recommended for remote site access (i.e. T1, ADSL, cable modem).**

B. Standard Client: The thin-client Web Browser BAS GUI shall be Microsoft Internet Explorer (10.0 or later) running on Microsoft 7+. No special software shall be required to be installed on the PCs used to access the BAS via a web browser.

2.2 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. HTML5 and Xhtml must comply with W3c standards.

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.

2.3 OPERATORS WORKSTATION PLATFORM (B-OWS)

A. Provide One (2) Portable Operators Workstation (Portable B-OWS) shall be notebook computer workstation. Portable Workstation Hardware minimum requirements are as follows:

1. 4 GB RAM
2. 500 GB to 1 TB or larger hard disc drive with 12 millisecond access time
3. At least one (1) Ethernet 10/100 Network Interface Card (NIC)
4. At least four (4) USB 2.0 ports
5. 87 key keyboard with touchpad and track stick pointing devices
6. All necessary cables

B. Communications and Protocols

1. B-OWS information access for the control system shall utilize the BACnet protocol only for communication to NAC's, EAC's, UC's and all other BAS DDC controllers
2. B-OWS shall reside on the same LAN as NAC'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.

C. 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.

D. 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

2.4 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.
2. All software must compatible with UH campus LDAP

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

D. Alarming and Event Notification

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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.

E. 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.

F. 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 (NAC, EAC, UC).

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.

G. 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

H. 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.

I. 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.

2.6 NETWORK AREA CONTROLLER (NAC)

A. Provide one or more Network Area Controllers (NAC) to meet the sequences of operation and the type and quantity of devices being integrated into the system. The NAC shall provide the interface between the local area network (LAN) or wide area network (WAN) and the field control devices. The NAC shall provide global supervisory control functions over the associated controllers and shall be capable of executing application control programs to provide: calendar functions; scheduling; trending; alarm monitoring and routing; time synchronization; integration of controller data for each applicable protocol; network management functions for all network devices. The user may view real-time information via web-based graphical displays at each NAC. Web software shall not be required to provide the following features.

B. The Network Area Controller shall provide the following hardware features as a minimum: two Ethernet Ports – 10/100 Mbps; one RS-232 port; one RS-485 BACnet MS/TP port; battery backup; 256 DDR RAM memory; 128 MB flash memory for long term data backup. If battery backup or flash memory is not supplied provide uninterruptible power source (UPS) per network controller to maintain memory for 48 hours.

C. The NAC shall be capable of operation over a temperature range of 32 to 122°F and operation over a humidity range of 5 to 95% RH, non-condensing; storage temperatures of between 32 and 158°F.

D. The NAC shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the NAC shall be an ODBC-compliant database or must provide an ODBC data access mechanism to read and write data stored within it.

E. Event Alarm Notification and actions: The NAC shall provide alarm recognition, storage; routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers. Alarm conditions shall be routed to any defined user location whether connected to a local or wide-area network.

1. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including but limited to: alarm; return to normal; fault.

2. Provide for the creation of a minimum of eight alarm classes for the purpose of routing types and or classes of alarms, i.e.: security, HVAC, Fire, etc. Allow timed routing of alarms by class, object, group, or node.

3. Provide alarm generation from binary object “runtime” and/or event counts for equipment maintenance (i.e. filter status, fan run status). Authorized users shall be able to reset runtime or event count values with appropriate password control.

4. Control equipment and network failures shall be treated as alarms and annunciated.

5. Alarms shall be annunciated in any of the following manners as defined by the user: screen message text; e-mail of the complete alarm message to multiple recipients. Provide the ability to route and email alarms based on: day of the week, time of day and recipient.

6. Color-graphic shall have flashing alarm object(s). Printed message may be routed directly to a dedicated alarm printer.

7. The following shall be recorded by the NAC for each alarm (at a minimum): time and date; location (building, floor, zone, office number, etc.); associated equipment. Upon acknowledgement of the alarm the NAC shall document the time, date and authorized user. The number of alarm occurrences since the last acknowledgement shall be recorded.

8. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user. Alarm actions may be initiated by user defined programmable objects created for that purpose.

9. Alarm archiving: A log of all alarms shall be maintained by the NAC and/or a server and shall be available for review by the user. Provide a “query” feature to allow review of specific alarms by user defined parameters. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.

F. Data Collection and Storage: The NAC shall have the ability to collect data for any property of any object and store this data for future use.

1. The user shall designate the log as an interval log or deviation log. For an interval log, the object shall be configured for time of day, day of week and the sample collection interval. For deviation log, the object shall be configured for the deviation of a variable to a fixed value. This value, when reached, will initiate logging of the object. For all logs, provide the ability to set the maximum number of data stores for the log and to set whether the log will stop collecting when full, or rollover the data on a first-in, first-out basis. Each log shall have the ability to have its data cleared on a time-based event or by a user-defined event or action.

2. All log data shall be stored in a relational database in the NAC and the data shall be accessed from the server or a standard web browser. All log data, when accessed from the server, shall be capable of being manipulated using standard SQL statements.

3. All log data shall be available to the user in the following data formats: HTML, XML, plain text, comma separated values (.csv) as a minimum.

4. The NAC shall have the ability to archive its log data either locally, or remotely to the server or other NAC on the network.

G. Local Access: The NAC shall provide redundancy of system access to the local controllers at the remote building if the Central Network Server should lose communication or be off-line. The NAC shall maintain setpoint and scheduling features, access to the color-graphic displays, maintain trend

logs and reports. Upon restoration of communication with the CNS the archived information shall be transmitted to the server for archiving.

NETWORK AREA CONTROLLERS (NAC)

2.7 EXPANDABLE APPLICATION CONTROLLERS (EAC)

A. Expandable application controllers shall be capable of implementing control strategies for the system based on information from any or all connected inputs. The EAC shall utilize factory pre-programmed global strategies that may be modified by field personnel on-site. Global control algorithms and automated control functions should execute via a 32-bit processor

B. Programming shall be object-oriented using control program blocks that will support a minimum of 500 Analog Values and 500 Binary Values. Analog and binary values shall support standard BACnet priority arrays. Provide means to graphically view inputs and outputs to each program block in real-time as program is executing.

C. Controller shall have adequate data storage to ensure high performance and data reliability. Battery shall retain static RAM memory and real-time clock functions for a minimum of 1.5 years (cumulative). Battery shall be a field-replaceable (non-rechargeable) lithium type. The onboard, battery-backed real time clock must support schedule operations and trend logs.

D. Controller shall include both on-board 10BASE-T/100BASE-TX Ethernet BACnet communication over a twisted pair cable (UTP) and shall include BACnet IP communication

E. The base unit of the EAC shall host up to 8 expansion modules with various I/O combinations including universal 10-bit inputs, binary triac outputs, and 8-bit switch selectable analog outputs (0-10V or 0-20 mA). Inputs shall support 3K and 10K thermistors, 0-5VDC, 0-10VDC, 4-20mA, dry contacts and pulse inputs directly.

F. All outputs must have onboard Hand-Off-Auto switches and a status indicator light. HOA switch position shall be monitored. Each analog output shall include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position. The position of each and every HOA switch shall be available system wide as a BACnet object.

G. BACnet Conformance

1. Standard BACnet object types supported shall include as a minimum: Analog Input, Binary Input, Analog Output, Binary Output, Analog Value, Binary Value, Device, File, Group, Event Enrollment, Notification Class, Program and Schedule object types. All necessary tools shall be supplied for working with proprietary information.

2. The Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs) and function as a BACnet Broadcast Management Device (BBMD).

H. Schedules: Each EAC shall support a minimum of 50 BACnet schedule objects.

I. Logging Capabilities: Each controller shall support a minimum of 200 trend logs. Sample time interval shall be adjustable at the operator's workstation. Controller shall periodically upload trended data to system server for long term archiving if desired. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.

J. Alarm Generation: Alarms may be generated within the system for any object change of value or state either real or calculated. This includes things such as analog object value changes, binary object state changes, and various controller communication failures. Alarm logs shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site via remote communications. Controller must be able to handle up to 200 alarm setups stored as BACnet event enrollment objects – system destination and actions individually configurable.

2.8 UNITARY CONTROLLERS – GENERAL

A. HVAC control shall be accomplished using LonMark or BACnet based devices where the application has a LonMark profile or BTL Listed PICS defined. Where LonMark devices are not available for a particular application, devices based on LonWorks shall be acceptable. For each LonWorks device that does not have LonMark certification, the device supplier shall provide an XIF file for the device. **The controller platform shall provide options and advanced system functions, programmable and configurable using Niagara 4 Framework, that allow standard and customizable control solutions required in executing the "Sequence of Operation".**

F. All PECs shall be application programmable and shall at all times maintain their certification. All control sequences within or programmed into the PEC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery to be retained.

G. The PEC shall provide LED indication of communication and controller performance to the technician, without cover removal.

H. The PEC shall not require any external configuration tool or programming tool. All configuration and programming tasks shall be accomplished and accessible from within the Niagara 4 environment.

I. The following integral and remote Inputs/Outputs shall be supported per each PEC:
1. Eight integral dry contact digital inputs.
2. Any two digital inputs may be configured as pulse counters with a maximum pulse read rate of 15 Hz.
3. Eight integral analog inputs (configurable as 0-10V, 0-10,000 ohm or, 20K NTC).
4. Six integral 4-20 ma analog outputs.
5. Eight integral 24 Vac Triac digital outputs, configurable as maintained or floating motor control outputs.
6. One integral 20 Vdc, 65-mA power supply for auxiliary devices.
7. If a 20 Vdc 65-mA power supply terminal is not integral to the PEC, provide at each PEC a separate, fully isolated, enclosed, current limited and regulated UL listed auxiliary power supply for power to auxiliary devices.

J. Each PEC shall have expansion ability to support additional I/O requirements through the use of remote input/output modules.

K. PEC Controllers shall support at minimum the following control techniques:
1. General-purpose control loops that can incorporate Demand Limit Control strategies, Set point reset, adaptive intelligent recovery, and time of day bypass.
2. General-purpose, non-linear control loops.
3. Start/stop Loops.
4. If/Then/Else logic loops.
5. Math Function loops (MIN, MAX, AVG, SUM, SUB, SQRT, MUL, DIV, ENTHALPY).

2.9 ADVANCED UNITARY CONTROLLER (AUC)

A. The advanced unitary controller (AUC) platform shall be designed specifically to control HVAC - ventilation, filtration, heating, cooling, humidification, and distribution. Equipment includes: constant volume air handlers, VAV air handlers, packaged RTU, heat pumps, unit vents, fan coils, natural convection units and radiant panels. The control shall use LonMark or BACnet based devices where the application has a LonMark profile or BTL Listed PICS defined. Where LonMark devices are not available for a particular application, devices based on LonWorks shall be acceptable. For each LonWorks device that does not have LonMark certification, the device supplier shall provide an XIF file for the device. The controller platform shall provide options and advanced system functions, programmable and configurable using Niagara 4 Framework, that allow standard and customizable control solutions required in executing the "Sequence of Operation".

B. Minimum Requirements:
1. The controller shall be fully programmable with full functionality on any Niagara 4 brand platform.
   a. Support downloads to the controller from any brand of Niagara 4 platform.
   b. Support uploads from the controller to any brand of Niagara 4 platform.
   c. Support simulation/debug mode of the controller.
   d. Maintain native GUI.
   e. Native function-block programming software and all controller “Setup Wizards” shall be embedded within the Niagara 4 environment.
2. The controller shall be capable of either integrating with other devices or stand-alone operation.
3. The controller shall have two microprocessors. The Host processor contains on-chip FLASH program memory, FLASH information memory, and RAM to run the main HVAC application. The second processor for network communications. Controller memory minimum requirements include:
   a. FLASH Memory Capacity: 60 Kilobytes with 8 Kilobytes for application program.
   b. FLASH Memory settings retained for ten years.
   c. RAM: 2 Kilobytes.
4. The controller shall have an internal time clock with the ability to automatically revert from a master time clock on failure.
   a. Operating Range: 24 hour, 365 day, multi-year calendar including day of week and configuration for automatic day-light savings time adjustment to occur on configured start and stop dates.
   b. Accuracy: ±1 minute per month at 77 degrees F (25 degrees C).
   c. Power Failure Backup: 24 hours at 32 degrees to 122 degrees F (0 degrees to 50 degrees C).
5. The controller shall have Significant Event Notification, Periodic Update capability, and Failure Detect when network inputs fail to be detected within their configurable time frame.
6. The controller shall have an internal DC power supply to power external sensors.
   a. Power Output: 20 VDC ±10% at 75 mA.
7. The controller shall have a visual indication (LED) of the status of the devise:
   a. Controller operating normally.
   b. Controller in process of download.
   c. Controller in manual mode under control of software tool.
   d. Controller lost its configuration.
   e. No power to controller, low voltage, or controller damage.
   f. Processor and/or controller are not operating.

8. The minimum controller Environmental ratings.
    a. Operating Temperature Ambient Rating: -40 degrees to 150 degrees F (-40 degrees to 65.5 degrees C).
    b. Storage Temperature Ambient Rating: -40 degrees to 150 degrees F (-40 degrees to 65.5 degrees C).
    c. Relative Humidity: 5% to 95% non-condensing.
9. The controller shall have the additional approval requirements, listings, and approvals:
    a. UL/cUL (E87741) listed under UL916 (Standard for Open Energy Management Equipment) with plenum rating.
    b. CSA (LR95329-3) Listed.
    c. Meets FCC Part 15, Subpart B, Class B (radiated emissions) requirements.
    d. Meets Canadian standard C108.8 (radiated emissions).
    e. Conforms requirements European Consortium standard EN 61000-6-1; 2001 (EU Immunity).
    f. Conforms requirements European Consortium standard EN 61000-6-3; 2001 (EU Emission).
10. The controller housing shall be UL plenum rated mounting to either a panel or DIN rail (standard EN50022; 7.5mm x 35mm).
11. The controller shall have a mix of digital inputs (DI), digital Triac outputs (DO), analog outputs (AO), and universal inputs (UI).
    a. Analog outputs (AO) shall be capable of being configured as digital outputs (DO).
    b. Input and Output wiring terminal strips shall be removable from the controller without disconnecting wiring.
    c. Input and Output wiring terminals shall be designated with color coded labels.
    d. Universal inputs shall be capable of being configured as binary inputs, resistive inputs, voltage inputs (0-10 VDC), or current inputs (4-20 mA).
12. The controller shall provide "continuous" automated loop tuning with an Adaptive Integral Algorithm Control Loop.
13. The controller platform shall have standard HVAC application programs that are modifiable to support both the traditional and specialized "sequence of operations" as outlined in Section 4.
    a. Discharge air control and low limit.
    b. Pressure-dependent dual duct without flow mixing.
    c. Variable air volume with return flow tracking.
    d. Economizer with differential enthalpy.
    e. Minimum airflow coordinated with CO2.
    f. Unit ventilator cycle (1, 2, 3) 2-pipe.
    g. Unit ventilator cycle (1, 2, 3) 2-pipe with face/bypass.
    h. Unit ventilator cycle (1, 2, 3) 4-pipe.
    i. Unit ventilator cycle (1, 2, 3) 4-pipe with EOC valve.

EXPANDABLE APPLICATION CONTROLLERS (EAC)Expandable Application Controllers (EAC)UNITARY CONTROLLERS (UC)Unitary Controllers (UC)

2.10 SYSTEM NETWORK CONTROLLER (SNC)

A. These controllers are designed to manage communications between the programmable equipment controllers (PEC), application specific controllers (ASC) and advanced unitary controllers (AUC) which are connected to its communications trunks, manage communications between itself and other system network controllers (SNC) and with any operator workstations (OWS) that are part of the BAS, and perform control and operating strategies for the system based on information from any

controller connected to the BAS.

B. The controllers shall be fully programmable to meet the unique requirements of the facility it shall control.

C. The controllers shall be capable of peer-to-peer communications with other SNC's and with any OWS connected to the BAS, whether the OWS is directly connected, connected via cellular modem or connected via the Internet.

D. The communication protocols utilized for peer-to-peer communications between SNC's will be Niagara 4 Fox, BACnet TCP/IP and SNMP. Use of a proprietary communication protocol for peer-to-peer communications between SNC's is not allowed.

E. The SNC shall employ a device count capacity license model that supports expansion capabilities.

F. The SNC shall be enabled to support and shall be licensed with the following Open protocol drivers (client and server) by default:
   1. BACnet
   2. Lon
   3. MODBUS
   4. SNMP
   5. KNX

G. The SNC shall be capable of executing application control programs to provide:
   1. Calendar functions.
   2. Scheduling.
   3. Trending.
   4. Alarm monitoring and routing.
   5. Time synchronization.
   6. Integration of LonWorks, BACnet, and MODBUS controller data.
   7. Network management functions for all SNC, PEC and ASC based devices.

H. The SNC shall provide the following hardware features as a minimum:
   1. Two 10/100 Mbps Ethernet ports.
   2. Two Isolated RS-485 ports with biasing switches.
   3. 1 GB RAM
   4. 4 GB Flash Total Storage / 2 GB User Storage
   5. Wi-Fi (Client or WAP)
   6. USB Flash Drive
   7. High Speed Field Bus Expansion
   8. -20-60°C Ambient Operating Temperature
   9. Integrated 24 VAC/DC Global Power Supply
   10. MicroSD Memory Card Employing Encrypted Safe Boot Technology

I. The SNC shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 16 simultaneous users.

J. The SNC shall provide alarm recognition, storage, routing, management and analysis to supplement distributed capabilities of equipment or application specific controllers.

K. The SNC shall be able to route any alarm condition to any defined user location whether connected

to a local network or remote via cellular modem, or wide-area network.

1. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including but not limited to:
    a. Alarm.
    b. Return to normal.
    c. To default.
2. Alarms shall be annunciated in any of the following manners as defined by the user:
    a. Screen message text.
    b. Email of complete alarm message to multiple recipients.
    c. Pagers via paging services that initiate a page on receipt of email message.
    d. Graphics with flashing alarm object(s).
3. The following shall be recorded by the SNC for each alarm (at a minimum):
    a. Time and date.
    b. Equipment (air handler #, access way, etc.).
    c. Acknowledge time, date, and user who issued acknowledgement.

L. **Programming software and all controller "Setup Wizards" shall be embedded into the SNC**.

M. The SNC shall support the following security functions.
1. Module code signing to verify the author of programming tool and confirm that the code has not been altered or corrupted.
2. Role-Based Access Control (RBAC) for managing user roles and permissions.
3. Require users to use strong credentials.
4. Data in Motion and Sensitive Data at Rest be encrypted.
5. LDAP and Kerberos integration of access management.

N. The SNC shall support the following data modeling structures to utilize Search; Hierarchy; Template; and Permission functionality:
1. Metadata: Descriptive tags to define the structure of properties.
2. Tagging: Process to apply metadata to components
3. Tag Dictionary

O. The SNC shall employ template functionality. Templates are a containerized set of configured data tags, graphics, histories, alarms... that are set to be deployed as a unit based upon manufacturer's controller and relationships. All lower level communicating controllers (PEC, AUC, AVAV, VFD…) shall have an associated template file for reuse on future project additions.

P. The SNC shall be provided with a 5 Year Software Maintenance license. Labor to implement not included.

2.11 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.

2.12 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	Orange jacketed sheath

2.13 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.

2.14 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:

        i. Standard Wall-Mount Space Sensor

        ii. Setpoint Adjustment Buttons (“+” & “-”)

        iii. Override/Bypass

        iv. Occupancy

        v. CO2

        vi. RH

        vii. 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. Three-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 Onicon F-1300 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. Onicon F-1100 or equal. [See also 33 10 00, Water Distribution]

F. Gas

Refrigerant leak detection monitors shall be provided for the refrigerant and number of chillers installed.

1. Power consumption: AC - 325 mA, DC - 250 mA. Volt free contacts to indicate an alarm condition.
2. Operating temperature range of 0 Deg. C. to 40 Deg. C. (32 Deg. F. to 105 Deg. F.). Operating humidity range: 0% to 95% non-condensing.
3. Measuring range of 0-1000 ppm proportional to 4 to 20mA output range for each sampling point.
4. System shall detect the presence of the following types of refrigerants regardless of refrigerant type using sequential sampling and multi-point monitoring method: CFC, HCFC and HFC as provided with the chillers.
5. System shall annunciate to the BCS through a contact closure and have a local alarm (audible and visual) Control panel shall have a silencing alarm button. Signage at all entry points to the chiller room shall be installed. Initial alarm shall comply with recommended Allowable Exposure Level (AEL). Adjustable 3 level alarm for each point shall be supplied with common alarm output contacts. Provide local digital indication of ppm level for a minimum of 1 sample point per chiller. A sample point shall be located close to each chiller and the refrigerant pump out unit location. Location to be approved by the engineer. Sample point if in alarm shall flash the associated LED. Provide local alarm horns and visual (stroboscopic) beacons at the following locations to activate upon alarm to an approved detail:
   a. Outside of entrance doors to chiller machine room.
   b. Inside rooms without an escape route other than through the chiller room.
   a. At each chiller location.
   b. At any other location in the chiller room as necessary to ensure that a person at any location in the chiller room and room that can be entered from the chiller room can see the visual alarm and hear the audible alarm and at any other location required to meet the applicable codes.
6. System shall shut down all electrical equipment (chiller systems and associated pumps, AHU, FCU, etc.) and sequence emergency extract equipment as required to meet regulations. Where combustion equipment is employed, refrigerant vapor monitoring system

shall automatically shut down the combustion process in event of refrigerant leakage if other alternative acceptable conditions are not applied. Ventilation system, chiller and associated pumps and other equipment shut down as a result of the refrigerant leak alarm shall return to normal operation when the refrigerant monitoring system is no longer detecting refrigerant levels above set points and alarms have been silenced.

7. System shall have self-diagnostics and supply common malfunction output. Loss of sample flow at either sample or ZERO line and electrical malfunction shall annunciate to the BCS.

8. Provide two (2) additional particulate filters and zero gas filter cartridges.

9. Provide self-contained breathing apparatus that is OSHA approved and certified meeting the following requirements:

   Certified for 20 minutes of use.

   Furnish in clearly marked wall mount metal enclosures to be located inside each room that does not have an escape route apart from through the chiller room, outside one exterior door serving the chiller machine room, within the chiller room at locations such that no point in the chiller room is more than 50 feet from an escape door or a SCBA and at all other locations required by the code. Locations of SCBA to be approved by the Engineer.

10. Provide an emergency shut-off control button outside each chiller plant room entrance/exit door. Button shall be mounted at 1200mm above finished floor adjacent to refrigerant leak detection alarm light. Activation of any one of the buttons shall de-energize all chillers and other electrical equipment within the chiller plant room. Button shall be manually reset.

11. Provide RS-485 BACnet interface to BCS.

12. Provide Vulcain VA301EM Expansion Module, VA301IRFS Infrared Refrigerant Gas Sensors, Strobe/Horns and Emergency Push Buttons.

13. 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, 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.

14. 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.

15. 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.

16. 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.

2.15 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.

2.16 AUTOMATIC CONTROL VALVES

A. Furnish all valves controlled by the BCS as detailed in the mechanical drawings, the sequences of operation and the input/output summary. Furnish chiller isolation valves as indicated in the sequences. Control valves shall be factory fabricated of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. Where necessary to achieve the required performance and pressure drop a control valve may be down sized up to two nominal sizes below line size. Two-position control valves shall be full-line size.

1. All chilled water, condenser water, and hot water valves shall meet, at minimum, the following ANSI Class 150 ratings. Valves 0.5 inch to 2 inches shall have NPT female screwed ends. Valves 2.5 inches and larger shall have flanged ends.

2. Equal Percentage control characteristic shall be provided for all 3-way water coil control valves.

B. Characterized Control Ball Valves (CCV) for ½’ to 2”: for **2 and 3-way applications** shall have equal percentage characteristics. Manufacturer shall be Belimo CCV, Honeywell or approved equal.

1. Valve housing shall consist of forged brass rated at no less than 400 psi at 250°F. Three-way valves shall have EPDM o-rings behind ball seals to allow for a minimum close-off pressure of 40 psi with an actuator that provides 35 in-lbs torque for ½ to 2 in. sizes. Three-way valves shall be installed in a “tee” configuration with actuator perpendicular to the shaft. Confirm mixing or diverting application for correct valve selection.

C. Butterfly valves: For chiller isolation control valves and cooling tower bypass valves butterfly control valves may be provided.

1. Butterfly valves shall be sized for modulating service at 60-70 degree stem rotation. Isolation valves shall be line-size. Design velocity shall be less than 12 feet per second

when used with standard EPDM seats. Butterfly valves shall have ductile iron body, 304 stainless steel disc and EPDM seat. The valve body close-off pressure rating shall be 150 psi over a range of -20 F to 250 F. The flange shall be ANSI 125/250. Belimo F6 and F7 series or approved manufacturer.

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

1. All internal trim regardless of body type shall be Type 300 Stainless Steel. Valves 3" and larger shall be butterfly valves

2.17 VALVE ACTUATORS: Honeywell and Belimo are preferred products.

A. Control Valve Actuators for CCV and Globe valves:.

1. Provide electric actuators for all control valves that are furnished as part of the BCS contract. Two way and three way control valve actuators shall meet, at minimum, the following requirements:
2. Motor driven type with gear assembly made of hardened steel. Actuator shall have an input voltage of 24 VAC. Interior actuator housings shall be NEMA-2 rated. Exterior housings shall require a weather shield or shall be NEMA-4 rated. Provide visual mechanical position indication
3. Valves shall be sized to meet the shut-off requirements when operating at the maximum system differential pressure and with the installed system pump operating at shut-off head. Actuators shall control against system maximum working pressures.
4. Normal and failure positions shall be as indicated in the operating sequences. Provide spring return action per the sequences.
5. Manual declutch lever to enable manual operation of the valve. It shall be possible for an operator to manually modulate valves located in mechanical rooms in the event of loss of power.
6. Overload Protection: Actuators shall provide protection against actuator burnout by using an internal current limiting circuit or digital motor rotation sensing circuit. Circuit shall insure that actuators cannot burn out due to stalled damper or mechanical and electrical paralleling. End switches to deactivate the actuator at the end of rotation are acceptable only for butterfly valve actuators.
7. All actuators shall be capable of being electronically programmed in the field by use of external computer software or a dedicated handheld tool for the adjustment of flow. Programming using actuator mounted switches or multi-turn actuators are not acceptable.
8. Electric actuators shall be Belimo or Honeywell compatible with valve furnished.

B. Butterfly Valve Industrial Actuators

1. Enclosure shall be NEMA 4 (weatherproof) enclosure and will have an industrial quality coating.
2. Actuator shall have a motor rated for continuous duty. The motor shall be fractional horsepower; permanent split capacitor type designed to operate on a 120 VAC, 1 phase, 60 Hz supply. Two

adjustable cam actuated end travel limit switches shall be provided to control direction of travel. A self-resetting thermal switch shall be imbedded in the motor for overload protection.

3. Reduction gearing shall be designed to withstand the actual motor stall torque. Gears shall be hardened alloy steel, permanently lubricated. A self-locking gear assembly or a brake shall be supplied.
4. Actuator shall have a 6 ft wiring harness provided for ease in field wiring (above 1500 in-lbs). Two adjustable SPDT cam-actuated auxiliary switches, rated at 250 VAC shall be provided for indication of open and closed position. Actuator shall have heater and thermostat to minimize condensation within the actuator housing.
5. Actuator shall be equipped with a hand wheel for manual override to permit operation of the valve in the event of electrical power failure or system malfunction. Hand wheel must be permanently attached to the actuator and when in manual operation electrical power to the actuator will be permanently interrupted. The hand wheel will not rotate while the actuator is electrically driven.
6. The actuator shall be analog, floating, or two position as called out in the control sequence of operation. All analog valves shall be positive positioning, and respond to a 2-10 VDC, 4-20 mA, or adjustable signal as required. Analog actuators shall have a digital control card allowing any voltage input for control and any DC voltage feedback signal for position indication.
7. Butterfly valve actuators shall be Belimo furnished with specified butterfly valves.

2.18 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.

2.19 AUTOMATIC CONTROL DAMPER ACTUATORS: (Belimo is a preferred product

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.

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. 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.

B. 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.

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 within the airstream 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. 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.

D. 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:

3.2 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 Building Automation Systems 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 Buidling Automation office and shall incorporate at a minimum the following:

8. WEB BROWSER GRAPHICAL USER INTERFACE

i. Web Browser Navigation: The Thin Client web browser GUI shall provide a comprehensive user interface. Using a collection of web pages, it shall be constructed to "feel" like a single application, and provide a complete and intuitive mouse/menu driven operator interface. It shall be possible to navigate through the system using a web browser to accomplish requirements of this specification. The Web Browser GUI shall (as a minimum) provide for navigation, and for display of animated graphics, schedules, alarms/events, live graphic programs, active graphic set point controls, configuration menus for operator access, reports and reporting actions for events.

ii. Login: On launching the web browser and selecting the appropriate domain name or IP address, the operator shall be presented with a login page that will require a login name and strong password. Navigation in the system shall be dependent on the operator's role-based application control privileges.

iii. Navigation: Navigation through the GUI shall be accomplished by clicking on the appropriate level of a navigation tree (consisting of an expandable and collapsible tree control like Microsoft's Explorer program) and/or by selecting dynamic links to other system graphics. Both the navigation tree and action pane shall be displayed simultaneously, enabling the operator to select a specific system or equipment and view the corresponding graphic. The navigation tree shall as a minimum provide the following views: Geographic, Network, Groups and Configuration.

1. Geographic View shall display a logical geographic hierarchy of the system including: cities, sites, buildings, building systems, floors,

equipment and objects.
2. Groups View shall display Scheduled Groups and custom reports.
3. Configuration View shall display all the configuration categories (Operators, Schedule, Event, Reporting and Roles).

iv. Action Pane: The Action Pane shall provide several functional views for each subsystem specified. A functional view shall be accessed by clicking on the corresponding button:
1. Graphics: Using graphical format suitable for display in a web browser, graphics shall include aerial building/campus views, color building floor-plans, equipment drawings, active graphic set point controls, web content and other valid HTML elements. The data on each graphic page shall automatically refresh.
~~2.~~ Dashboards: User customizable data using drag and drop HTML5 elements. Shall include Web Charts, Gauges, and other custom developed widgets for web browser. User shall have ability to save custom dashboards.
3. Search: User shall have multiple options for searching data based upon Tags. Associated equipment, real time data, Properties, and Trends shall be available in result.
4. Properties: Shall include graphic controls and text for the following: Locking or overriding objects, demand strategies, and any other valid data required for setup. Changes made to the properties pages shall require the operator to depress an 'accept/cancel' button.
5. Schedules: Shall be used to create, modify/edit and view schedules based on the systems hierarchy (using the navigation tree).
6. Alarms: Shall be used to view alarm information geographically (using the navigation tree), acknowledge alarms, sort alarms by category, actions and verify reporting actions.
7. Charting: Shall be used to display associated trend and historical data, modify colors, date range, axis and scaling. User shall have ability to create HTML charts through web browser without utilizing chart builder. User shall be able to drag and drop single or multiple data points, including schedules, and apply status colors for analysis.
8. Logic - Live Graphic Programs: Shall be used to display' live' graphic programs of the control algorithm, (micro block programming) for the mechanical/electrical system selected in the navigation tree.
9. Other actions such as Print, Help, Command, and Logout shall be available via a drop-down window.

v. Color Graphics: The Web Browser GUI shall make extensive use of color in the graphic pane to communicate information related to set points and comfort. Animated .gifs or .jpg, vector scalable, active set point graphic controls shall be used to enhance usability. Graphics tools used to create Web Browser graphics shall be non-proprietary and conform to the following basic criteria:
1. Display Size: The GUI workstation software shall graphically display in a minimum of 1024 by 768 pixels 24 bit True Color.

2. General Graphic: General area maps shall show locations of controlled buildings in relation to local landmarks.
3. Color Floor Plans: Floor plan graphics shall show heating and cooling zones throughout the buildings in a range of colors, as selected by Owner. Provide a visual display of temperature relative to their respective set points. The colors shall be updated dynamically as a zone's actual comfort condition changes.
4. Mechanical Components: Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. Selected I/O points being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units. Animation shall be used for rotation or moving mechanical components to enhance usability. .
5. Minimum System Color Graphics: Color graphics shall be selected and displayed via a web browser for the following:
    a. Each piece of equipment monitored or controlled including each terminal unit.
    b. Each building.
    c. Each floor and zone controlled.

vi. Hierarchical Schedules: Utilizing the Navigation Tree displayed in the web browser GUI, an operator (with proper access credentials) shall be able to define a Normal, Holiday or Override schedule for an individual piece of equipment or room, or choose to apply a hierarchical schedule to the entire system, site or floor area. For example, Independence Day ' Holiday' for every level in the system would be created by clicking at the top of the geographic hierarchy defined in the Navigation Tree. No further operator intervention would be required and every control module in the system with would be automatically downloaded with the ' Independence Day' Holiday. All schedules that affect the system/area/equipment highlighted in the Navigation Tree shall be shown in a summary schedule table and graph.
    1. Schedules: Schedules shall comply with the LonWorks and BACnet standards, (Schedule Object, Calendar Object, Weekly Schedule property and Exception Schedule property) and shall allow events to be scheduled based on:
        a. Types of schedule shall be Normal, Holiday or Override.
        b. A specific date.
        c. A range of dates.
        d. Any combination of Month of Year (1-12, any), Week of Month (1-5, last, any), Day of Week (M-Sun, Any).
        e. Wildcard (example, allow combinations like second Tuesday of every month).
    2. Schedule Categories: The system shall allow operators to define and edit scheduling categories (different types of "things" to be scheduled; for example, lighting, HVAC occupancy, etc.). The categories shall include: name, description, icon (to display in the hierarchy tree when icon option is selected) and type of value to be

scheduled.

3. Schedule Groups: In addition to hierarchical scheduling, operators shall be able to define functional Schedule Groups, comprised of an arbitrary group of areas/rooms/equipment scattered throughout the facility and site. For example, the operator shall be able to define an ' individual tenant' group - who may occupy different areas within a building or buildings. Schedules applied to the ' tenant group' shall automatically be downloaded to control modules affecting spaces occupied by the ' tenant group'.
4. Intelligent Scheduling: The control system shall be intelligent enough to automatically turn on any supporting equipment needed to control the environment in an occupied space. If the operator schedules an individual room in a VAV system for occupancy, for example, the control logic shall automatically turn on the VAV air handling unit, chiller, boiler and/or any other equipment required to maintain the specified comfort and environmental conditions within the room.
5. Partial Day Exceptions: Schedule events shall be able to accommodate a time range specified by the operator (ex: board meeting from 6 pm to 9 pm overrides Normal schedule for conference room).
6. Schedule Summary Graph: The schedule summary graph shall clearly show Normal versus Holiday versus Override Schedules and the net operating schedule that results from all contributing schedules. Note: In case of priority conflict between schedules at the different geographic hierarchy, the schedule for the more detailed geographic level shall apply.

vii. Alarms: Alarms associated with a specific system, area, or equipment selected in the Navigation Tree, shall be displayed in the Action Pane by selecting an ' Alarms' view. Alarms, and reporting actions shall have the following capabilities:

1. Alarms View: Each Alarm shall display an Alarms Category (using a different icon for each alarm category), date/time of occurrence, current status, alarm report and a bold URL link to the associated graphic for the selected system, area or equipment. The URL link shall indicate the system location, address and other pertinent information. An operator shall easily be able to sort events, edit event templates and categories, acknowledge or force a return to normal in the Events View as specified in this section.
2. Alarm Categories: The operator shall be able to create, edit or delete alarm categories such as HVAC, Maintenance, Fire, or Generator. An icon shall be associated with each alarm category, enabling the operator to easily sort through multiple events displayed.
3. Alarm Templates: Alarm template shall define different types of alarms and their associated properties. As a minimum, properties shall include a reference name, verbose description, severity of alarm, acknowledgement requirements, and high/low limit and out of range information.

4. Alarm Areas: Alarm Areas enable an operator to assign specific Alarm Categories to specific Alarm Reporting Actions. For example, it shall be possible for an operator to assign all HVAC Maintenance Alarm on the 1st floor of a building to email the technician responsible for maintenance. The Navigation Tree shall be used to setup Alarm Areas in the Graphic Pane.
5. Alarm Time/Date Stamp: All events shall be generated at the DDC control module level and comprise the Time/Date Stamp using the standalone control module time and date.
6. Alarm Configuration: Operators shall be able to define the type of Alarm generated per object. A ' network' view of the Navigation Tree shall expose all objects and their respective Alarm Configuration. Configuration shall include assignment of Alarm, type of Acknowledgement and notification for return to normal or fault status.
7. Alarm Summary Counter: The view of Alarm in the Graphic Pane shall provide a numeric counter, indicating how many Alarms are active (in alarm), require acknowledgement and total number of Alarms in the BAS Server database.
8. Alarm Auto-Deletion: Alarms that are acknowledged and closed shall be auto-deleted from the database and archived to a text file after an operator defined period.
9. Alarm Reporting Actions: Alarm Reporting Actions specified shall be automatically launched (under certain conditions) after an Alarm is received by the BAS server software. Operators shall be able to easily define these Reporting Actions using the Navigation Tree and Graphic Pane through the web browser GUI. Reporting Actions shall be as follows:
    a. Print: Alarm information shall be printed to the BAS server's PC or a networked printer.
    b. Email: Email shall be sent via any POP3-compatible e-mail server (most Internet Service Providers use POP3). Email messages may be copied to several email accounts. Note: Email reporting action shall also be used to support alphanumeric paging services, where email servers support pagers.
    c. File Write: The ASCII File write reporting action shall enable the operator to append operator defined alarm information to any alarm through a text file. The alarm information that is written to the file shall be completely definable by the operator. The operator may enter text or attach other data point information (such as AHU discharge temperature and fan condition upon a high room temperature alarm).
    d. Write Property: The write property reporting action updates a property value in a hardware module.
    e. SNMP: The Simple Network Management Protocol (SNMP) reporting action sends an SNMP trap to a network in response to receiving an alarm.
    f. Run External Program: The Run External Program reporting

action launches specified program in response to an event.

viii. Trends: As system is engineered, all points shall be enabled to trend. Trends shall both be displayed and user configurable through the Web Browser GUI. Trends shall comprise analog, digital or calculated points simultaneously. A trend log's properties shall be editable using the Navigation Tree and Graphic Pane.
    1. Viewing Trends: The operator shall have the ability to view trends by using the Navigation Tree and selecting a Trends button in the Graphic Pane. The system shall allow y- and x-axis maximum ranges to be specified and shall be able to simultaneously graphically display multiple trends per graph.
    2. Local Trends: Trend data shall be collected locally by Multi-Equipment/Single Equipment general-purpose controllers, and periodically uploaded to the BAS server if historical trending is enabled for the object. Trend data, including run time hours and start time date shall be retained in non-volatile module memory. Systems that rely on a gateway/router to run trends are NOT acceptable.
    3. Resolution. Sample intervals shall be as small as one second. Each trended point will have the ability to be trended at a different trend interval. When multiple points are selected for displays that have different trend intervals, the system will automatically scale the axis.
    4. Dynamic Update. Trends shall be able to dynamically update at operator-defined intervals.
    5. Zoom/Pan. It shall be possible to zoom-in on a particular section of a trend for more detailed examination and ' pan through' historical data by simply scrolling the mouse.
    6. Numeric Value Display. It shall be possible to pick any sample on a trend and have the numerical value displayed.
    7. Copy/Paste. The operator shall have the ability to pan through a historical trend and copy the data viewed to the clipboard using standard keystrokes (i.e. CTRL+C, CTRL+V).

ix. Security Access: Systems that are accessed from the web browser GUI to BAS server shall require a Login Name and Strong Password. Access to different areas of the BAS system shall be defined in terms of Role-Based Access Control privileges as specified:
    1. Roles: Roles shall reflect the actual roles of different types of operators. Each role shall comprise a set of ' easily understood English language' privileges. Roles shall be defined in terms of View, Edit and Function Privileges.
        a. View Privileges shall comprise: Navigation, Network, and Configuration Trees, Operators, Roles and Privileges, Alarm/Event Template and Reporting Action.
        b. Edit Privileges shall comprise: Set point, Tuning and Logic, Manual Override, and Point Assignment Parameters.
        c. Function Privileges shall comprise: Alarm/Event Acknowledgement, Control Module Memory Download,

Upload, Schedules, Schedule Groups, Manual Commands, Print and Alarm/Event Maintenance.

2. Geographic Assignment of Roles: Roles shall be geographically assigned using a similar expandable/collapsible navigation tree. For example, it shall be possible to assign two HVAC Technicians with similar competencies (and the same operator defined HVAC Role) to different areas of the system.

9. GRAPHICAL PROGRAMMING

i. **The system software shall include a Graphic Programming Language (GPL) for all DDC control algorithms resident in all control modules. Any system that does not use a drag and drop method of graphical icon programming shall not be accepted**. All systems shall use a GPL method used to create a sequence of operations by assembling graphic microblocks that represent each of the commands or functions necessary to complete a control sequence. Microblocks represent common logical control devices used in conventional control systems, such as relays, switches, high signal selectors etc., in addition to the more complex DDC and energy management strategies such as PID loops and optimum start. Each microblock shall be interactive and contain the programming necessary to execute the function of the device it represents.

ii. Graphic programming shall be performed while on screen and using a mouse; each microblock shall be selected from a microblock library and assembled with other microblocks necessary to complete the specified sequence. Microblocks are then interconnected on screen using graphic "wires," each forming a logical connection. Once assembled, each logical grouping of microblocks and their interconnecting wires then forms a graphic function block which may be used to control any piece of equipment with a similar point configuration and sequence of operation.

iii. Graphic Sequence: The clarity of the graphic sequence shall be such that the operator has the ability to verify that system programming meets the specifications, without having to learn or interpret a manufacturer's unique programming language. The graphic programming shall be self-documenting and provide the operator with an understandable and exact representation of each sequence of operation.

iv. GPL Capabilities: The following is a minimum definition of the capabilities of the Graphic Programming software:
    1. Function Block (FB): Shall be a collection of points, microblocks and wires which have been connected together for the specific purpose of controlling a piece of HVAC equipment or a single mechanical system.
    2. Logical I/O: Input/Output points shall interface with the control modules in order to read various signals and/or values or to transmit signal or values to controlled devices.
    3. Microblocks: Shall be software devices that are represented

graphically and may be connected together to perform a specified sequence. A library of microblocks shall be submitted with the control contractors bid.

4. Wires: Shall be Graphical elements used to form logical connections between microblocks and between logical I/O.
5. Reference Labels: Labels shall be similar to wires in that they are used to form logical connections between two points. Labels shall form a connection by reference instead of a visual connection, i.e. two points labeled 'A' on a drawing are logically connected even though there is no wire between them.
6. Parameter: A parameter shall be a value that may be tied to the input of a microblock.
7. Properties: Dialog boxes shall appear after a microblock has been inserted which has editable parameters associated with it. Default parameter dialog boxes shall contain various editable and non-editable fields, and shall contain 'push buttons' for the purpose of selecting default parameter settings.
8. Icon: An icon shall be graphic representation of a software program. Each graphic microblock has an icon associated with it that graphically describes its function.
9. Menu-bar Icon: Shall be an icon that is displayed on the menu bar on the GPL screen, which represents its associated graphic microblock.
10. Live Graphical Programs: The Graphic Programming software shall support a ' live' mode, where all input/output data, calculated data and set points shall be displayed in a ' live' real-time mode.

10. LONWORKS NETWORK MANAGEMENT

i. Systems requiring the use of third-party LonWorks network management tools shall not be accepted.

ii. Network management shall include the following services: device identification, device installation, device configuration, device diagnostics, device maintenance and network variable binding.

iii. The Network configuration tool shall also provide diagnostics to identify devices on the network, to reset devices and to view health and status counters within devices.

iv. These tools shall provide the ability to "learn" an existing LonWorks network, regardless of what network management tool(s) were used to install the existing network, so that existing LonWorks devices and newly added devices are part of a single network management database.

v. The network management database shall be resident in the Network Area Controller (NAC), ensuring that anyone with proper authorization has access to the network management database at all times. Systems employing network management databases that are not resident, at all times and within the control system shall not be accepted.

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

A. Server Hardware shall be provided and maintained by the owner (University of Houston)

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

C. 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.

D. 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.

E. 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 NAC, 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.

F. Provide sufficient RAM to meet system performance requirements.

3.4 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.

3.5 BACnet PROTOCOL VERIFICATION SOFTWARE

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

3.6 NETWORK AREA CONTROLLER (NAC)BACnet

A. Provide as required to meet performance requirements of the system with a 20% increase in connected ddc controllers on any individual network. NACProvide as many NAC's necessary as recommend by the manufacturer.

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

3.7 UNITARY CONTROLLERS (UC

C. Provide a dedicated UC for each major mechanical system, such as AHU's, UV's, & FCU's etc..

D. All points used for a single mechanical system shall be connected to the same UC. 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.

3.8 UNITARY CONTROLLERS (UC)UNITARY CONTROLLER (UC) FOR TERMINAL UNITS

A. Provide a dedicated UC for each Terminal Unit Mechanical Device on the project, including VAV and Fan Powered Terminal Units. 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 UC 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 UC 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 through the use of the system or handheld.

3.9 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 EAC and UC this may require that a higher level LAN be routed to each mechanical equipment space with a jack. If the controllers do not allow for connection, the owner shall be able to access through the network at any network switch. Also, the owner shall be able to connect via WiFi using a smart tablet.

3.10 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 NAC shall be mounted in an enclosure.

3.11 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; NAC'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.

3.12 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 stainless steel flat plate sensors.

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 Three-valve bypass assembly with snubbers

D. Flow

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

3.13 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.

3.14 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 exceed5 PSI.

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

3.15 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

3.16 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 3