UNIVERSITY OF KENTUCKY
Purchasing Division

REQUEST FOR PROPOSAL

UK-2113-21
ADDENDUM # 1
09/29/2020

ATTENTION: This is not an order. Read all instructions, terms and conditions carefully.

IMPORTANT: OFFER AND ADDENDUM MUST BE RECEIVED BY 10/06/2020 @ 3:00 P.M. LEXINGTON, KY TIME

Offeror must acknowledge receipt of this and any addendum as stated in the Request for Proposals.

1. Please refer to and incorporate within the offer, the attached documents for Addendum #1.

OFFICIAL APPROVAL
UNIVERSITY OF KENTUCKY

Procurement Manager / (859) 323-5405

SIGNATURE

Typed or Printed Name

University of Kentucky
Purchasing Division
322 Peterson Service Building
Lexington, KY 40506-0005

Addendum 001

Affiliated Engineers, Inc.

10 S, LASALLE STREET, SUITE 2700
CHICAGO, IL 60603
PHONE 312-977-2800

Construct Research Building #2 Phase 3 - Design Release 1 – Fit-Out	001
Project	Addendum Number
	15576-06
Project Location	AEI Project Number
Controls Addendum	
	Client Project Number
	9.28.2020
To	Date
	Page 1 of 1
Bid Due Date	Page Typist

This addendum is issued to modify or interpret previously issued documents by additions, deletions, clarifications, or corrections. It forms a part of the previously issued documents.

This addendum may include revised pages and drawings, which shall be inserted before the corresponding page or drawings in the previously issued documents. Revised pages and drawings are identified by the corresponding addendum number and date

SPECIFICATIONS

230901 – ADDED new UK standards to specification, including providing point count license.
230923 – ADDED new UK standards to specification, including point naming examples. Point names are not allowed to contain special characters except underscores.

END OF ADDENDUM

SECTION 23 0901 CONTROL SYSTEMS INTEGRATION

PART 1 - GENERAL

1.1 RELATED WORK

A. Section 01-9913 – Building Systems Commissioning

B. Section 20-0000 – General Mechanical Requirements

C. Section 20 0513 – Motors

D. Section 23 0550 - Vibration Isolation

E. Section 20-0553 – Mechanical System Identification

F. Section 23 0902 - Control Valves and Dampers

G. Section 23 0903 - Control Instrumentation

H. Section 23 0923 - Direct Digital Controllers and Networks

I. Section 23 0924 - Graphical User Interface Integration

J. Section 23 0993 - Control Sequences

K. Section 23 2118 - Valves

L. Section 23 3600 - Air Terminal Devices

M. Section 23 3614 - Laboratory Temperature and Airflow Control System

N. Section 26 0000 - General Electrical Requirements

O. Section 26 0533 - Raceway and Fittings

P. Section 26 0519 - Conductors and Cables

Q. Section 23-3614 – Pressure Relationship, Temperature and Airflow Control System

R. Section 26-0519 – Low-Voltage Electrical Power Conductors and Cables

S. Section 26-0533 – Raceway and Boxes for Electrical Systems

T. Section 26-0926 – Lighting Control Systems

U. Section 26-2300 – Low Voltage Switchgear

V. Section 26-2713 – Electrical Metering

W. Section 28-3116 – Multiplexed Fire Detection and Alarm Systems

1.2 REFERENCE

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

B. ASHRAE FUN IP - (2013) Fundamentals Handbook, I-P Edition

C. ASHRAE 135 - (2012) BACnet - A Data Communication Protocol for Building Automation and Control Networks (ANSI Approved) .13

D. Electrical Standards: Provide electrical components of pneumatic control systems which have been UL listed and labeled, and comply with NEMA standards.

E. NFPA Compliance: Comply with NFPA 90A "Standard for the installation of Air Conditioning and Ventilating Systems" where applicable for controls and control sequences.

F. Kentucky Building Code: Comply with requirements where applicable for controls.

~~C.~~

~~D.~~G. BUILDING SYSTEMS COMMISSIONING

1. "An independent third party Commissioning Agent will document completion of the Mechanical, Fire Suppression, Plumbing, HVAC, Electrical, Communications and Electronic Safety and Security Systems for the project. The Construction Manager, Division Contractors, and Control Contractor are members of the Commissioning Team and will facilitate completion of the Commissioning process. Refer to section 019113 "Building Systems Commissioning" for the project Commissioning requirements and roles and responsibilities of each member of the Commissioning Team."

1.3 DEFINITIONS

A. The following abbreviations, acronyms, and definitions may be used in addition to those found elsewhere in Contract Documents.

1.	Actuator:	Control device to provide motion of valve or damper in response to control signal.
2.	AI:	Analog Input
3.	AO:	Analog Output
4.	Analog:	Continuously variable state over stated range of values
5.	Auto-Tune:	Software routine used to adjust tuning parameters based on historical data.
6.	BAS:	Building Automation System
7.	BMS	Building Management System
8.	DDC:	Direct Digital Control
9.	DDCP:	Direct Digital Control Panel
10.	Discrete:	Binary or digital state
11.	DI:	Discrete Input (Sometimes referred to as Binary Input BI)
12.	DO:	Discrete Output (Sometimes referred to as Binary Output BO)
13.	EMCS:	Energy Management and Control System (Typically interchangeable with BAS or BMS)
14.	E/P:	Voltage to pneumatic transducer (Often solenoid valve is referred to as an E/P transducer)

15. FA — Field Adjustable
16. FC: — Fail Closed position of control device or actuator. Device moves to closed position on loss of control signal or energy source.
17. FMS: — Facility Management System linking two or more BAS
18. FO: — Fail Open position of control device or actuator. Device moves to open position on loss of control signal or energy source.
19. I/P: — Current to pneumatic transducer
20. Instrument: — Device used for sensing input parameters or used for actuation.
21. Modulating: — Movement of control device through an entire range of values proportional to an infinitely variable input value.
22. Motorized: — Control device with actuator
23. NC: — Normally Closed position of switch after control signal is removed or normally closed position of manually operated valves or dampers.
24. NO: — Normally Open position of switch after control signal is removed or normally open position of manually operated valves or dampers.
25. Node: — DDCP, operator workstation, or other control device connected to communications network.
26. Operator: — Same as actuator for motorized devices. Also refers to an individual who physically "operates" facility.
27. PC: — Personal Computer
28. Peer-to-Peer: — Mode of communication between controllers in which each device connected to network has equal status and each share its database values with other devices connected to network.
29. P: — Proportional control, control mode with continuous linear relationship between observed input signal and final controlled output element.
30. PI: — Proportional - Integral control, control mode with continuous proportional output plus additional change in output based on both amount and duration of change in controlled variable (reset control).
31. PID: — Proportional - Integral - Derivative control, control mode with continuous correction of final controlled output element versus input signal based on proportional error, its time history (reset), and rate at which its changing (derivative).
32. Point: — Analog or discrete instrument with addressable database value.
33. Self-Tune: — Same as Auto-Tune
34. Solenoid: — Electric two-position actuator. (See E/P.)
35. TCC: — Temperature Control Contractor (Same as Control Contractor)
36. TCP: — Temperature Control Panel

1.4 ACCEPTABLE CONTROL CONTRACTORS

A. Control Contractor shall have full service office within 100 miles of project site. Full service office is defined as being home office of applications engineers, supervisors, and field technicians, having complete parts inventory, and having required test and diagnostic equipment.

B. Acceptable controls manufacturers shall include any controls manufacturers which utilize a BACnet protocol in accordance with the specification. If the bidding manufacturer is not listed above,

documentation for approval as an equal must be submitted 10 days prior to the bid opening date to allow for evaluation by the university.

~~A.~~C. Control Contractors shall be factory authorized agent or dealer of controllers and control hardware as manufactured by:

1. Tier 1 BACnet/IP controls
   a. Vykon
   b. Johnson Controls, Inc.
   c. Alerton Technology
2. Tier 2 Controls – BACnet/MSTP
   a. Honeywell
   b. Johnson Controls
   c. Alerton
   d. Distech

~~1. Johnson Controls, Inc.~~
~~2. Alerton Technology~~
~~3. Vykon~~

D. Installing Contractor: Installing controls contractors must comply with the following requirements:

~~B.~~1. The systems integration contractor must have on staff the following number of key personnel as a minimum each with a minimum of 5 years of related controls installation experience, and a minimum of 3 hospital or university renovation projects of similar size and scope where they utilized a BACnet system.:

~~1.~~a. Project Manager – 2 years
~~2.~~b. Controls applications Engineer – 2 years
~~3.~~c. Programmer – 2 years
~~4.~~d. Installation Supervisor – 2 years
~~5.~~e. Controls Technician – 5 years

~~C.~~2. Prefer contractor staff to include Niagara Tridium AX or N4 certified technicians, and one advanced certified.

~~D.~~3. Have experience with successful integrations of controls with Niagara Tridium systems.

E. Contractor to have a minimum of 3 years of installation history with the brand of controls being bid.

F. Contractor ~~M~~must have help desk operation or staff available for phone contact 24/7 for providing technical support to university staff. Call forward and emergency service numbers are not acceptable during normal business hours.

G. Bids will be accepted only from prequalified Control Contractor per "Instruction to Bidders".

1.5 SYSTEMS DESCRIPTION

A. Control system shall be Direct Digital Control (DDC).

B. Damper and valve actuators shall be electronic type, unless otherwise noted.

C. Control system shall be 100% DDC unless otherwise indicated.

D. Furnish a BACnet system compatible with existing University systems. All building controllers, application controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2001, BACnet. The system shall communicate with the University of Kentucky Facility Management's existing BACnet head-end software using BACnet/IP at the tier 1 level and BACnet/MSTP at the tier 2 level. No gateways shall be used for communication to controllers installed under section BACnet/MSTP or BACnet/IP shall be used for all other tiers of communication. No servers shall be used for communication to controllers installed under this section. If servers are required, all hardware and operating systems must be approved by the Facilities Management Controls Engineering Manager and/or the Facilities Management Information Technology Manager.

E. All Building Automation Devices should be located behind the University firewall, but outside of the Medical Center Firewall and on the environmental VLAN.

F. . BAS shall be fully expandable with addition of BACnet based hardware and/or software. Expansion shall not require removal of existing DDCPs, sensors, actuators, or communication networks.

G. System must be able to communicate with Tridium Niagara Framework at the University Medical Center via Protocol Address assigned by the University at the building location. Provide PICS for Windows-based control software and every controller in system, including unitary controllers. PICS and BIBBS shall comply with Tridium PICS and BIBBS.

~~G.~~ Provide all necessary hardware and software to meet the system's functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for Windows-based control software and every controller in system, including unitary controllers. These must be in compliance with Front End systems PICS and BIBBS and attached Tridium PICS and BIBBS. Provide all hardware and software to backup, restore, troubleshoot and install system. Software, backups, unitary, and ASC files shall be delivered to UEM (Utilities & Energy Management) for archiving purposes.

H. Ethernet network cabling shall be installed by Division 27 contractor with cable runs from central EIDF/IDF communication closet to multiple central locations on each floor. Ethernet cabling shall be utilized for BAS BACnet/IP communication from each zone to the existing BAS operator workstation. Controls contractor shall provide BACnet/IP to BACnet/MSTP small capacity Building Level Controller in each zone. BACnet/MSTP communication network shall be provided and installed by controls contractor between each room level controller in zones to BACnet/IP to BACnet/MSTP Building Level Controller. BACnet/MSTP communication network node capacity for each small capacity Building Level Controller zone shall be limited to a maximum of 80% manufacturer's recommended DDC controller capacity or 25 devices per trunk total, whichever total number of nodes is smaller

I. It is the contractor's responsibility to insure that the University of Kentucky Facilities Management's head-end system's licensed device/point count is increased to accommodate the number of devices and/or points that are added to fulfill the contractor's obligation to meet the requirements of the project.

J. Provide complete manufacturer's specifications for all items that are supplied. Include vendor name of every item supplied.

K. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

L. Provide a comprehensive operator, administrator and technician training program as described herein.

M. Provide as-built documentation, programming software for use site wide, electronic copies of all diagrams, and all other associated project operational documentation (such as technical manuals on approved media, the sum total of which accurately represents the final system.

~~H.~~N. Furnish, install, and fit-up in complete working order, with all accessories required, the automatic temperature control and monitoring systems shown on the Drawings and specified herein. The systems shall be properly connected, piped and wired in a manner conforming to the laws, ordinances and codes now in force in the Commonwealth of Kentucky.

~~I.~~O. System intelligence shall be such that existing operator workstation(s) can be used for programming controls, performing analysis on filed data, perform trending of user defined inputs, generating maintenance and operation reports and providing permanent storage for programs and data, and the ability to connect to the Internet.

~~J.~~P. System shall be web-based, telnet or HyperTerminal capable. No graphics shall be provided. All graphics will be owner provided to existing Tridium system.

~~K.~~Q. All building automation products utilizing BACnet shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2001, BACnet and be tested by BACnet Testing Laboratories (BTL) and have passed the necessary requirements for BACnet compliance and interoperability.

~~L.~~R. New BAS shall seamlessly integrate with existing site **Tridium** web server. Existing web server shall be able to access and read all input, output and calculated points and issue commands to all output points in new BAS by means of a standard web browser. Contractor shall provide necessary hardware and software components to accomplish this interface.

S. Provide modular designed stand-alone controllers capable of future BAS architecture with peer-to-peer and/or low/medium speed communication networks. Upgrade to full BAS architecture shall not require removal of existing controllers, sensors, actuators, etc.

T. Provide DDC controls for the air terminal units. Provide electronic operators controlled and monitored by direct digital control systems which shall include, but not be limited to, air handling systems, pumps, terminal units, etc.

U. The control equipment shall be complete and shall include, but not be limited to, all necessary valves, damper operators, pipe, fittings, etc.

V. The control and monitoring system for this project shall be made up using standard materials, equipment and components regularly manufactured for systems of this type. The system shall be complete in every respect and shall be a functioning system.

W. Electronic Control System installer must physically demonstrate to Owner and Owner's representatives (UEM) via software simulations that the proposed building automation system and control sequences will function as outlined in the contract documents prior to field implementation.

X. Electrical power wiring and interlock wiring for all controls, signal devices, equipment, alarms, etc., shall be in accordance with diagrams and instructions from the supplier of the systems. All power

and control wiring, conduit and wiring connections required for the complete installation, including wiring to smoke dampers and combination fire/smoke dampers and their motors, shall be provided by this Contractor in accordance with Electrical specification requirements. Controls shall be on emergency power.

~~M.~~

~~N.~~Y. BAS network architecture shall be based on an Open implementation of BACnet using ASHRAE 135-2012 exclusively as the communications protocol for communication between DDC Hardware devices, including BAS Web Server, to allow multi-vendor interoperability.

~~O.~~Z. Building Automation System (BAS) shall control building's HVAC components and provide interface with Lighting Control System.

~~P.~~AA. Division 27 Contractor shall provide Ethernet work connections for BAS equipment requiring network connects.

~~Q.~~BB. Provide BAS architecture consisting of communication network, operator workstations, web servers and modular designed controllers with all points addressable and modifiable from operator workstations or from master controller using laptop computer. BAS shall be fully expandable with addition of hardware and/or software. Expansion shall not require removal of existing controllers, sensors, actuators, or communication networks.

~~R.~~CC. System shall support operator workstations as specified and shall be capable of additional workstations, limited only by systems maximum node capacity.

~~S.~~DD. Operator workstations connected to building Ethernet network shall be able to access BAS information as determined by Graphical User Interface (GUI) software through standard web browsing software (Internet Explorer, Mozilla Firefox, Opera, or Google Chrome). GUI software shall allow transparent access to each building component/system for control and/or monitoring.

~~T.~~EE. System intelligence shall be such that operator workstation(s) can be used for programming controls, performing analysis on filed data, generating maintenance and operation reports and providing permanent storage for programs and data.

FF. Workstation PCs and printers will be furnished by Owner. Provide hardware interface card to communicate with BAS Network and required software for each workstation, as defined in this Section, to make each PC full function workstation.

GG. The controls and all listed I/O points from this project shall communicate with the University of Kentucky Facilities Management's existing BACnet software head-end station using BACnet/IP. All BACnet points shall be exposed to the University of Kentucky Facilities Management's head-end station. Graphics will be installed by UEM on the head-end system. All point and device names shall comply with the University Facilities Management standards and shall be approved before and included in the shop drawings submittal. Cooperate with the Owner (UEM) to ensure that all specified points and alarms communicate and operate on the head-end system. All point and device names shall comply with the University Facilities Management standards (format listed below, consult Utilities and Energy Management (UEM) for the correct abbreviations) and shall be included in the shop drawings submittal for review and approval. Point naming conventions and formats are listed further in this specification in the Direct Digital Controls Equipment section. Refer to University Standard 230553S02 for the AHU Naming Convention.

HH. Related to the alarms, the contractor is to set up the alarm parameters specified by the system sequences of operations without enabling the alarms. Contractor is to provide a list of points

containing alarm extensions to Owner (UEM). UEM will be responsible for doing the alarm names, alarm texts and enabling the alarm points provided on the list.

II. Provide products of the temperature control system with the following agency approvals:

1. UL-916; Energy Management Systems
2. UL-873; Temperature Indication and Regulating Equipment
3. UL-864; Subcategories UUKL, OUXX, UDTZ; Fire Signaling and Smoke Control Systems
4. CSA; Canadian Standards Association
5. FCC, Part 15, Subpart J., Class A Computing Devices

JJ. All products shall be labeled with the appropriate approval markings. System installation shall comply with NFPA, NEMA, NEC, Local and National Codes.

KK. All work must be coordinated and scheduled with the UEM Controls group prior to any work being done on site.

~~U.~~LL. Refer to other Mechanical Division sections for installation of instrument wells, valve bodies, and dampers in mechanical systems; not work of this section.

1.

1.6 SCOPE OF WORK

A. Provide all labor and materials for complete fully functioning control systems in accordance with Contract Documents including this Section plus:
   1. Section 23 0902 - Control Valves and Dampers
   2. Section 23 0903 - Control Instrumentation
   3. Section 23 0923 - Direct Digital Controllers and Networks
   4. Section 23 0993 - Control Sequences
   5. Section 23-3600 – Air Terminal Devices
   6. Section 23-3614 – Pressure Relationship, Temperature and Airflow Control System

B. Engineering services shall be performed by factory trained engineers that are employed by the control manufacturer. System shall be installed either by trained mechanics directly employed by Control Contractor or by subcontractors who are under direct supervision of Control Contractor's representative. Owner reserves the right to exclude any project managers, engineers, field supervisors, or technicians whose past experience are not sufficient to meet needs of project. The manufacturer shall be responsible for the engineering, installation, startup, checkout, commissioning and warranty of control systems.

C. Engineering services shall be performed by Factory Trained Engineers. System shall be installed either by trained mechanics directly employed by Control Contractor or by subcontractors who are under direct supervision of Control Contractor's representative. Engineer reserves right to exclude Project Managers, Engineers, Field Supervisors, or Technicians whose past experience is not sufficient to meet needs of Project.

D. Control Contractor’s Project Managers, Engineers and Digital System Programmers shall have previously performed in capacity that qualifies them to successfully engineer system of scope and magnitude similar to this Project.

E. Submit qualification of Project Managers, Engineers, Programmers, Field Supervisors, and Technicians to be assigned to this Project within 30 days after contract award. Use Qualification Form attached at end of this Section.

F. Labor shall include, but not be limited to:
   1. Engineering services to size unscheduled valves and dampers based on design criteria specified in Section 23 0902 - Control Valves and Dampers, and confirm sizing of scheduled valves and dampers.
   2. Engineering services to produce requested submittals and working construction drawings and record drawings as specified here within.
   3. Engineering services for required software programming including integration of all BAS functionality into existing Tridium BAS.
   4. Engineering services for mapping control points from Laboratory Temperature and Airflow Control System (Section 23 3614), if provided for the project.
   5. Engineering services for BAS Ethernet network design.
   6. Project management services as single point contact to coordinate construction related activities.
   7. Field mechanics for installation of control wiring and related control devices.
   8. Field technicians to startup, calibrate, adjust, and tune control loops.
   9. Field technicians to perform system checkout and testing, and to complete required reports.
   10. Field supervisor during controls installation and startup.
   11. Field technicians to assist Mechanical Contractor and Testing and Balancing (TAB) Contractor in adjusting controls and determining setpoints related to TAB work.
   12. Field representatives and/or classroom instructors to provide Owner training as specified.

G. Control Contractor shall be responsible for complete installation of control devices (except as noted), wiring terminations at controller locations to accomplish control sequences specified in project manual or on drawings. Control Contractor is required to provide power for air terminal controllers and other field mounted devices that require 24 VAC, 60 Hertz and shall be powered from 120 to 24 VAC transformer panels provided by Control Contractor. Control Contractor shall also be responsible for additional instrumentation described in point schedules found in Contract Documents, which may not be directly related to specified control sequences.
   1. Control contractor shall provide unique tag numbers for all devices under this specification and reference those tag numbers in control sequences and control diagrams.
   2. If Owner has tagging convention, Control contractor shall utilize it. If no tagging convention exists, Control contractor shall provide one for all devices under this specification.

H. Control Contractor shall furnish all actuators, linkages if required, differential pressure transmitters, controllers and any other devices required for unit control that are not provided by air terminal unit manufacturer for air terminal unit manufacturer's factory mounting. Control Contractor shall coordinate with Air Terminal Unit manufacturer for timely delivery and for proper factory installation.

I. Mechanical Contractor shall provide wells, taps, and other mechanical interfaces required for control equipment mounting into piping systems. Mechanical Contractor shall install in-line mounted devices, such as valves, dampers, flow meters, static pressure probes, etc., furnished by Control Contractor. Control Contractor shall be responsible for installation of other control devices, such as actuators, linkages, sensors, air terminal controllers, flow transducers, remote mounted control devices, control panels, control transformers, etc.

J. Electrical work required as integral part of control work is responsibility of Control Contractor. Control Contractor is responsible for providing final power connections, including conduit, wire, and/or disconnect switches, to control devices from appropriate electrical distribution panels.
   1. Electrical Contractor will provide circuit breakers required to provide electrical power to controllers.
   2. 120 to 24 VAC transformer panels shall be provided by Control Contractor and mounted adjacent to controller panels or in Equipment Intermediate Distribution Frame (EIDF) rooms and powered from dedicated electrical circuit.
   3. Should any change in number of controllers or addition of other electrical equipment after Contracts are awarded, Control Contractor shall immediately notify Electrical Contractor of change. Additional costs due to these changes shall be responsibility of Control Contractor.
   4. Coordinate with Electrical Contractor for additional power requirements.

K. Fully functioning BAS Ethernet network, including all hardware (horizontal network cabling, routers, switches, firewalls, patch panels, patch cords, cabinets, etc.), is provided by the University and division 27 contractor.

L. Materials shall be as specified unless approved through procedures for product substitution specified in Division 01. Control Contractor shall provide components not specifically indicated or specified, but necessary to make system function within the intent of specification.

M. If during the installation period any of the factory equipment or material provided in the system is found to be defective in material or workmanship, it shall be replaced or repaired by the Control Contractor within a two day working period from the time the problem was reported at no additional cost to the Owner.

N. Any part/device or equipment installed as part of this contract found to be malfunctioning or defective during the warranty period shall be replaced by the Contractor within a two day working period from the time the problem was reported.

O. Electrical products shall be listed and labeled by UL and comply with NEMA Standards.

P. Control Contractor is responsible for integration of the following independent systems into the Control System.
   1. Low Voltage Switchgear.
      a. Low Voltage Switchgear provider will supply a data port for communication with BAS. BAS contractor shall coordinate and provide communication connection via BACnet/IP or BACnet/MSTP from data port to the BAS. BAS contractor shall supply cabling, conduit, and gateway/integrator necessary to make an interface connection from the gateway/integrator to the Low Voltage Switchgear data port. BAS contractor responsible for a BAS solution to communicate data directly or through a gateway/integrator to all suppliers listed in Division 26 for Low Voltage Switchgear bidders. BAS contractor and Low Voltage Switchgear provider shall be responsible for coordination of gateway requirements if needed, translation of network protocols, testing of communications between systems, and joint commissioning of systems. BAS contractor to refer to Section 26 2300 – Low Voltage Switchgear and Section 23 0992 – DDC Point List for programming and monitoring requirements.
   2. Lighting Control System (LCS):
      a. LCS provider will provide appropriate network termination points for connection to BAS. Contractor shall supply cabling, conduit, and gateway (if necessary) to make an interface connection from BAS to LCS point of connection. Contractor is responsible for a BAS

solution to communicate data directly or through a gateway to all suppliers listed in Division 26 for LCS bidders. Contractor and LCS provider are responsible for coordination of gateway requirements if needed, translation of network protocols, testing of communications between systems, and joint commissioning of systems. Contractor to refer to P&ID's, DDC Point Schedules, and Division 26 for programming and monitoring requirements.

Q. Provide weather protection cover or weatherproof control devices where required for control devices located outdoors.

R. Provide tamper resistant screws and fasteners for equipment located in accessible and/or public areas.

S. Contractor is responsible for integration of the following independent systems into BAS:
   1. Electrical Metering:
      a. Electrical Metering provider will provide BACnet/IP connection(s) for interfacing to BAS. Control contractor responsible for a BAS solution to communicate data directly or through a gateway to all suppliers listed in Division 26 for Electrical Metering. Control contractor and Electrical Metering provider responsible for coordination of gateway requirements if needed, translation of network protocols, testing of communications between systems, and joint commissioning of systems. Control contractor to refer to P&ID's, Section 26 2413 Switchboards and Section 26 2713 Electrical Metering for programming and monitoring requirements.

1.7 SUBMITTALS

A. Extended Service Agreement:
   1. Control manufacturer shall, upon completion of warranty period, make available to Owner annual service agreement covering all labor and material required to effectively maintain control system after warranty period. Owner reserves the right to accept or reject any such offers and to cancel on-going agreements with 30-day written notice.
   2. During extended service period, Contractor shall maintain Operation and Maintenance manuals to reflect all changes made to BAS.
   3. Each submittal shall have a cover sheet with the following information provided: submittal ID number; date; project name, address, and title; BAS Contractor name, address and phone number; BAS Contractor project manager, quality control manager, and project engineer names and phone numbers.

B. Shop Drawings:
   1. Submit manufacturer's printed product data sheets for control devices and materials listed in bill of material in Control Contractor's control drawings. An index listing of all control devices and equipment applicable to project to be listed in the following format:
      a. Room #
      b. Device Part #
      c. Device Description
      d. Sheet # where cut sheet is located
   2. Datasheets shall be submitted electronically in pdf format with bookmarks provided for each individual device and table of contents listing each device manufacturer and full model number with links to device pages. Organize sheets in order of model number, alphabetically, then numerically. If more than 20 product data sheets are submitted, provide front index and tabs

for logical groups of devices. When a manufacturer's data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Data sheets shall include sufficient technical data to describe instrument parameters required as specified. Refer to Specification section 20-0000 General Mechanical Requirements for additional submittal requirements and formatting. Data sheets shall include sufficient technical data to describe instrument parameters required as specified in Section 23 0903 - Control Instrumentation.

3. BAS manuals to be in two parts: 1) Operation and maintenance, and 2) System application manuals.
4. One (6) hard copy and (1) electronic copy of BAS manuals shall be provided to Physical Plant by BAS contractor at date of submittal completion.
5. Submit data concerning type of signal wiring and installation methods including raceway types and grounding methods.
6. Submit control drawings including, but not limited to, the following:
   a. Each submittal shall have a cover sheet with the following information provided: submittal ID number; date; project name, address, and title; BAS Contractor name, address and phone number; BAS Contractor project manager, quality control manager, and project engineer names and phone numbers.
   ~~a.~~b. Front sheet index for projects with more than 10 control drawing sheets.
   c. Overall system/network architecture drawings: Provide block diagram showing relationship of each controller, control panel, or other network devices relative to each other. Label room location of each device. Number and indicate model number of each device. Indicate network types.
      ~~b.~~1). BAS riser diagram showing all DDC controllers, network repeaters, and network wiring.
   d. Control Drawings: Including graphic representation of systems with major in-line components to properly locate all control devices. Identify controlled devices with their software designation on drawings, including unique valve and damper tag numbers.
      1). One-line schematics and system flow diagrams showing the location of all control devices.
      ~~c.~~
   e. Detailed wiring and piping diagrams showing point-to-point hookup details of transducers, relays, outputs, inputs and subsystem components.
      ~~d.~~1). Detailed Bill of Material list for each panel, identifying: quantity, part number, description, and associated options.
   ~~e.~~f. Bill of material identifying actual product model number used for each control device for each schematic control drawing.
   ~~f.~~g. Drawings showing proposed locations of sensors and flow meters in ductwork and piping systems.
   ~~g.~~h. Vendor's own written description for each sequence of operations, to include the following:
      1). Sequences shall reference input/output and software parameters by name and description.
      2). The sequences of operations provided in the submittal by the BAS Contractor shall represent the detailed analysis needed to create actual programming code from the design documents.

3). Points shall be referenced by name, including all software points such as programmable setpoints, range limits, time delays, and so forth.

4). The sequence of operations shall cover normal operation and operation under the various alarm conditions applicable to that system.

~~h.~~i. BACnet Compliance Documentation: The Protocol Implementation Conformance Statement for each component.

~~i.~~j. Points list for each DDC controller, including: Tag, Point Type, System Name, Object Name, Expanded ID, Display Units, Controller Type, Address, Cable Destination, Module Type, Terminal ID, Panel, Slot Number, Reference Drawing, and Cable Number. The initial shop drawing submittal for review needs to include all point names meeting the naming convention outlined in this specification for UEM approval at the shop drawing phase prior to the contractor beginning any programming.

~~1).~~

~~j.~~k. Control Damper Schedules. This spreadsheet type schedule shall include a separate line for each damper and a column for each of the damper attributes, including:

1). Code Number,

2). Fail Position,

3). Damper Type

4). Damper Operator

5). Blade Type

6). Bearing Type

7). Seals

8). Duct Size

9). Damper Size

10). Mounting

11). Actuator Type.

~~k.~~l. Control Valve Schedules. This spreadsheet type schedule shall include a separate line for each valve and a column for each of the valve attributes, including:

1). Code Number

2). Configuration

3). Fail Position

4). Pipe Size

5). Valve Size

6). Body Configuration

7). Close off Pressure

8). Capacity

9). Valve CV

10). Calc CV

11). Design Pressure

12). Actual Pressure

13). Actuator Type.

m. Cataloged cut sheets of all equipment used. All models used shall be highlighted. This includes, but is not limited to, the following: DDC panels, peripherals, sensors, actuators, dampers, and so forth.

~~l.~~n. Submit manufacturer's technical product data for each control device furnished, indicating dimensions, capacities, performance and electrical characteristics, and material finishes, also include installation and start up instructions.

~~m.~~o. Range and scale information for all transmitters and sensors. This sheet shall clearly indicate one device and any applicable options. Where more than one device to be used is on a single sheet, submit two sheets, individually marked.

~~n.~~p. Hardware data sheets for all local access panels.

~~o.~~q. Software manuals for all applications programs to be provided as a part of the programming devices, and so forth for evaluation for compliance with the performance requirements of this Specification.

~~p.~~r. The controls contractor shall include their BACnet PICS and BIBB statements (as described in ASHRAE 135-2001) for each device.

~~q.~~s. BAS Contractor shall not order material or begin fabrication or field installation until receiving authorization to proceed in the form of an approved submittal. BAS Contractor shall be solely responsible for the removal and replacement of any item not approved by submittal at no cost to the Owner.

~~r.~~t. Submittal shall have approved point names.

1). Refer to 230923 for point naming conventions and formats.

C. Operation and Maintenance Manuals

1. Maintenance Data:
   a. Submit maintenance instructions and spare parts lists for each type of control device. Include that type data, product and shop drawings in maintenance manual.
   b. This contractor shall prepare an electronic Operations Manual entitled "Automatic Temperature Control and Monitoring Systems Operation and Maintenance Data." Manual shall be PDF files with separate PDFs for each of the items noted below.
   c. Each manual shall contain the following information:
      1). Name and address of Consulting Engineer, Contractor, and index of equipment, including vendor (name and address).
      2). Complete brochures, descriptive data and parts list, etc., on each piece of equipment, including all approved shop drawings.
      3). Complete maintenance and operating instructions, prepared by the manufacturer, on each major piece of equipment, including preventative maintenance instructions.
      4). Complete shop drawing submittal on temperature and monitoring controls including control diagrams updated to reflect "as built" conditions.
      5). All wiring and component schematics necessary for Owner (UEM) to troubleshoot, repair and expand the system.
      6). All manuals shall be submitted to the Engineer prior to final inspection of the building.
      7). Provide a laminated copy mounted in a sleeve on the outside of the panels for the controls sequences pertinent to equipment supplied by that specific controls panel.
2. Layout Design Drawing for each control panel:
   a. The layout drawing shall be to scale with all devices shown in their proposed positions.
   b. All control devices shall be identified by name.
   c. All terminal strips and wire channels shall be shown.
   d. All control transformers shall be shown.
   e. All 120 VAC receptacles shall be shown.

f. All IP connection points shall be shown.

3. Wiring/Pneumatic Design Diagram for each control panel.
   a. The control voltage wiring diagram shall clearly designate devices powered by each control transformer. If the control devices use half wave power, the diagram shall clearly show the consistent grounding of the appropriate power connection. All wire identification numbers shall be annotated on the diagram.
   b. The Field Bus wiring diagram shall clearly show the use of the daisy chain wiring concept, the order in which the devices are connected to the Field Bus, and the location of end of segment termination devices. All wire identification numbers shall be annotated on the diagram.
   c. If shielded communication wiring is used, the grounding of the shield shall be shown.
   d. The terminal strip wiring diagram shall identify all connections on both sides of the terminal strip. Wiring label numbers for all wiring leaving the control panel shall be annotated on the diagram.
   e. Detailed piping diagrams showing point-to-point hookup details of transducers, relays, outputs, inputs and subsystem components. Label pneumatic lines with field ID numbers/colors.
4. Wiring Design Diagram for individual components (controllers, protocol translators, etc.): The wiring diagram for each component shall identify all I/O, power, and communication wiring and the locations on the terminal blocks to which the wires are landed. Example: Fan Status sensor is wired from terminals 5/6 on the controller to terminals 17 and 18 on the terminal strip.
5. Installation Design Detail for each I/O device.
   a. A drawing of the wiring details for each sensor and/or end device.
   b. For devices with multiple quantities, a standard detail may be submitted.
6. A System Flow Design Diagram for each controlled system.
   a. A two dimensional cross sectional diagram showing key components such as fans, coils, dampers, valves, pump, etc.
   b. Identify the locations and names of all sensors and end devices that are associated with the control system. Label the panel name and terminal numbers where the connections are landed.
   c. A legend shall be provided for all symbols used.
7. BACnet Compliance Documentation:
   a. The Protocol Implementation Conformance Statement (PICS) for each component.
8. Direct Digital Control System Hardware Technical Data.
   a. A complete bill of materials of equipment to be used indicating quantity, manufacturer, and model number.
   b. Manufacturer’s description and technical data for each unique device to include performance curves, product specification sheets, and installation instructions. When a manufacturer’s data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means.
   c. This requirement applies to:
      1). Controllers
      2). Transducers/Transmitters
      3). Sensors
      4). Actuators

5). Valves
6). Relays and Switches
7). Control Panels
8). Power Supplies
9). Batteries

9. An Instrumentation List for each controlled system.
   a. The list shall be in a table format.
   b. Include name, type of device, manufacturer, model number, and product data sheet number.
10. Sequence of Control: A sequence of control for each system being controlled. Include the following as a minimum.
   a. Process control sequence for each end device.
   b. Supervisory logic sequence of control for each system.
   c. The impact of each global application program on the sequence of control (Example: Demand Control).
   d. A list of all physical inputs and outputs associated with each sequence.
   e. Within the sequence of control, all application parameters that are to be user adjustable from an Operator Workstation shall be annotated with (FA) after the name of the parameter. This shall include set points, reset schedule parameters, calibration offsets, timer settings, control loop parameters such as gain, integral time constant, sample rates, differentials, etc.
   f. Within the sequence of control, all calculated values that are to be viewable at the Operator Workstation shall be annotated with (rpt) after the name.
   g. All points that shall be subject to manual control from an operator workstation.
   h. A list of all alarm points, a description of the alarm and a description of the alarm criteria.
   i. A list of all variables for which historical trending will be applied, the sample rates and any criteria used to start and stop the historical trending.
11. Binding Map
   a. A list of the device to device data flow. This shall not include the flow of data from devices to the presentation system.
   b. Include:
      1). Description of the variable.
      2). Sending device.
      3). Receiving device.

D. Completion Checklist:
   1. Submit with shop drawings, detailed completion checklist including written procedures for adjusting and calibrating each type of instrument and sensor. Engineer reserves the right to request modifications to any procedure, which is incomplete or not adequate to prove system performance.
   2. Checklist shall include references to the following additional requirements:
      a. Instruments and sensors shall be calibrated by comparison to known device, which is traceable to National Institute of Standards and Testing.
      b. Each point shall be checked for calibration, connection to correct control loop, and proper setting of limit and alarm values.

c. Transducers and other output devices shall be properly zeroed and calibrated at both minimum and maximum output. Document settings for discrete instruments and set points for analog instruments shall include minimum and maximum positions for safe operating conditions where applicable (max. pump speed or max. frequency of fan drive, etc.).

d. Control loops shall be tuned to maintain controlled process variable at set point through seasonal conditions without operator intervention. Provide multiple sets of tuning parameters if necessary. Controller shall automatically use tuning parameters appropriate to existing ambient conditions. Maintain record on completion checklist, of control loops that require tuning at alternate times of year. Instruct technicians to supply default parameters that can approximate stable control until actual load conditions allow proper tuning of control loops.

e. Performance tests of analog control loops shall be performed by changing set points and verifying that sequences can come into stable control within reasonable time period appropriate for each sequence. Simulate load changes for pressure and flow control loops.

f. Performance tests of discrete control loops shall be performed by adjusting set point and verifying sequence action.

g. Alarms, including network failures, shall be tested for each controller and device connected to network. Ensure that alarms are properly acknowledged at operator's workstation.

h. Schedules for each system/device shall be verified.

i. Testing of BAS to ensure cyber security. Coordinate testing requirements with Owner.

E. Control Contractor and Mechanical Contractor shall walk proposed static pressure sensor and flow meter locations and mark up drawings for review and approval by Owner and Engineer prior to installation.

1.8 WARRANTY

A. Warranty period shall begin as authorized by the UEM representative in writing. A Certificate of Occupancy does not initiate the control system warranty. Any defects in materials and workmanship arising during this warranty period shall be corrected without cost to the owner.

B. All applicable software as detailed in this specification shall be updated by the BAS Contractor free of charge during the warranty period. This will ensure that all system software will be the most up-to-date software available from the BAS Contractor.

C. Authorization will not be given before the following conditions are met:

1. All verified completion checklists provided to Owner.
2. Completion of all punch list items.
3. Conduction of a preliminary training session for personnel. The training shall consist of an orientation session at the job site to familiarize the personnel with the location and type of controlled equipment and controls on the project, a discussion of the control sequences, and a review of the control drawings.
4. Completion and distribution of the as-built control drawings, including correction of all items noted by Owner and Engineer after review of the documents.

D. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one year from completion of system acceptance.

E. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. A telephone number where the service supervisor can be reached at all times shall be provided. The maximum acceptable response time to provide this service at the site shall be 24 hours Monday through Friday, 48 hours on Saturday and Sunday.

F. The system including all hardware and software components shall be warranted for a period of one year when the system performance is deemed satisfactory in whole by UEM. The system parts will be accepted for beneficial use and placed under warranty at that time. A Certificate of Occupancy does not initiate the control system warranty. Any defects in materials and workmanship arising during this warranty period shall be corrected without cost to the Owner.

~~F.~~G. ~~This warranty shall apply equally to both hardware and software.~~ All applicable software as detailed in this specification shall be updated by the EMS/BAS/BSM Contractor free of charge during the warranty period. This will ensure that all system software will be the most up-to-date software available from the EMS/BAS/BSM Contractor.

~~G.~~H. Service personnel shall be qualified to accomplish work promptly and satisfactorily. Owner shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

~~H.~~I. Scheduled Inspections:

1. Two inspections shall be performed prior to warranty expiration and all work required shall be performed. Inspections shall be scheduled 6 months after Owner acceptance and one month prior to end of warranty period.
2. These inspections shall include:
   a. Visual checks and operational tests of equipment.
   b. Clean control system equipment including interior and exterior surfaces.
   c. Check and calibrate each field device. Check and calibrate 50 percent of the total analog inputs and outputs during the first inspection. Check and calibrate the remaining 50 percent of the analog inputs and outputs during the second major inspection. Certify analog test instrumentation accuracy to be twice the specified accuracy of the device being calibrated. Randomly check at least 25 percent of all digital inputs and outputs for proper operation during the first inspection. Randomly check at least 25 percent of the remaining digital inputs and outputs during the second inspection.
   d. Run system software diagnostics and correct diagnosed problems.
   e. Resolve any previous outstanding problems.
   f. Install software upgrades, patches and fixes. Contractor to provide verification to facility personnel that all upgrades, patches and fixes to be installed have been tested in accordance with site testing and deployment procedures.

~~I.~~J. Scheduled work shall be performed during regular working hours, Monday through Friday, excluding holidays.

~~J.~~K. Dated records and logs shall be kept of each task, with cumulative records for each major component, and for the complete system chronologically. A continuous log shall be maintained for all devices. The log shall contain initial analog span and zero calibration values and digital points. Complete logs shall be kept and shall be available for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the control system.

~~K.~~L. Each service call request shall be recorded as received and shall include its location, date and time the call was received, nature of trouble, names of the service personnel assigned to the task, instructions describing what has to be done, the amount and nature of the materials to be used, the time and date work started, and the time and date of completion. A record of the work performed shall be submitted within 5 days after work is accomplished.

~~L.~~M. Recommendations for system modification shall be submitted in writing. No system modifications, including operating parameters and control settings, shall be made without prior approval of the Owner. Any modifications made to the system shall be incorporated into the Operations and Maintenance Instructions, and other documentation affected.

N. During the warranty period, the Contractor shall maintain a backup of all software installed in the system. The backup shall be updated monthly or whenever the Contractor makes a change to the software. A reload of backup software into the system shall be performed by the Contractor immediately upon notification by the Owner. The reload shall be free of charge.

~~M.~~1. : At the end of the project, the contractor is to supply digital back-up copies of all final complete operating controls programs. These shall be delivered to UEM for archiving purposes.

~~N.~~O. At the end of the warranty period, the Contractor shall provide updated copies of the latest versions of all project record documentation as described in Paragraph 1.10, Record Documents. This includes final updated drawings, software documentation, and electronic media backups that include all changes that have been made to the system during the warranty period.

1.9 COORDINATION WITH TAB CONTRACTOR

A. Control Contractor shall allow sufficient time to provide assistance and instruction to TAB Contractor in proper use and setting of control components such as, Operator Workstation computers, static pressure controllers, "K" Factors for VAV boxes, or any other devices that may need set points changes so that TAB work can be performed.

B. Provide required hardware and software related to control system to TAB Contractor to allow testing of systems and continued operation.

1.10 OPERATION AND MAINTENANCE MANUALS

A. Refer to Division 01 - General Requirements.
   1. One (1) physical and one (1) electronic copy of FMS Manuals shall be provided to University of Kentucky by the BAS Contractor at date of completion.

B. Operation and Maintenance manuals shall provide descriptions of maintenance on all system components, including sensors and controlled devices. Descriptions shall include:

C. Facility Management System (FMS) Manuals
   1. FMS manuals are to be split into two parts:
      a. Operation and Maintenance
         1). Index of all control devices
         2). Detailed Data sheets
         3). Detailed Sequence of operations
         4). Detailed Diagrams

a). System architecture diagram for components within the building annotated with specific location information.

5). List of recommended maintenance tasks associated with the system, controllers, instruments, operator workstations, data servers, web servers, and web clients.
   a). Define the task.
   b). Recommend a frequency for the task.
   c). Reference the product manual that includes instructions on executing the task.

6). Licenses, guarantees, and warranty documents for equipment and systems.

7). System architecture diagram for components within the building annotated with specific location information.

8). As-built drawing for each control panel

9). As-built wiring design diagram for each control panel

10). As-built system flow diagram for each system

11). Binding map for the building
   a). A list of the device to device data flow. This shall not include the flow of data from devices to the presentation system.
   b). Include:
   c). Description of the variable
   d). Sending device
   e). Receiving device

12). Product data sheet for each component

13). Troubleshooting guide

14). Repair parts list

15). Calibration instructions

16). Control Contractor's completion checklist

17). Manufacturer representative's name, address, and phone number

b. System Application manuals
   1). Detailed Sequence of operations
   2). Definitions of all DDCP software programs
   3). Flow chart of all DDCP software programs
   4). Points list of all hardwired devices
   5). A programming section that includes a description of programming language used
   6). Full documentation and program description of all separately written programs
      a). Operating the system
      b). Administering the system
      c). Engineering the Operator workstation
      d). Application programming
      e). Engineering the network
      f). Setting up the web server
      g). Report creation
      h). Graphics creation
      i). Data backup & Archiving

1.11 RECORD DRAWINGS

A. Refer to Division 01 - General Requirements.

B. Submit revised shop drawings indicating changes made during Project.

C. Record drawing submittals shall be inclusive of BAS as installed and commissioned.

D. Update control diagrams to include tuning parameters and set points applicable to systems depicted as of date of system completion. This information shall be incorporated with sequence of operation for each system.

E. Include floor plans showing location of control panels and routing of BAS network cabling.

F. List of all IP addresses assigned on IFMS complete with description of device and associated vendor.

G. BACnet systems and devices:
   1. Submit finished device addressing documentation.
   2. Submit finished hardcopy of device binding database.

H. Provide passwords, if used, for back-up and restore functions for each controller.

I. Software (as installed and commissioned)
   1. All software submittals shall be provided in a format suitable for restoration of the programming and configuration of respective digital controllers, servers, workstations and peripheral devices, etc. provided as part of the BAS.
   2. Submit a copy of all software installed on the servers and workstations. These copies shall be delivered to UEM for archiving purposes.
   3. Submit all licensing information for all software installed on the servers and workstations.
   4. Submit a copy of all software used to execute the project even if the software was not installed on the servers and workstations.
   5. Submit all licensing information for all of the software used to execute the project.
   6. All software revisions shall be as installed at the time of the system acceptance.

J. Firmware Files (as installed and commissioned)
   1. All firmware files shall be provided in a format suitable for restoration of the programming and configuration of respective digital controllers, servers, workstations and peripheral devices, etc. provided in the BAS.
   2. Submit a copy of all firmware files that were downloaded to or pre-installed on any devices installed as part of this project. This does not apply to firmware that is permanently burned on a chip at the factory and can only be replaced by replacing the chip.
   3. Submit control listing of firmware version for all firmware that is permanently burned on a chip at the factory.
   4. Submit a copy of all application files that were created during the execution of the project.

K. BACnet Protocol Implementation Conformance Statement
   1. The controls contractor shall include their BACnet PICS and BIBB statements (as described in ASHRAE 135-2001) for their BACnet Interface with their shop drawings. The interface shall comply with the following as a minimum.

2. Vendor Name: Tridium, Inc.
3. Product Family: Niagara Framework, including N4 Web Supervisor, JACE 6XX at Release 3.8, JACE 8xxx at release 4.6 or greater using the most current version of JAVA or HTML 5. All control work associated with this project must be fully compatible with this version of Tridium such that all alarms, points, etc. communicate and clear alarms seamlessly with the existing system.
4. Description: This product family provides bi-directional communication between the Tridium Niagara Framework and a BACnet system operating at BACnet Conformance Class 3, over Ethernet media.

1.12 OWNERSHIP OF PROPRIETARY MATERIAL

A. Owner shall retain all rights to software for this project.

~~B. 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 the Owner as defined by the manufacturer's license agreement, but shall protect the manufacturer's rights to disclosure of Trade Secrets contained within such software.~~

~~C.~~B. ~~Licensing agreement shall not preclude the use of the software by individuals under contract to the Owner for commissioning, servicing, or altering the system in the future.~~ Use of the software by individuals under contract to the Owner shall be restricted to use on the Owner's computers and only for the purpose of commissioning, servicing, or altering the installed system.

~~D.~~C. All project developed software, files and documentation shall become the property of Owner. These include but are not limited to:

1. Server and Workstation software
2. Application Programming Tools
3. Configuration Tools
4. Addressing Tools
5. Application Files
6. Configuration Files
7. Graphic Files
8. Report Files
9. Graphic Symbol Libraries
10. All Documentation.

PART 2 - PRODUCTS

2.1 CONTROL WIRING

A. Control wiring shall be in accordance with National Electrical Code and Local Electrical Codes. Final connection points at controllers and panels shall be made either at terminal blocks integral to device or at separate terminal blocks mounted inside of control panel enclosures. Use of wire nuts and crimped connections are not allowed for terminating control wiring unless approved by Engineer.

B. Refer to Division 26 for specification requirements for conduits and conductors, except as noted.

C. Terminal Blocks:

1. Terminal blocks which are not integral to other equipment shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, shall be suitable for rail mounting, and shall have end plates and partition plates for separation or shall have enclosed sides.

D. Signal and Power Conductors (24 V and Under):
   1. Wires smaller than #18 AWG shall not be used, except for manufacturer supplied instrument specific wire, or where otherwise specified. Use 2-wire stranded twisted/shielded pair 24 VDC for analog and discrete input and 24 VAC/VDC output devices. For 3-lead RTD signal wiring, use #18 AWG stranded, tinned copper twisted/shielded 3-conductor. Provide isolated instrument grounding system as per manufacturer's recommendations.
   2. Conductors not concealed in raceway shall have UL Listed plenum rated Teflon insulation.
   3. Provide 250 ohm, 5 watt, 0.1% tolerance dropping resistors in 4 - 20 mA circuits as required to generate 1 to 5 volt signals in 24 VDC powered instrument loops.
   4. 24 VAC Power Conductors shall be #18 AWG 2 wire twisted pair or larger. Provide Metal Oxide Varistors (MOVs) on 24 VAC/VDC discrete outputs connected to inductive loads to reduce noise levels (i.e., solenoid valves, motor contactors, relays, damper/valve electric actuators, etc.).

E. Communication Cable:
   1. Cable not concealed in raceway shall have UL Listed plenum rated insulation.
   2. Floor Level Network Communication Cable (Twisted Pair): Use control system manufacturer's standard communications cable or #22 AWG to #24 AWG twisted, shielded pairs, coaxial cable, or fiber optics for communications between remote controllers/devices
   3. Interior LAN Horizontal Communication Cable:
      a. Refer to specification 27 1500 - Communications Horizontal Cabling.
      b. Horizontal copper LAN cable shall meet or exceed all requirements of Category 6 cable as specified in TIA/EIA-568-B.2.
      c. BAS Ethernet network Horizontal copper LAN cable shall be yellow.
      d. Horizontal copper LAN cable shall be terminated in an eight-position modular Jack with color to match system cable.
      e. Horizontal copper LAN cable shall be terminated in a telecommunication room that is on the same floor as the area being served in a 4-pair 100Ω twisted pair modular patch panel with color to match system cable.
      f. Horizontal copper LAN cabling shall not exceed 295 ft.
      g. Provide minimum of 10’ of slack at telecommunication room and 12” of slack at outlet

F. All wiring, conductors and transmission medium shall be in conduit.
   1. Minimum conduit size shall be ¾”
   2. Size conduit for 75% fill.
      a. Example: for each three conductors in the conduit, room for one additional conductor must be provided.
   3. All EMT fittings used on conduit sizes 2 ½” and smaller shall be compression type. No set-screw type fittings are allowed.

G. Transient Voltage Surge Suppression Devices:
   1. Devices shall be designed for 120 V power conditioning devices for electronic equipment. Devices shall be designed, manufactured, tested, and installed in compliance with ANSI/IEEE

C62.41 and C62.45, Federal Information Processing Standards Publication 94 (FIPS PUB 94), NEMA, NFPA 70, 75, and 78, and UL 1449 and 1283. Devices shall be labeled for UL 1449.

2. Clamping voltage for 120 V power systems shall be 400 V.
3. Provide visual indicator of when surge device has been used.

H. Uninterruptible Power Supply
1. Manufacturers: MGE UPS Systems, Eaton Powerware, Liebert PowerSure or approved equal
2. Provide UPS for backup power for Operator Workstations, Building Level Controllers, Floor Level Controllers and field panels required for control of emergency/standby powered equipment, UPS shall maintain control upon loss of normal power and until emergency/standby power supply is brought on line.
3. Select UPS for minimum of 5 minutes backup time for load connected. This will allow emergency/standby power sources to come on line and provide backup power to emergency/standby powered equipment.
4. Upon sensing loss of normal power, transfer time shall be 8 milliseconds maximum.
5. Operating Parameters:
   a. Operating Temperature: 32°F to 104°F
   b. Relative Humidity: 0 to 95% rh, non-condensing
   c. Recharge Time: 8 hours, typical
6. UPS shall have self-diagnostic capability with DO to BAS to allow remote monitoring/alarming of UPS trouble or alarm conditions.

2.2 INPUT/OUTPUT SUMMARY

A. The system as specified shall monitor, control and calculate all of the points and functions as listed in the Input/Output Summary.

2.3 LOCAL CONTROL PANELS

A. Control panels shall meet the following minimum requirements:
1. Outdoors: Control panels located outdoors shall comply with NEMA 3R or 4X requirements.
2. Mechanical Rooms: Control panels located in mechanical or electrical rooms shall comply with NEMA 12 requirements.
3. Other Locations: Control panels in other locations, including but not limited to occupied spaces, above ceilings, and plenum returns shall comply with NEMA 1 requirement.

B. Local control panels shall be constructed of steel or extruded aluminum with hinged door and keyed lock, with baked enamel finish of manufacturer's standard color. Construction shall comply with NEMA **1** Standards for interior panels, NEMA **3R** for exterior panels.

C. Provide panels of adequate size to accommodate instruments for future expansion of approximately 25% beyond space required for this scope of work.

2.4 NETWORK HARDWARE

A. Ethernet Switches, Routers, and Bridges:
1. Network hardware shall be provided and configured to form a campus-wide Fast Ethernet (a combination of 100BASE-TX and 100BASE-BX, -FX, and –SX or higher).

2. Ethernet devices shall be IEEE Std 802.3 which shall function as the center of a distributed-star architecture and shall be "learning" type with spanning tree algorithms per IEEE Std 802.1D. All devices shall have a non-blocking architecture.
3. The switch shall support the connected media types and shall have a minimum of 150% the required ports and no fewer than 4 ports. One port shall be switch selectable as an uplink port.
4. Network hardware shall be compatible with the copper and fiber optic cabling installed by the Division 27 contractor. Refer to specifications 27 1300 and 27 1500 for media types.
5. Switch located in BAS server rack shall be managed type and shall have a minimum of two fiber optic ports.
6. Switch shall include N.O./N.C. alarm contact for monitoring by BAS.

B. Network Components:
1. Network components (Racks, enclosures, patch panels, etc.) shall comply with respective sections of specification 27 1100 – Communications Equipment Room Fittings.

PART 3 - EXECUTION

3.1 GENERAL

A. Install control equipment, **[~~and wiring~~]** in neat and workmanlike manner.

B. Coordinate timely delivery of materials and supervise activities of other trade contractors to install devices such as immersion wells, pressure tappings, any associated shut-off valves, flow switches, level switches, flow meters, air flow stations, valves, dampers, and other such items furnished by Control Contractor, which are to be installed by Mechanical Contractor.

C. Install control devices in accessible location.

D. All BAS associated 120 VAC power wiring (including all input and output power supplies) shall originate from clearly-marked, BAS-dedicated circuit breakers. All input/output transducers shall be powered from the same circuit that supplies power to the associated BAS controller. All BAS equipment shall be fused in accordance with manufacturer's recommendations.

E. BAS controllers shall be labeled with the source of electrical power including panel number, circuit breaker number, and room number where electric panel is located.

F. Devices containing mercury are not allowed.

G. Coordinate mounting height and location of control devices so that NEC workspace clearances are maintained.

H. All anchors used for mounting equipment, devices, or panels shall be metal. Plastic anchors are not allowed.

3.2 DELIVERY, STORAGE AND HANDLING

A. Provide factory shipping cartons for each piece of equipment and control device. Maintain cartons while shipping, storage and handling as required to prevent equipment damage and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protect from weather.

3.3 CONTROL WIRING

A. Provide electrical wiring required for complete functional control systems, including power circuit to control panels, both line and low voltage, in accordance with applicable local codes, and latest version of National Electrical Code and NFPA. Refer to Paragraph 1.6.H. for definition of scope of Work.
   1. Voltage drops for all low voltage circuits shall be calculated prior to installing low voltage circuits. Voltage drop calculations shall be made available to Engineer on demand.

B. Control panels serving equipment fed by emergency/standby power shall also be served by emergency/standby power. Equipment fed by emergency/standby power is so indicated on mechanical equipment schedules and electrical panelboard schedules. Control panels shall be powered by local UPS (Uninterruptible Power Supply) to ensure continued control of equipment powered by site standby power sources when primary power source is lost. Devices such as Operator Workstations, Floor Level and Building Level Controllers, Application Specific Controllers and fume hood controls shall be provided with local UPS power.

C. Where multiple controllers reside in a single control panel, provide a separate disconnect (or fuse) for each controller.

D. Power wiring to control compressors and dryers will be provided by Electrical Contractor. Furnish field-mounted starters to Electrical Contractor for installation and supervise installation.

E. Install control wiring in raceway system per Division 26 – Electrical, except as noted.
   1. All 24 VAC or any cabling carrying AC voltage will not be allowed in cable tray. 24 VAC and any other AC voltage cabling will require conduit or raceway separate from data cable raceway.

F. Install control wiring in raceway system per Division 26 – Electrical, except as noted.
   1. All 24 VAC or any cabling carrying AC voltage will not be allowed in cable tray. 24 VAC and any other AC voltage cabling will require conduit or raceway separate from data cable raceway.

G. Control wiring shall be installed in raceway or rigid conduit. Cabling connections between control devices and raceway/conduit shall be installed in flexible conduit not more than 6’ in length.

H. Color-code each junction box cover plate as to signal type using 1/2" self-adhesive color dot or enamel spray paint. Use green for low voltage signal wiring, blue for pneumatic tubing, and yellow for line voltage wiring used for signal wiring or dedicated power wiring.

I. Tag each wire termination at control panels, junction boxes, and remote control devices with unique wire ID number.

J. All wiring, conductors and transmission medium shall be in conduit.
   1. Minimum conduit size shall be ¾”
   2. Size conduit for 75% fill.
      a. Example: for each three conductors in the conduit, room for one additional conductor must be provided.
   3. All EMT fittings used on conduit sizes 2 ½” and smaller shall be compression type. No set-screw type fittings are allowed.

K. Terminate low voltage DC instrument signal cable with black terminated on positive terminal and white terminated on negative unless otherwise noted.

L. Connect electrical components to wiring systems and to ground as indicated and instructed by manufacturer. Tighten connectors and terminals, including screws and bolts, according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torqueing requirements are not indicated, tighten connectors and terminals according to tightening requirements specified in UL 486A.

~~L.~~M. Run direct current instrument conductors separately from alternating current conductors. Where allowed by NEC wiring classification, AC-DC route crossings shall be at 90 degrees. Install special sensor to transmitter cables in accordance with manufacturer's installation drawings or in compliance with manufacturer's instructions. Extra precautions shall be taken when pulling and shortening these "vendor furnished" cables. Any extra length on these cables shall be neatly coiled into minimum 3" diameter coils and installed into junction box.

~~M.~~N. All wiring terminating in a control panel/enclosure shall be landed on terminal strips, with one wire per terminal. All I/O points on a DDC/BAS controller shall be wired to panel-side of terminal strip, including all spare I/O points.

~~N.~~O. Route intrinsic safe wiring separately from other conductors. These conductors shall not be run with, nor cross, conductors of other NEC classifications and shall require intrinsic barrier if run in the same path with wiring of other classifications.

~~O.~~P. Follow Control Contractor’s Company standard cabling color codes.

~~P.~~Q. Suggested instrument and control conductor cables and color codes are as follows:

Type	Configuration	Colors	Manufacturer Part No.
120 VAC, 14 AWG	2 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Gray PVC	Belden 9411
120 VAC, 14 AWG	3 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Gray PVC	Belden 9495
24 VAC, 18 AWG	2 Cond., Unshielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 89740
24 VAC, 18 AWG	2 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Gray PVC	Belden 9409
Analog Input, 18 AWG	2 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 88760
Analog Input, 18 AWG	2 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT	Belden 1032A

Type	Configuration	Colors	Manufacturer Part No.
		Jacket - Black PVC	
Analog Input, 18 AWG	3 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Red FEP	Belden 88770
Analog Input, 18 AWG	3 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Black PVC	Belden 1036A
Analog Output, 18 AWG	2 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 88760
Analog Output, 18 AWG	2 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Jacket - Black PVC	Belden 1032A
Analog Output, 18 AWG	3 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Red FEP	Belden 88770
Analog Output, 18 AWG	3 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Black PVC	Belden 1036A
Discrete Input, 18 AWG	2 Cond., Unshielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 89740
Discrete Input, 18 AWG	2 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Gray PVC	Belden 9409
Discrete Output, 18 AWG	2 Cond., Unshielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 89740
Discrete Output, 18 AWG	2 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Gray PVC	Belden 9409
Discrete Output, 18 AWG	3 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Red FEP	Belden 88770

Type	Configuration	Colors	Manufacturer Part No.
Discrete Output, 18 AWG	3 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Black PVC	Belden 1036A
General Purpose, 18 AWG	2 Cond., Unshielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Red FEP	Belden 88760
General Purpose, 18 AWG	2 Cond., Unshielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Gray PVC	Belden 9409
General Purpose, 18 AWG	3 Cond., Shielded, Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Red FEP	Belden 88770
General Purpose, 18 AWG	3 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Black PVC	Belden 1036A
Intrinsically Safe Control Cable, 17 AWG	2 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - RED Jacket - Light Blue PVC	Anixter BL0012650
Intrinsically Safe Control Cable, 17 AWG	3 Cond., Shielded, Non-Plenum Rated	Cond. 1 - BLK Cond. 2 - WHT Cond. 3 - RED Jacket - Light Blue PVC	Anixter BL0012651

~~Q.~~R. Electric Signal Cables:

1. Analog electric signal cables from electronic transmitters to controllers/receivers and from controllers to other analog devices shall be continuously shielded to reduce effects of EMI on control signals residing on those cables. Electric signal cables to discrete devices typically do not require shielding, but for better noise immunity use twisted/shielded pairs.
2. Shields shall be grounded at power source end only and floated at other end. Pay particular attention to floating shields through termination points, maintaining only one single grounding point, and insulating from ground at other points.
3. Provide 250 ohm, 5 watt, 0.1% tolerance, dropping resistors as required to generate 1 - 5 VDC signals or 500 ohm, 5 watt, 0.1% tolerance, dropping resistors as required to generate 2 - 10 VDC signals from 4 - 20 mA control loop powered by 24 VDC power supply.

~~R.~~S. BAS Network Communication Cable:

1. Install special cable connectors in accordance with BAS manufacturer's recommendations.

2. Typically, #22 AWG, but no smaller than #24 AWG, twisted pairs, twisted shielded pairs, coaxial cable, fiber optics or manufacturer's standard cabling for communications between remote control devices and BAS controllers.
3. BAS Network communication cable shall not be spliced.
4. Provide isolated instrument grounding system as necessary per manufacturer's recommendations.

3.4 LOCAL CONTROL PANELS

A. Provide local control panel for each system where more than one control device requires field mounting, (air handling units, exhaust fans, miscellaneous control systems including pump controls, heat exchanger controls, etc.). Single devices may be mounted on piping, wall or ductwork. Install local control panel where indicated on drawings or suitable location adjacent to system served.

B. Mount panels on wall with suitable brackets or on self-supporting stand. Mount top of panels no higher than 6 ft above floor. Install panels so front cover door can swing fully open without interference.

C. Label local control panels with respective unique ID numbers in accordance with Section 20 0553 - Mechanical Identification.

D. All control panels located in accessible areas be provided with keyed locks. Locks shall utilize a single master key. Provide 2 spare key sets to Owner.

~~D.~~E. Furnish and install power cabling and conduit for temperature controls panels and equipment from emergency power panels. Each temperature control panel shall be connected to a separate circuit. Conduits shall connect to panels at the locations directed by the Contractor under Division 26. Final connection in the power panels shall be by Temperature Control Contractor in coordination with Division 26 Contractor.

~~E.~~F. Panel Layout:

1. Locate controllers in lower half of panel first and upper half second.
2. Locate terminal strips either horizontally in upper half of back panel or vertically. Do not locate terminal strips below 2'-0" or above 6' above finished floor.
3. Separate 24 VDC and 120 VAC, wire, cable, and devices by 6" minimum space.
4. Enclose wire and cable in wireways or bundle w/ wire ties and secure to back-panel. This does not apply to wire exiting wireways to terminal strips or panel mounted devices.
5. Space controllers according to manufacturer's requirements with 3" minimum between controllers and other devices on panel and 6" between controller front and door mounted devices. Ensure adequate space is allowed for device heat dissipation.
6. Do not place controller or control devices on enclosure sides.
7. Do not use any control panel as wire or cable pass-through to adjacent panel.

3.5 BAS ETHERNET NETWORK TESTING AND BENCHMARKING

A. Test and document connectivity, latency, and integrity of network from each switch to each BAS controller and BAS server switch and from switch-to-switch.
   1. Latency between any ports shall be equal to or less than 1 millisecond.
   2. Packet loss shall be less than 0.5% between any ports when tested with frame sizes between 64 and 1518 frames for duration of 60 seconds.

B. Test and document all telecommunication protection/security techniques employed on system including access control into BAS Ethernet network from other building networks and access control to other building networks from BAS Ethernet network. Coordinate testing procedures with Owner.

3.6 ADJUSTMENT AND COMPLETION CHECKLIST

A. After completion of installation, follow checklist procedure defined in checklist submittal to adjust and calibrate thermostats, control valves, control actuators, controllers, sensors, and other equipment provided in this Contract. Include signed and dated, completed checklist in Operation and Maintenance Manuals.

B. Upon completion of Work but before final acceptance of systems, Engineer or Owner's representative will verify performance of control loops. Control Contractor shall immediately remedy any deficiencies found. Corrective measures may include modification or addition of equipment and devices, control strategies and/or software program. Corrective modifications made by Control Contractor during warranty period shall be incorporated and updated in Operation and Maintenance Manuals.

C. After final acceptance of system, Contractor shall work with Owner to remove all existing user names and passwords for all software and hardware used on project and create new user names and passwords as required.

D. Upon completion of the installation, the BAS Contractor shall start up the system and perform all necessary testing and debugging operations. An acceptance test in the presence of the Owner's representative shall be performed. The vendor shall check all sensors that exhibit any problems or faulty reading. When the system performance is deemed satisfactory in whole by UEM, the system parts will be accepted for beneficial use and placed under warranty. The BAS Contractor is to be available for system commissioning at the end of the installation when requested by the Engineer and/or Owner. The contractor is to also be available for seasonal commissioning for the other seasons beyond the initial commissioning.

E. This Contractor shall work with the Owner (UEM), who is developing the graphics, to ensure that all points report, function and alarm as required on the BACnet head-end system. The Contractor will also work with the Project Manager or CNS/MCIS to obtain all necessary IP's and Ethernet drops needed for BACnet panel. The Owner (UEM) will assign all BACnet/IP instance numbers and all BACnet/MSTP network numbers for use by the Contractor. All BACnet/IP devices will report directly to the head-end system.

F. After completion of the installation, the automatic temperature control manufacturer shall regulate and adjust all thermostats, control valves, motors, and other equipment provided under his contract and shall place them in complete operating condition, subject to approval by the Engineer and Owner.

G. This shall include but not be limited to "tuning" of all control systems. Systems shall be tuned for decaying wave response and minimal overshoot of setpoint. Contractor is to not leave any system in an Auto Tune mode.

H. Room temperature controls shall have one temperature setpoint with less than a 0.5˚F between calculated heating and cooling temperatures.

I. This Contractor shall work with Balancing Contractor to provide verification of CFM reading from the DDC terminal unit controllers.

J. Final adjustment shall be performed by specially trained personnel in direct employ of manufacturer of primary temperature control system.

K. After completion of installation, perform the following:
   1. Installation.
      a. Check proper installation and connection of each control device.
      b. Verify electric power.
      c. Verify each sensor and actuator connection to field computer.
   2. Field Computer Operation.
      a. Point Test.
      b. - check of wiring of each sensor and actuator end-to-end
      c. - verify calibration of each sensor.
      d. - verify manual operation of each actuator.
   3. Local loop control.
      a. - bring each local loop under control.
      b. - check response to upset, change in setpoint.
      c. - check full and partial load operation.
   4. Supervisory functions.
      a. - verify time clock schedules.
      b. - verify reset control.
   5. Verify communication with each field device.
      a. - perform end-to-end sensor and actuator checks.
      b. - verify that the database is correct.
   6. Test other software.
      a. Trend Logging.
      b. Report Generation.
      c. Remote Access.
      d. System Documentation.

L. Verify proper operation of every control point in the presence of the Engineer. Include point-by-point checkout.

~~E.~~M. The control manufacturer shall provide a period of free service extending through one complete heating season and one complete cooling season, after acceptance of the control system, and shall report the condition of the control equipment to the Owner and the Architect.

~~F.~~N. UEM will be performing their own complete point by point evaluation as part of this project, independently of the commissioning activity. This will occur during the warranty period of the project.

3.7 OWNER TRAINING

A. Provide full time BAS operator to run system after systems have been started and are regularly used until Owner has completed on-site training specified.

B. Provide minimum of **24** hours of on-site training to Owner's representatives. Conduct training sessions during normal business hours after system start-up and acceptance by Owner.

Scheduling of training session(s) will be established by Owner. Portions of training may be performed before system is completely operational, but no sooner than one month before system is planned to be fully operational. Final training session shall be held after systems are complete including all graphics programming.

C. *The BAS Contractor shall provide two copies of an electronic version of the operator's manual describing all operating and routine procedures to be used with the system. This user's manual should contain subjects such as: standard operation, error message explanations, software usage, commands, system troubleshooting, etc. The Contractor shall also provide wiring schematics for all system components.*

D. *The BAS Contractor shall instruct the Owner's designated representatives in these procedures during the start up and test period. The duration of the instruction period shall be no less than four (4) hours during two 2 hour sessions. (Number of hours may be adjusted to a max of 40 dependent upon the size and scope of project. For larger projects, training vouchers for instructional training at the manufacturer's facilities may be requested in lieu of on-site training.) These instructions are to be conducted during normal working hours at the Owner's convenience and are to be prearranged with the Owner. The owner can request this training any time within the one year warranty period and may request any number of classes adding up to the total number of hours. The contractor shall provide an hourly unit price for additional on-site training.*

E. *The instructions shall consist of both hands on at the job site and classroom training at a classroom location on the University of Kentucky campus coordinated with the Project Manager and UEM.*

F. Course content shall include, but not be limited to, the following topics:
   1. Upon completion, the attendees shall be able to operate the system and implement system changes including start up, boot load, add point to the data base, enter messages, and down line load field units.
   2. Prior to the scheduling of the sessions, an agenda outlining the training topics must be submitted for approval. Agenda items shall include, but not be limited to, the following topics:
      a. Explanation of control sequences. Include which sensors are used and how output device operates.
      b. Explanation of control drawings and manuals, including symbols, abbreviations, and overall organization.
         1). Walk-through of project to identify controller locations and general routing of network cabling.
      c. Review of operation and maintenance of hardware devices including air compressor, air dryers, controllers, instruments, and sensors. Include schedule for routine maintenance.
      d. Programming Application Specific Controllers
         1). Backing up and Restoring Application Specific Programming
         2). Adding/Deleting/Editing points on Application Specific controllers
         3). Troubleshooting Application Specific controllers (inputs/outputs/logic/master – slave relationships/bus issues)
      e. Programming Building Specific Controllers
         1). Backing up and Restoring Building Specific Controllers Programming
         2). Adding/Deleting/Editing points on Building Specific Controllers controllers
         3). Troubleshooting Building Specific Controllers controllers (inputs/outputs/logic/network issues)
      f. How to use tools and cables

G. Course content shall include, but not be limited to, the following topics:
   1. Review of operation of operator's workstation; include hardware (PC's, printers, etc.).
   2. Review of operator's workstation software using specific examples of operating hardware.
   3. Review of portable operator's workstation software using specific examples of operating hardware.
   4. Any additional item(s) specifically requested by Owner.

H. Provide listing of regularly scheduled factory classroom training sessions concerning advanced topics covering proper operation and maintenance of control systems, sensing, monitoring and control equipment. Additional classes travel and lodging will be arranged and paid by Owner.

I. Provide minimum of **8** hours of additional on-site training to Owner's Representatives, 6 months after initial training is completed.

J. Scheduling of training session(s) will be established by Owner.

END OF SECTION

Qualification Form	
Brief resume of **key** persons, specialists, and individual consultants anticipated for this project:	
a. Name & Title:	b. Project Assignment:
c. Name of Firm with which Associated:	d. Years of Experience: With this Firm_____ Other firms_____
e. Education: Degree(s)/Year/Specialization	f. Responsibility Level Proposed for this Project:
g. Other experience and qualifications relevant to the proposed project (include training courses/certifications):	

Recent Relevant Experience (see example below) ▪ Company, Location - Name of Specific Project, Facility - Description of Work and Responsibilities	**Qualifications**

SECTION 23 0923 DIRECT DIGITAL CONTROLLERS AND NETWORKS

PART 1 - GENERAL

1.1 RELATED WORK

A. Section 23 0901 - Control Systems Integration

B. Section 23 0903 - Control Instrumentation

C. Section 23 0993 - Control Sequences

D. Control Sequences: Refer to Drawings

1.2 REFERENCE

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

1.3 DEFINITIONS

A. The following abbreviations, acronyms, and definitions may be used in addition to those found elsewhere in Contract Documents.

1. ASC: Application Specific Controller. A networked device or node that contains a complete, configurable application that is specific to a particular task.
2. Alarms & Events: The exchange of data between devices related to the occurrence of a predefined condition that meets specific criteria (event).
3. BC: Building Controller. Provide supervisory control, scheduling, trend logging & alarm handling.
4. B-OWS: BACnet Operator Workstation
5. B-BC: BACnet Building Controller. Same as SLC.
6. B-AAC: BACnet Advanced Application Controller. Same as PPC.
7. B-ASC: BACnet Application Specific Controller
8. B-SA: BACnet Smart Actuator
9. B-SS: BACnet Smart Sensor
10. BBMD: BACnet Broadcast Management Device
11. BIBBS: BACnet Interoperability Building Blocks. Specific individual function blocks for data exchange between interoperable devices.
12. Broadcasting: The propagation of data from a device to the control network. Software objects that broadcast data to the network may include the following parameters:
13. Send on Delta: An adjustable parameter that defines a requirement to broadcast when the data generated by the software object changes by an amount that exceeds this parameter's value. For binary data, this parameter defaults to a change of state. The broadcast of data is initiated when this criteria and the minimum send time requirement have been met. Also referred to as a "Change of Value".

14. Minimum Send Time: An adjustable parameter that defines a mandatory time period during which no broadcasting of data will occur. Once this time period has been exceeded without a broadcast, the send on delta parameter or the maximum send time parameter shall determine when a broadcast is initiated.
15. Maximum Send Time: An adjustable parameter that defines the maximum time period between broadcasts of a software object's data to the network. Should the value of a software object remain constant over an extended period of time, the value will be rebroadcast once every maximum time period.
16. BTL: BACnet Testing Laboratory.
17. Channel: One or more segments not containing a router.
18. Domain: A logical collection of devices on one or more channels.
19. FLN: Floor Level Network. BACnet MS/TP.
20. HMI: Human-Machine Interface. Graphical operator BAS interface. Same as Graphical User Interface (GUI).
21. LAN: Local Area Network. Same as Floor Level Network.
22. Maximum Send Time: Event driven communication parameter specifying the time period for which data must not be sent more than once.
23. Minimum Send Time: Event driven communication parameter specifying the time period for which data must be sent at least once.
24. PICS: Protocol Implementation Conformance Statement. Detailed description for a given BACnet device stating its inherent BACnet capabilities.
25. Point: Group of data, which corresponds to a hardware input, output, or calculated value.
26. PPC: Programmable Process Controller. Same as Advanced Application Controller (AAC)
27. Scheduling: The exchange of data between devices related to the establishment and maintenance of dates and times at which specified output actions are to be taken.
28. Send on Delta: Event driven communication parameter specifying the amount of variable change before data is to be sent between the Minimum and Maximum send times.
29. SLC: Supervisory Level Controller. Same as Building Controller.
30. Segment: A section of uninterrupted cable where multiple devices may be installed.
31. Subnet: Logical division of a domain.
32. Trending: The accumulation of (time, value) pairs at specified rates for a specified period duration.

1.4 SUBMITTALS

A. Shop Drawings:
   1. Submit shop drawings for each hardware device used and submit complete description of software applications used. Submit manufacturer's printed product data sheets for each

device or software program used. Datasheets shall be submitted electronically in pdf format with bookmarks provided for each individual device and table of contents listing each device manufacturer and full model number with links to device pages. Organize sheets in order of model number, alphabetically, then numerically. When a manufacturer's data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means.

2. Submittals shall include points list of each control input and output, controlled devices, locations of devices, and symbol or label of each control point in software.

B. Operating and Maintenance Manuals: Refer to Section 23 0901 - Control Systems Integration.

C. Software Manual:
   1. As part of operating and maintenance manuals, submit one software manual per workstation plus one extra copy for archive use. Software manuals shall be divided into separate parts with tabs for each part.
   2. Software manual parts shall include:
      a. Complete description of operating system including all commands, configuration programs, printouts, logs, database functions and passwords. Describe general operating procedures, starting with system overview and proceeding to detailed description of each software command feature with sample printed displays and system function description for each option. Include instructions on verifying errors, status, changing passwords and initiating or disabling control programs.
      b. Complete description of programming language including all commands, configuration programs, control loop functions and testing. Describe general programming procedures, starting with system overview and proceeding to detailed description of each software command feature. Include instructions on creating or modifying any control algorithm or parameter, debugging, etc. This shall include all control functions, algorithms, mathematic equations, variables, setpoints, time periods, messages, and other information necessary to load, alter, test and execute custom or pre-written programs.
      c. Software Backup: Upon successful completion of acceptance testing, submit to Owner 2 archive copies of all accepted versions of source code and compiled code for all application programs and data files on CD ROM backup disks. All control software must be readily accessible by Owner using BAS workstation hardware and software.
      d. Web server/data historian SQL database schema (table format) for trend data and event/alarm data.
      e. Control Loop Documentation: Submit indexed summary of each control loop program. Summary shall list in tabular form, name of system, name of control loop, all I/O points used, and reference to sheet number in shop drawings to describe control sequence programmed. For each control loop submit complete printed listing of source code used, all setpoints, high/low alarm points, time event schedules, proportional gains, integrals, derivative values, and other database values.
      f. BAS Points List Summary: Provide detailed summary for each point in the system. Summary shall be cross-index listing of all points in alpha/numerical order with list of control loops which use each point. For each point, include an abbreviated point name, expanded point description, detailed description of each input instrument or output device, and detailed description of exact location of all field hardware. Location descriptions shall include room names, column numbers, elevation (above ceiling, bottom of duct, etc.).

1.5 WARRANTY

A. Provide 1 year warranty on all materials and labor.

B. Warranty requirements shall include furnishing and installing software upgrades issued by the manufacturer during the 1 year warranty period.

1.6 FCC COMPLIANCE

A. Digital equipment furnished under this contract shall be tested and made to comply with limits for Class A computing devices pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against interference when operated in commercial environments. Literature shall so note and equipment shall be so labeled to show this compliance.

PART 2 - PRODUCTS

2.1 DIRECT DIGITAL CONTROL (DDC) CONTROLLERS

A. General:

1. DDC controllers shall be microprocessor based, field programmable controllers, capable of performing control and energy management functions, and shall be UL listed as Signaling Systems. Each controller shall include its own microprocessor, power supply, input/output modules, and termination modules as required to perform intended function.
2. DDC controller shall receive discrete electrical and/or analog electronic field input signals, convert signals for use by controller, perform control sequences, convert controller information into output signals, and provide control output signals to actuators and field control devices. Inputs and outputs, including communication connections, shall be electrically or optically isolated from controllers.
3. All BACnet devices shall be BTL certified or BTL compliant.
4. All DDC controllers shall be provided by the same manufacturer.
5. DDC controller with analog input modules shall be capable of accepting any form of linear or non-linear voltage (0-5 VDC or 0-10 VDC), current (4-20 mA) or resistive input (0-1000 ohm).
6. DDC controller with discrete input modules shall be capable of accepting discrete inputs from any device with isolated, dry-type contacts (no grounds or no voltage) of either normally open (NO) or normally closed (NC) configuration. Provide visible status lights (LEDs) to indicate input point status.
7. Provide input modules capable of interfacing with pulsed output type sensors as required.
8. DDC controller with discrete output modules shall have isolated, dry-type contacts (no grounds or no voltage) of either normally open (NO) or normally closed (NC) configuration. Provide visible status lights (LEDs) to indicate output point status.
9. DDC controller shall have capability to scale, offset, and display proper analog value without field hardware modification. DDC controller shall convert analog input signals to digital values (A/D conversion) and convert digital values to analog outputs (D/A conversion) for modulating control purposes. Some application specific controllers may utilize tri-state or Triac outputs for floating point control of control devices. Floating point control should be limited to non-critical room temperature control and mechanical space heating and cooling.
10. Failsafe hardware shall be provided such that BAS failures result in immediate return to local control. If DDC controller uses database values from other DDC controllers and communication network fails or malfunctions, control loop outputs shall continue to function using last value received from BAS.

11. Failure of network or control devices (i.e. building level controllers, floor level controllers, application specific controllers, routers, etc.) shall be alarmed at the Operator Workstation as a Level 3 Critical Alarm.
12. All DDC Hardware shall meet the following requirements:
    a. All DDC controllers shall be connected to an ASHRAE 135 MS/TP, BACnet/IP control network and communicate via ASHRAE 135 exclusively.
    b. MS/TP controllers shall operate at a minimum baud rate of 38.4 kbps.
    c. All DDCP shall implement all required functionality of the application network interface via BACnet objects, properties, and services.
    d. All DDC controllers shall conform to the BACnet Testing Lab's Device Implementation Guidelines and be BTL Listed.
    e. Application programs and configuration settings shall be stored in a manner such that a loss of power does not result in a loss of the application program or configuration settings.
    f. All settings and parameters used by the application shall be fully configurable to the greatest extent possible, via properties of BACnet objects that can be written to via BACnet services or via properties of BACnet objects that can be written to via BACnet services for the following:
        1). Setpoint
        2). Alarm limit
        3). Schedule modification
        4). Trend modification
    g. All other settings and parameters that cannot be written to via BACnet services shall be fully configurable via either properties of BACnet objects that can be written to with a configuration tool, or via hardware settings on the controller itself to support the application.
13. Each DDC panel shall have sufficient I/O capacity to perform specified control sequences and/or include points listed in point schedules. If DDC controller does not have sufficient capacity, provide additional slave I/O panels to achieve required point count.
14. Analog and critical safety discrete control loops shall have inputs and outputs into/from same DDC panel. Analog control loops for major equipment (chilled water, hot water, convertors, air handling units, etc.) shall have PID control.
15. For function short names and building short names and numbers, contact the University Controls Engineering Department.
16. Contractor shall provide all equipment, engineering and technical specialist time to check the installation required for a complete and functioning system. The contractor shall furnish and install all interconnecting system components. Components to include, but not be limited to: power line conditioners, field panels, sensors, motor starter interfaces, and any other hardware items not mentioned above but required to provide the Owner with a complete workable system.
17. Any feature or item necessary for complete operation, trouble shooting, and maintenance of the system in accordance with the requirements of this specification shall be incorporated, even though that feature or item may not be specifically described herein. This shall include hardware and software.
18. All materials and equipment used shall be standard components, regularly manufactured for this and/or other systems and not custom designed especially for this project. All systems and components shall be thoroughly tested and proven in actual use.

19. Contractor shall provide all equipment, engineering and technical specialist time to check the installation required for a complete and functioning system. The contractor shall furnish and install all interconnecting system components. Components to include, but not be limited to: power line conditioners, field panels, sensors, motor starter interfaces, and any other hardware items not mentioned above but required to provide the Owner with a complete workable system.
20. Any feature or item necessary for complete operation, trouble shooting, and maintenance of the system in accordance with the requirements of this specification shall be incorporated, even though that feature or item may not be specifically described herein. This shall include hardware and software.
21. All materials and equipment used shall be standard components, regularly manufactured for this and/or other systems and not custom designed especially for this project. All systems and components shall be thoroughly tested and proven in actual use.
~~18.~~22. The system as specified shall monitor, control and calculate all of the points and functions as listed in the Input/Output Summary.

B. BACnet Building Controller (B-BC):
   1. BACnet Building Controllers (B-BCs) shall provide direct connection to high speed, BACnet/IP Local Area Network (LAN) and Campus Ethernet network and serve as communications router for other controllers on slower speed BACnet MS/TP Floor Level Network (FLN).
   2. B-BC controllers shall be:
      a. Tridium N4 JACE 8XXX with 4.6 or greater using most current version of JAVA or HTML 5
      ~~3.~~b. Building Controller (B-BC) shall be minimum 16 bit microcomputer based, utilizing a multi-tasking, multi-user operating system.
      c. The B-BC controllers shall permit the simultaneous operation of all control, communication facilities management and operator interface software, as programmed by the Contractor or User. Modification of the on-board B-BC controller database shall be performed on-line using the built-in software. Systems which require the B-BC to be removed from service while DDC control sequences are modified shall not be acceptable.
      d. The B-BC controller shall additionally provide diagnostic LED indication of device transmit and receive data communications for all communication port and peripheral ports, normal operation, abnormal operation and control relay operation indication.
      ~~4.~~e. The B-BC controller shall provide commanded override capability from the built-in operator interface. Such overrides shall be annunciated to the head-end station. Such overrides shall be valid as long as power is applied to the controller.
      ~~5.~~f. B-BC controllers shall utilize true floating point arithmetic capabilities.
      g. All B-BC controllers shall have open licensing to connect to existing UK UEM Tridium BACnet BAS.
      h. B-BC controllers shall be equipped with a minimum of one operator service port for the connection of a laptop computer. The service port shall be either a built-in standard RS-232 data terminal port, USB port, CAT5 cable or RJ11/12 connection.
      ~~6.~~i. Connection of a service device, to a service port, shall not cause the B-BC controller to lose communications with its peers or other networked device controllers.
   ~~7.~~3. All programming defining the functions to be performed by the B-BC, including but not limited to application programs and point database within each B-BC, shall be protected from loss due to power failure for a minimum of 72 hours. All database and backup shall be provided to the UK UEM Controls group.
   ~~8.~~4. Communication between B-BC's shall be through BACnet/IP communication.

a. The Building Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork. It must support interoperability on the campus area network and function as a BACnet Broadcast Management Device (BBMD) and/or a BACnet router.

~~9.~~5. B-BC's shall have sufficient processor capabilities, hard-drive storage and RAM to implement all types of custom software applications and shall provide supervisory control, scheduling, trend logging & alarm handling functions as follows:

a. Scheduling:

1). Each B-BC shall support a minimum of 250 BACnet Schedule Objects and 250 BACnet Calendar Objects.

b. Trending:

1). Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.

2). B-BC shall periodically upload trended data to networked BAS Web Application Server for long term archiving.

3). Archived data shall be stored in standard database format and shall be made available for use in third-party spreadsheet or database programs.

c. Alarm Generation:

1). Alarms may be generated within the system for any object change of value or state either real or calculated. This includes analog object value changes, binary object state changes, and various controller communication failures.

2). B-BC shall periodically upload alarm logs to networked BAS Web Application Server for long term archiving.

~~10.~~6. B-BC's shall have uninterrupted real time clocks capable of time of day, week, and year information to the system as needed to perform software functions. Clock shall be programmed to reset twice per year to allow for Daylight Savings Time. Clocks in multiple DDC Controllers shall be synchronized to automatically match designated B-BC's or Web server. Accuracy shall be within 1 second per day.

~~11.~~7. All control sequences programmed into the B-BC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained. Power failures shall not cause the GDC memory to be lost, nor shall there be any need for batteries to be recharged or replaced to maintain the integrity of the controller database. The B-BC shall allow for the creation of unique application control sequences. Batteries shall maintain real time clocks for a period of at least 72 hours during power failure. Batteries shall be maintenance free and have minimum life of 2 years. When power has been restored, the following shall occur automatically:

a. Orderly startup of controlled equipment (user defined)

b. Continuation of control algorithms

c. Database revision

d. Logging of power interruption and restoration times

e. Battery recharging

~~12.~~8. Provide local visual indication and system annunciation of low battery power for each battery.

~~13.~~9. Each B-BC shall include its own micro-processor, power supply, input/output modules, and termination modules as required to perform intended function. Systems that only allow selection of sequences from a library or table are not acceptable.

~~14.~~10. B-BC controllers shall be equipped with a minimum of one operator service port for the connection of a laptop computer. The service port shall be either a built-in standard RS-232 data terminal port, USB port, CAT5 cable or RJ11/12 connection.

~~15.~~11. Connection of a service device, to a service port, shall not cause the B-BC controller to lose communications with its peers or other networked device controllers.

a. BACnet UDP port number to always be set to 47808 (BAC0).

~~16.~~12. Display and Readout Capability

a. The B-BC controller shall additionally provide diagnostic LED indication of device transmit and receive data communications for all communication port and peripheral ports, normal operation, abnormal operation and control relay operation indication.

~~17.~~13. Manual/Auto Control and Notification

a. The B-BC controller shall provide commanded override capability from the built-in operator interface. Such overrides shall be annunciated to the head-end station. Such overrides shall be valid as long as power is applied to the controller.

~~18.~~14. Adjustments

a. Every control panel shall provide adjustments for the functions specified. In general, adjustments shall be provided for all setpoints used by controllers within each control panel. In addition, adjustments shall be provided for throttling ranges, mixed air damper minimum positions, or other items as specified. Adjustments shall be integral to each individual B-BC. The built-in operator interfaces shall allow the easy execution of the adjustment through named identifiers within the B-BC. From a single B-BC user interface, any other B-BC shall be accessible and full adjustment capabilities shall be provided.

~~19.~~15. B-BC Naming Convention

a. No special characters are allowed, except underscores.

~~a.~~b. B-BC devices shall be named using the following naming convention:

1). B-BC devices shall be named using the following format:

a). BuildingName_BuildingNumber_Floor_RoomNumber_B-BC Device Type OR

b). BuidlingNumber_BuildingName_Floor_RoomNumber_B-BC Device Type

~~b.~~c. All B-AAC points shall be named using the following format:

1). Building_Floor_RoomNumber_Device Type_Equipment ShortName_Function

~~c.~~d. Examples:

1). A B-BC device located in the Pavilion HA mechanical room HA4001 would be named as follows:

a). PAVHA_0293_04_HA4001_JACE

2). An exhaust fan status point for a fan in Pavilion HA mechanical room HA3001 fed directly from the above panel would be named as follows:

a). PAVHA_03_HA3001_HVA_EF1_STAT

3). For function short names and building short names and numbers, contact the University Controls Engineering Department.

~~3).~~

C. BACnet Advanced Application Controllers (B-AAC):

1. Controls shall be microprocessor based, Advanced Application Controllers (B-AAC's). B-AAC's shall be provided for Air Handling Units, packaged Rooftops, primary and secondary pumping loop systems and other applications as shown on the drawings. B-AAC's shall be based on a minimum 16 bit microprocessor working from software program memory which is physically located in the B-AAC. The application control program shall be resident within the same enclosure as the input/output circuitry which translates the sensor signals. All input/output signal conversion shall be performed through a minimum of a 10 bit A to D converter. All input points shall be universal in nature allowing their individual function definition to be assigned through the application software. All unused input points must be available as universally definable at the discretion of the owner. If the input points are not fully universal in nature, unused points must be equal in quantity between Analog Inputs and Digital Inputs.
2. All B-AAC controllers shall have open licensing to connect to existing UK UEM Tridium BACnet BAS.
3. Contractor shall provide a minimum of one B-AAC controller per air handling or mechanical system as shown on the drawings.
4. The BAS contractor shall provide and field install all B-AAC's specified under this section. Mechanical equipment manufacturers desiring to provide B-AAC' type controls as factory mounted equipment, shall provide a separate bid for their products less all controls, actuators, valve assemblies and sensors, which are specified to be provided by the BAS/Temperature control contractor.
5. All input/output signals shall be directly hardwired to the B-AAC. Troubleshooting of input/output signals shall be easily executed with a volt-ohm meter (VOM). As a result of this intent, it is specified that power line carrier systems, or other systems which command multiple outputs over a single pair of wires, shall not be utilized.
6. B-AAC's shall be in continuous direct communication with the network which forms the facility wide Building Automation System. The B-AAC's shall communicate with the B-BC at a minimum baud rate of 9,600 baud.
7. B-AACs are defined as having sufficient processor capabilities and RAM to implement all types of custom software applications.
   a. Scheduling:
      1). The B-AAC shall be provided with integral time schedules; as a minimum, two seven day schedules with eight on/off periods per day shall be provided. Holiday override of weekly schedules shall be provided for pre-scheduling of holidays, for the year in advance.
8. B-AACs shall be capable of communicating to BAS network via BACnet MS/TP connected to Building Controller or via BACnet/IP directly.
9. All B-AACs controlling major mechanical equipment/systems and lab equipment monitoring shall communicate via BACnet/IP as indicated on BAS Network Architecture drawings.

10. Provide at least one extra communication port at each B-AAC for direct connecting a notebook computer or hand-held terminal. The port will allow the lab top direct access to any B-AAC or B-ASC in the network.
11. The B-AAC shall provide an input/output point trending utility that is capable of accumulating 48 analog point samples and 10 digital point samples per Input/Output point. Each sample shall be taken on a user defined interval. The digital readings shall be on a change of state occurrence for the digital points.
12. The samples shall be protected against loss due to power interruptions through a battery or capacitor backup method for a minimum of 30 days.
13. The B-AAC shall provide LED indication of transmit/receive communications performance as well as for the proper/improper operation of the controller itself.
14. The B-AAC shall be provided with a battery backed time clock that is capable of maintaining the time of day and calendar for up to thirty days, upon loss of power to the B-AAC, without loss of setting. The battery for the time clock shall be replaceable by the customer.
15. The B-AAC shall be capable of being mounted directly in or on the controls compartment of the air handling system. The B-AAC shall be housed in a NEMA 1 enclosure to accommodate direct mounting on the equipment to be controlled. The B-AAC shall be constructed in a modular orientation such that service of the failed components can be done quickly and easily. All logic, control system, power supply and input/output circuitry shall be contained on a single plug –in circuit board. When required to replace a printed circuit board, it shall not be necessary to disconnect any field wiring. The B-AAC shall be directly wired to sensory devices, staging relays or modulating valves for heating and cooling.
16. Non-Volatile Memory
    a. All control sequences programmed into the B-BC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained. Power failures shall not cause the GDC memory to be lost, nor shall there be any need for batteries to be recharged or replaced to maintain the integrity of the controller database. The B-BC shall allow for the creation of unique application control sequences. Systems that only allow selection of sequences from a library or table are not acceptable.
    b. All control sequences shall be fully programmable at the B-AAC, allowing for the creation and editing of an application control sequence, while at the unit.
    c. The B-AAC shall be provided with an interface port (standard RS232 data terminal port or USB port) for a laptop computer. The interface port shall allow the laptop to have full functionality as described above. From the interface port or network terminal, the laptop shall be able to directly access any B-AAC or B-ASC in the network.
    d. The B-AAC shall provide an input/output point trending utility that is capable of accumulating 48 analog point samples and 10 digital point samples, per Input/Output point. Each sample shall be taken on a user defined interval, ranging from 1 second to 255 hours per sample. The digital readings shall be on a change of state occurrence for the digital points. All samples shall be recorded with the engineering units for the value, along with a time and date identifier for each sample taken. The samples shall be protected against loss due to power interruptions through a battery or capacitor backup method for a minimum of 30 days.
    e. Systems unable to provide the above capability shall provide for the individual Input/Output point trending at the B-BC. Specifics as to how each B-AAC point will be trended, at the B-BC, shall be provided in the submittal documents. Included in the explanation shall be the sample intervals, the memory allocation in the B-BC and the number of B-AAC’s per B-BC that can be expected.

f. The B-AAC shall provide LED indication of transmit/receive communications performance, as well as for the proper/improper operation of the controller itself.

g. The B-AAC shall be provided with a battery backed time clock that is capable of maintaining the time of day and calendar for up to thirty days, upon loss of power to the B-AAC, without loss of setting. The battery for the time clock shall be replaceable by the customer. The B-AAC shall be provided with integral time schedules; as a minimum, two seven day schedules with eight on/off periods per day shall be provided. Holiday override of weekly schedules shall be provided for pre-scheduling of holidays, for the year in advance.

17. Controller Location

a. To simplify controls and mechanical service troubleshooting, the B-AAC shall be capable of being mounted directly in or on the controls compartment of the air handling system. The B-AAC shall be housed in a NEMA 1 enclosure to accommodate direct mounting on the equipment to be controlled. The B-AAC shall be constructed in a modular orientation such that service of the failed components can be done quickly and easily. The modular construction should limit the quantities of printed circuit boards to a maximum of two. All logic, control system, power supply and input/output circuitry shall be contained on a single plug-in circuit board. When required to replace a printed circuit board, it shall not be necessary to disconnect any field wiring. This shall allow all controls maintenance and troubleshooting to be made while at the air handling unit. The B-AAC shall be directly wired to sensory devices, staging relays or modulating valves for heating and cooling.

b. Every controller and control panel shall be labeled with a lamacoid plate permanently secured to the device. Sticky tape or glued labels are not acceptable. The labeling shall describe the device and include related information such as MAC address, IP address, BACnet Instance numbers, etc.

c. All power feeds shall be clearly identified and shall include panel number, breaker and electrical panel location if not in the same room.

d. For compatibility to the environment of the air handling unit, B-AAC's shall have wide ambient ratings. B-AAC's shall be rated for service from -40 DegF (Degrees Fahrenheit) to 140 DegF.

e. Contractor shall submit description of location of B-AAC's on all mechanical and air handling equipment.

18. B-AAC Naming Convention

a. B-AAC devices shall be named using the following format:

1). Building_Floor_RoomNumber_B-AAC Device Type_Equipment Short Name

19. All B-AAC points shall be named using the following format:

a. No special characters are allowed, except underscores.

1). Building_Floor_RoomNumber_Device Type_Equipment ShortName_Function

b. Examples:

1). An Air Handler controller in the Pavilion HA mechanical room HA4001 for AHU7 would be named as follows:

a). PAVHA_04_HA4001_HVA_AHU7

2). The mixed air temperature point for the above system would be named as follows:

a). MAT

3). Therefore, when this point is learned, the entire point name will be:

a). PAVHA_04_HA4001_HVA_AHU7_MAT

4). For function short names and building short names and numbers, contact the University Controls Engineering Department.

D. BACnet Application Specific Controllers (B-ASC):

1. Controls shall be microprocessor based Application Specific Controller (B-ASC). B-ASC's shall be provided for Unit Ventilators, Fan Coils, Heat Pumps and other applications as shown on the drawings. B-ASC's shall be based on a minimum 16 bit microprocessor working from software program memory which is physically located in the B-ASC. The application control program shall be resident within the same enclosure as the input/output circuitry which translates the sensor signals. All input/output signal conversion shall be performed through a minimum of a 10 bit A to D converter.
2. Contractor shall provide a minimum of one B-ASC controller per unitary system as shown on the drawings.
3. The BAS contractor shall provide and install all B-ASC's specified under this section.
4. All input/output signals shall be directly hardwired to the B-ASC. Troubleshooting of input/output signals shall be easily executed with a volt-ohm meter (VOM). As a result of this intent, it is specified that power line carrier systems, or other systems which command multiple outputs over a single pair of wires, shall not be utilized.
5. B-ASC's shall be in continuous, direct communication with the network which forms the facility wide building automation system. The B-ASC's shall communicate with the B-BC at a baud rate of no less than 38,400 baud.
6. B-ASCs are defined as having standard software burned into EPROM, set points in EEPROM or RAM maintained by battery, and are designed to handle specific types of control sequences. B-ASC's shall be provided for Unit Ventilators, Fan Coils, Heat Pumps and other applications as shown on the drawings.
7. Control outputs may be in the form of floating point control or true analog output control of end devices. Floating point control shall be limited to non-critical room temperature control or mechanical space heating and cooling. All input/output signal conversion shall be performed through a minimum of a 10 bit A to D converter. All input/output signals shall be directly hardwired to the B-ASC.
8. Troubleshooting of input/output signals shall be easily executed with a volt-ohm meter (VOM). As a result of this intent, power line carrier systems, or other systems which command multiple outputs over a single pair of wires, shall not be utilized.
9. Provide communication ports integral room temperature sensors/thermostats for interface with local terminal equipment controllers or a low range wireless (Bluetooth®) Commissioning tool that provides a temporary wireless connection between the MS/TP network and the laptop computer used to commission.
10. The B-ASC shall provide an input/output point trending utility that is capable of accumulating 48 analog point samples and 10 digital point samples per Input/Output point. Each sample shall be taken on a user defined interval. The digital readings shall be on a change of state occurrence for the digital points.
11. Specifics as to how each B-ASC point will be trended, at the B-BC, shall be provided in the submittal documents. Included in the explanation shall be the sample intervals, the memory allocation in the B-BC and the number of B-ASC's per B-BC that can be expected.
12. The B-ASC shall be mounted directly in the controls compartment of the unitary system. The B-ASC shall be provided with a sheet metal or polymeric enclosure that is constructed of material allowing for the direct mounting within the primary air stream, as defined by UL-465. The direct mounting shall allow all controls maintenance and troubleshooting to made while at

the unitary equipment. The B-ASC shall be directly wired to sensory devices, staging relays or modulating valves for heating and cooling.

13. Contractor shall submit description of location of B-Asc's on all mechanical and unitary equipment.
14. Non-Volatile Memory
    a. All control sequences programmed into the B-ASC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained. Power failures shall not cause the B-ASC memory to be lost, nor shall there be any need for batteries to be recharged or replaced to maintain the integrity of the controller database. The B-ASC shall allow for the creation of unique application control sequences.
    b. The B-ASC shall be provided with the ability to interface with a laptop computer. The interface port shall be provided at the wall sensor or within the unitary equipment. Connection to the wall sensor must be a standard RJ-45 or USB port.
    c. The B-ASC shall provide an input/output point trending utility that is capable of accumulating 48 analog point samples and 10 digital point samples per Input/Output point. Each sample shall be taken on a user defined interval, ranging from 1 second to 255 hours per sample. The digital readings shall be on a change of state occurrence for the digital points. All samples shall be recorded with the engineering units for the value, along with a time and date identifier for each sample taken.
    d. Systems unable to provide the above capability shall provide for the individual input/output point trending at the B-BC. Specifics as to how each B-ASC point will be trended, at the B-BC, shall be provided in the submittal documents. Included in the explanation shall be the sample intervals, the memory allocation in the B-BC and the number of B-ASC's per B-BC that can be expected.
15. Controller Location
    a. To simplify controls and mechanical service troubleshooting, the B-ASC shall be mounted directly in the controls compartment of the unitary system. The B-ASC shall be provided with a sheet metal or polymeric enclosure that is constructed of material allowing for the direct mounting within the primary air stream, as defined by UL-465. The direct mounting shall allow all controls maintenance and troubleshooting to be made while at the unitary equipment. The B-ASC shall be directly wired to sensory devices, staging relays or modulating valves for heating and cooling.
    b. For compatibility to the environment of the unitary equipment, B-ASC shall have wide ambient ratings. B-ASC's shall be rated for service from 32 DegF (Degrees Fahrenheit) to 140 DegF.
    c. Contractor shall submit description of location of B-ASC's on all mechanical and unitary equipment.
16. B-ASC Naming Convention
    a. B-ASC devices shall be named using the following format:
        1). No special characters are allowed, except underscores.
        2). Building_Floor_RoomNumber_B-ASC Device Type
    b. Examples:
        1). A VAV controller in the Pavilion HA room HA498 would be named as follows:
            a). PAVHA_04_HA498_VAV
        2). The discharge air temperature point for the above room would be named as follows:
            a). DAT
        3). Therefore, when this point is learned, the entire point name will be:

a). PAVHA_04_HA498_VAV_DAT

4). For function short names and building short names and numbers, contact the University Controls Engineering Department.

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E. BACnet Router

1. BACnet MS/TP to BACnet/IP and to BACnet/IP Routers shall perform layer 3 routing of BACnet MS/TP packets over an IP network in accordance with ASHRAE 135 Annex J. The router shall provide the appropriate connection to the IP network and connections to the BACnet MS/TP network. BACnet Routers shall be capable of configuration via DHCP and Write-Broadcast-Distribution-Table messages but shall not rely on these services for configuration.
2. One router in the IP subnetwork shall be designated as the BBMD (BACnet Broadcast Management Device) and shall be indicated as so on the Network Architecture.
3. BACnet router functionality can also be incorporated into BACnet Building Controllers.

F. Power Supplies:

1. Power supplies shall operate on nominal 120 V, 60 Hz, single-phase power. DDC Controllers shall be provided with surge and noise protection. Power fluctuation shall not affect control system. Include surge protection on telephone line.
   a. Isolation transformers shall be included when connections are being made between 2 separate buildings.

2.2 DIRECT DIGITAL CONTROL SOFTWARE

A. General:

1. All software required for monitoring, modifying, configuring and backup for the system shall be embedded in the controller and accessible via VT terminal, hyper-terminal or the web. This software shall allow any computer with access (and security) to the University's network to perform the work described above using a web browser or provided software. No software upgrades should be required unless provided at no additional cost to the customer. The software version used for installation of any new devices must either be at the current software version used on the University Facilities Management campus at the current JAVA version or the new software at the most current JAVA version must be installed on all devices and the current system prior to the installation of the new devices. All software is to also operate on the latest version of Microsoft Windows operating system. All configuration and programming tools required for the upgraded version must be provided at the time of installation.
2. Provide a USB, standard RS-232 9 pin female, Bluetooth, RJ11, RJ12 or RJ45 connection for on-site access. DDC Controller control strategies shall be Owner definable from engineering workstations.
3. Software functions and algorithms shall be sufficient to enable implementation of control sequences as specified and shall be able to maintain continuous control as intended.
4. Control functions shall include both mathematical and logical operators. Control algorithms shall include proportional, integral and derivative control (PID). Adaptive (self-tuning) PID loop parameters, if offered by DDC Controller manufacturer, shall not be used unless adaptive limits are used to adjust limit values based on system status; or written request is submitted and approved by Engineer.
5. Allow operators to assign unique identifiers of their choice to each connected point. Identifiers shall have at least 8 alpha/numeric characters. References to these points in programs, reports and command messages shall be by these identifiers.

6. Provide access control (user defined passwords) for system operation. There shall be minimum of 3 access levels. First level shall allow system monitoring only. Second level shall allow monitoring, set point adjustment, and scheduling revision. Third level shall allow modification of control algorithms. System shall return to secured (monitoring only) mode after 5 minutes of inactive operation.
7. Each DDC Controller shall contain self-diagnostics that continuously monitor proper operation of panel.
8. If microprocessor malfunctions, control loop outputs shall continue to function using last value received from microprocessor.
9. Control software and hardware for equipment operation shall be selected and engineered such that equipment shall function according to sequence of operation described in section 23 0993 – Control Sequences with interruption to network communication for extended periods of time.
10. Configuration software for all controllers shall be embedded in the controllers and shall be accessible through Internet Explorer, telnet, or hyper terminal.

B. Building Controller Software:
1. Provide DDC Controller software application program modules for performing energy management control functions such as time of day change of database values (programmed start/stop, temperature setbacks, etc.), supply air temperature reset based on space load demand, economizer control, optimum start/stop based on current indoor and outdoor psychometrics, duty cycling and client tailored programs required for special applications such as VAV fan matching and supply fan control, enthalpy control, intermediate season or "dead band" control, totalizing, and holiday programming.
2. Provide manufacturer's standard operating system for real time control of system interactions, including database information requests/transfers by system hardware or by operators. Operating system shall also have the following additional capabilities (given that operator has appropriate security access level):
    a. User interface and online system configuration software embedded in Building Controller.
    b. Support for Web services at the automation network level.
    c. Displaying database (point) value including measured values, controlled variables, setpoints, gain factors, and any other adjustable parameters.
    d. Changing or overriding any database value.
    e. Error detection, correction, re-transmission of database values, arithmetic or logical faults.
    f. Alarm reporting including sending alarms to remote workstations, User Interface Web Server or Data Historian on network.
    g. Alarm buffer to retain alarms in order of importance without losing any alarms.
    h. Creating and displaying historical trend logging of any value, limited only by available memory.
    i. Creating new variable database values (soft points) based on arithmetic calculation (including summation or totalizing) on other database values.
    j. Adding new hardware points without overall BAS shutdown.
3. Building Controller shall as a minimum support MS/TP and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a BACnet device and shall support simultaneous routing functions between all supported LAN types. Global controller shall be a BACnet conformance class 3 device and support all BACnet services necessary to provide the following BACnet functional groups:
    a. Clock Functional Group

b. Files Functional Group
c. Reinitialize Functional Group
d. Device Communications Functional Group
e. Event Initiation Functional Group

4. Please refer to end of this section for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data.
5. Standard BACnet object types supported shall include as a minimum: Analog Value, Binary Value, Calendar, Device, File, Group, Notification Class, Program and Schedule object types. Alarms should also be setup on this system with limits. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data.
6. The Building Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork. It must support interoperability on the campus area network and function as a BACnet Broadcast Management Device (BBMD) and/or a BACnet router.

~~j.~~

C. B-ASC Controller Software:
   1. Manufacturer's standard software for B-ASC's may be used only if control sequences can be implemented without modification. If control sequence cannot be accomplished with standard software, provide battery backed RAM or EEPROM DDC Controller (B-AAC) capable of being programmed for specified control sequence.
   2. Provide software for portable PC units to communicate with terminal controllers at the room level network. Software shall allow access to modify, delete or create control strategies at the room sensor location.

2.3 WEB APPLICATION SERVER

A. Refer to 25 0924 – Graphical user Interface Integration.

2.4 DDC ENGINEERING (PROGRAMMING) - SOFTWARE

A. Provide engineering software for **5** Engineering Servers/Workstations.

B. Software shall have the same characteristic and capabilities as DDC Controllers. In addition, operator's workstations shall have the following features.

C. User Programmability:
   1. Engineering workstation software shall include field-engineering tools (software & hardware) for programming all controllers supplied.
   2. All application software shall be interactive, fully prompted, and menu driven and shall provide the following functionality as a minimum:
      a. Determine control strategies, which have been defined for specific piece of equipment.

b. Add control loops to system using English language type program language equal to BASIC or other easily learned language or function block programming. (PASCAL, C, or other assembly type languages are not acceptable.)
c. Add points to system.
d. Create, modify or delete control strategies.
e. Create, modify or delete system graphics.
f. Assign sensors and/or actuators to control strategy.
g. Tune control loops through adjustment of control loop parameters.
h. Enable or disable control strategies.
i. Generate hard copy records of control strategies on printer or soft copies to files compatible with Microsoft Office applications.
j. Select points to be alarmable and define alarm state(s).
k. Select points to be trended over a period of time and initiate recording of values.
l. Override Input/Output points for each individual controller.

2.5 NETWORK HARDWARE

A. Provide network interface hardware for each device connected to network. Each device shall have sufficient performance as not to degrade specified processing speed.

B. Provide network cabling with sufficient performance as not to degrade specified communication speed. Cabling shall be compatible with proposed system and shall comply with requirements specified in Section 23 0901 - Control Systems Integration.

C. Provide other network support devices that are required for proper operation of network, such as file servers, network hubs, etc.
1. Signal repeaters are not allowed for University of Kentucky building automation networks. Unless approved by the University.

D. Provide network diagnostic tool for measuring/confirming bandwidth usage on IP layer.

PART 3 - EXECUTION

3.1 GENERAL

A. Install control equipment in neat, professional manner to satisfaction of Architect and Engineer.

B. Coordinate timely delivery of materials and supervise installation of DDC Controllers and network cabling and devices.

C. Install DDC Controllers and network control devices in accessible locations.

3.2 OVERALL BAS ARCHITECTURE

A. Provide hardware/software to update database in less than 1 second for fast-acting control loops such as pressure control, air or water flow rate control, and air handling unit temperature control, or 10 seconds or less for other control loops.

B. Control software algorithm and inputs and outputs for a single system or piece of equipment shall reside on a single controller and shall not be distributed amongst multiple controllers. If multiple

pieces of equipment are to be interlocked, a single “Master” controller shall provide control for all interlocked pieces of equipment, i.e. an AHU and interlocked return fan and exhaust fans.

C. Control loop software algorithm for each analog control loop shall reside on same controller as inputs and outputs required for that specific control loop.

D. Networks that operate via polled response or other types of protocols that rely on central processors, file servers, or other such devices to maintain or manage peer-to-peer communications, shall have redundant components to maintain network in event of failure at central device. Provide automatic changeover (without operator intervention) to redundant device upon failure of any central type processor.

E. Floor Level Network (FLN) network shall be multi-drop digital transmission network utilizing BACnet MS/TP (38.4kbs) communication.

F. Each multi-drop trunk shall be within manufacturer's allowable line lengths without signal degradation. Multi-drop trunks shall be interfaced to system via standard EIA or other industry recognized interfaces so that single failure does not disrupt or halt network.

G. Communications between Building Level DDC Controllers and operator's workstations shall be peer-to-peer, allowing multiple users to access and use system simultaneously with no loss of system performance.

H. Provide levels of connected networks to connect all DDC Controllers, including terminal DDC Controller. Communications to terminal devices shall be similar to capabilities and functions of other DDC Controllers and shall be transparent to operator.

I. Quantity of nodes (devices connected) on any one FLN (MS/TP) shall not exceed 50% of maximum node capacity published by equipment manufacture and Building Controller processor usage shall not be greater than 30% nominal. Provide additional hardware to meet this requirement.

J. Alarm reports from DDC Controllers shall not be impeded by use of either remote or local monitor, or control stations on network either in access mode or programming mode.

K. Provide transient voltage surge suppression devices for controllers and other electronic devices requiring separate line voltage power source.

3.3 DIRECT DIGITAL CONTROLLERS

A. DDC Controller Usage:

1. Select DDC Controller to provide speed of response required for each control loop type. Pressure, flow rate, and air handling unit temperature control must be via Building Level DDC Controller. Application specific DDC Controller may be used for other control loop types.
2. Each DDC Controller shall have sufficient I/O capacity to perform specified control sequences and/or include points listed in any point schedules. If DDC Controller does not have sufficient capacity, provide additional slave panels to achieve required point count.
3. Analog and critical safety discrete control loops shall have inputs and outputs into/from same DDC Controller. Analog control loops for major equipment (chilled water, hot water, convertors, air handling units, etc.) shall have PID control. Air terminal control loops may utilize floating point control from tri-state or Triac outputs from the controller, but require some type of feedback device to prove position.

4. Provide at least one Building Level DDC Controller per mechanical equipment room and, if required, at each PC workstation location.
5. For valves and dampers within 100 ft of associated DDC Controller, mount current to pneumatic (I/P) converter within DDC Controller panel or in adjacent panel. Otherwise mount I/P converters at valve or damper. Provide pressure gauges on main air, and all control output signals.

B. Point Capacity:
1. Provide point capacity required plus spare I/O point capacity in each B-AAC. Spare I/O point capacity is defined as terminal connections, which are ready to accept digital or analog inputs, dry contacts for digital outputs, and variable voltage or current terminals for analog outputs. Universal type points are acceptable for both discrete and analog type points. Spare points do not include any input or output conversion devices.
2. Spare points in each B-AAC shall be a minimum expansion capability of 20%.

C. Building Controllers:
1. Provide one BBMD in each IP subnet.
2. BACnet UDP port number to always be set to 47808 (BAC0).

D. Cabinets:
1. Provide local control cabinets for DDC Controllers. DDC Controller cabinets may be used directly if enclosures are rated for NEMA 1. All cabinets shall utilize a single master key. Provide 2 spare key sets to Owner. Otherwise shall be 0.06-inch-thick, furniture-quality steal or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock, with manufacturer's standard shop-painted finish and color.
2. All control cabinets shall be labeled. Labels shall be keyed to the unique identifiers shown on the As-Built drawings.
3. Panel boards shall be wall-mounted or stand-mounted and shall be completely enclosed with engraved nameplate.
4. Panelboard shall contain all instruments and accessories. Provide each item of equipment with an engraved nameplate. Panelboard shall be wall mounted or stand mounted and shall be completely enclosed.
5. As far as is practical, the control components for each system shall be grouped. Provide each group of components with identification.
6. The entire panelboard shall be pre wired and brought to a main terminal strip. All relays, switches, etc., shall be installed, furnished and wired on panelboard. Clearly mark each terminal strip as to which wire from which component is to be connected.
7. Fabricate panels of 0.06-inch- (1.5-mm-) thick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock, with manufacturer's standard shop-painted finish and color.
8. Panel-Mounted Equipment: Temperature and humidity controllers, relays, and automatic switches; except safety devices. Mount devices with adjustments accessible through front of panel.
9. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.

~~3.~~10. Graphics: Color-coded graphic, laminated-plastic displays on doors, schematically showing system being controlled, with protective, clear plastic sheet bonded to entire door.

~~4.~~11. All panel board shall be pre-wired and brought to a main terminal strip. All relays, switches, etc., shall be installed, furnished and wired on panel board. Clearly mark each terminal strip as to which wire from which components is to be connected.

a. Panel-Mounted equipment includes temperature controllers, humidity controllers, relays, and automatic switches (except for safety devices). Mount devices with adjustments accessible through front of panel.

b. Door-Mounted equipment shall be flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.

c. Color-coded graphic, laminated-plastic displays, schematically showing system being controlled, with protective clear plastic sheet bonded to entire door.

E. Controller Firmware

1. Provide latest version of controller firmware. Include firmware updates for period of one year after system acceptance, coinciding with warranty period. If the upgrade of firmware causes the need to upgrade or reconfigure/reprogram related systems, controllers or software, Contractor shall notify Owner prior to upgrade and provide additional work scope in coordination with other Contractors, as required, at no cost to Owner.

3.4 DDC SOFTWARE INSTALLATION

A. Operating system (OS): Contractor shall install the OS on workstations and laptops and configure user names and passwords.

B. Virus Protection software: Contractor shall install the virus protection software on each server, laptop and workstation and shall configure weekly virus scans.

C. Contractor shall install and configure all software packages required to maintain and configure all types of controllers provided as part of this project on each engineering workstation.

D. Software from panels shall be permanently stored on CD ROM and on at least one hard disk at operator's workstation or Web Application Server. Provide auto re-boot feature on power up from system failure. System failures shall not necessitate manual reprogramming to restore normal system function.

E. Provide the latest version of all standard software, including operating system and control software. Include any software updates for period of one year, coinciding with warranty period. Beta released software shall not be used.

3.5 INITIAL PROGRAMMING

A. Control Contractor shall provide initial programming of controllers to accomplish sequences specified.

B. Provide back-up documentation per software manual submittals for all programs, in both written and electronic media formats.

C. Outputs, whether sequenced or not, shall have separate programmable hardware outputs. For air handling units, minimum outside air, maximum (economizer) outside air, return air, relief air, smoke dampers, heating valves, cooling valves, humidifier valves, etc., shall each have separate output.

D. BACnet Naming and Addressing
   1. Every BACnet device shall have an assigned and documented MAC Address unique to its network. For Ethernet networks, document the MAC Address assigned at its creation. For MS/TP, assign from range as indicated by vendor documentation.
   2. Instance number will be assigned by owner. Provide ability for changing the network number; either by device switches, network computer, or field operator interface. The BACnet internetwork (all possible connected networks) can contain up to 65,534 possible unique networks.
   3. Every BACnet Building Controller (B-BC) and BACnet Router UDP port number shall be set to 47808 (BAC0).
   4. Assign unique Device "Object_Identifier" property numbers or device instances for each device on the BACnet internetwork. Provide for future modification of the device instance number; either by device switches, network computer, or field interface. BACnet allows up to 4,194,302 possible unique devices per internetwork.
   5. The Object Name property field shall support 32 minimum printable characters. Assign Object Name properties with plain-English names descriptive of the application. Examples include "Zone 1 Temperature" and "Fan Start/Stop".

E. Minimum BACnet Object Requirements
   1. For the following points and parameters, use standard BACnet objects, where all relevant object properties can be read using BACnet's Read Property Service, and all relevant object properties can be modified using BACnet's Write Property Service: all device physical inputs and outputs, all set points, all PID tuning parameters, all calculated pressures, flow rates, and consumption values, all alarms, all trends, all schedules, and all equipment and lighting circuit operating status.
   2. The Object Description property shall support 32 minimum printable characters. For each object, complete the description property field using a brief, narrative, plain English description specific to the object and project application. For example: "HW Pump 1 Proof." Document compliance, length restrictions, and whether the description is writeable in the device PICS.
   3. Support and provide Description and/or Device Type text strings matching signal type and engineering units shown on the points list.
   4. Support and provide Inactive Text and Active Text property descriptions matching conditions shown on the points list.
   5. For devices with scheduling capability, provide at least one Calendar Object with ten-entry capacity. Enable the writeable Date List property and support all calendar entry data types.
   6. Use Schedule Objects for all building system scheduling.
   7. Use Loop Objects or equivalent BACnet objects in each applicable field device for PID control. Regardless of program method or object used, allow authorized operators to adjust the Update Interval, Setpoint and all constraints associated with Object, such as Proportional Constant, Integral Constant, and Derivative Constant for Loop Object, using BACnet read/write services.

F. Minimum BACnet Service Requirements
   1. Use commandable BACnet objects to control machinery and systems, providing the priority levels listed below.

Priority Level	Application

1	Manual-Life Safety
2	Automatic-Life Safety
3	(User Defined)
4	(User Defined)
5	Critical Equipment Control
6	Minimum On/Off
7	(User Defined)
8	Manual Operator
9	(User Defined)
10	(User Defined)
11	Load Shedding
12	(User Defined)
13	(User Defined)
14	(User Defined)
15	(User Defined)
16	(User Defined)

G. Data Sharing:
   1. Data communication from Building Controllers to Engineering Workstation and BAS web server shall be programmed to use Change of Value (COV) data sending and not continuous data polling to limit net work traffic.
   2. Data communication parameters for analog values shall be operator configurable and setup as follows:
      a. Minimum Send Time: 2 seconds
      b. Maximum Send Time: 60 seconds
      c. Send on Delta (COV) :
         1). Space Temperature: ±0.5°F
         2). Process Temperature: ±0.5°F
         3). Air Pressure, AHU: ±0.05“ W.C.
         4). Relative Humidity: ±0.5%
         5). Air Flow: ±200 cfm
         6). Water Flow: ±50 gpm
         7). Water Pressure ±0.2 psi
         8). Space Pressure: ±0.01“ W.C.
   3. Digital data points shall be sent whenever a state change occurs.

H. Historical Trending:
   1. All trending alarms, archiving, scheduling, alarm management, graphics are to be done by UEM..

I. UEM, when adding to an existing system, groupings, tag names, descriptions, engineering units, etc. shall match the existing system. Transitions from the existing system to the new system shall be seamless in look, functionality, and operation.

J. Program historical file for run-times and quantity of start/stops of motor driven equipment.

K. Program maintenance alarms based on run-times and quantity of start/stops for motor driven equipment.
   1. Provide the following additional alarms:
      a. Controller loss of communications for each controller.
      b. Controller battery alarm for each controller (where available)
      c. Out-of-range, bad, or missing data (fault) for each device.

L. Program alarms using the following levels:
   1. Level 1 - Maintenance Alarm, requiring attention within 1 to 2 days. (Examples: 2-3°F temperature variance from set point; 15-25% relative humidity variance; etc.)
   2. Level 2 - Low Level Alarm, requiring attention within 8 h, preferably during the same shift. (Examples: More than 3°F variance from set point, 30 percent relative humidity or more variance from set points; excess start/stops per day; etc.)
   3. Level 3 - Critical Alarm, requiring immediate attention. (Examples: Non-operation of primary equipment; H-O-A overrides; failure of controllers, and routers.)
   4. Level 1 and 2 alarms shall not interrupt current user operation, but shall be logged into alarm summary file, indicating status, acknowledgment, and by whom. Level 3 alarms shall interrupt user via audible and/or flashing warning until acknowledged, without losing any work in progress. When alarms are acknowledged, program shall display point group or appropriate graphic display. Level 3 alarms shall also be logged into alarm summary file in similar manner as Level 1 and 2 alarms.

M. Time Schedules:
   1. Provide time schedules for HVAC components/systems as indicated in Control Sequences.
   2. All time schedules shall be fully configured with weekly schedules and all holidays identified by the Owner.
   3. Time schedules are to reside in the Building Controllers.

3.6 POINT LIST

A. Provide points required to implement control sequences specified, whether or not they are listed in schedules. In addition to control points, provide additional points listed in point schedules or defined in Control Sequences.

B. All points shall be named per the UEM naming convention with a detailed description.

3.7 AUTO-DIAL ALARM MESSAGES

A. Program up to 30 types of prerecorded voice or fax messages assigned to different alarm types. Assign up to 10 phone numbers for each message. BAS shall automatically call phone numbers without answering machines in predetermined order. If an acceptable phone response is not received after 6 rings (adjustable), system shall automatic retry 3 times (adjustable) before calling next number. Systems shall print level 3 alarm message if no phone numbers were reached.

3.8 GRAPHICS PROGRAMMING

A. Graphics shall be done by UEM.

END OF SECTION